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Certification of OSH Professionals through an Accredited Competency Assessment Model

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Abstract
Using the BCRSP and BCSP certification schemes and their years of collective expertise in delivering competency assessments, this thematic paper will explore the following concepts:

- The value of certification of the Occupational Safety and Health (OSH) professional
- Certification of OSH Professionals through a Competency Assessment Model
  - The role delineation process
  - Certification scheme structures
  - Validity and reliability of competency-based examination models
- The accreditation (ISO/IEC 17024) process and continuous improvement
- How certification standards impact industry practices and OSH education
- How certification standards promote lifelong learning of the OSH professional
- Transportability and international influence

Keywords: certification, OSH professionals, accreditation

1.0 INTRODUCTION

Both the Board of Canadian Registered Safety Professionals (BCRSP) and Board of Certified Safety Professionals (BCSP) have well-established and ISO accredited models of certification for occupational safety and health (OSH) professionals. The BCSP, established in 1969, and the BCRSP, established in 1976, have developed comprehensive certification schemes that are highly valued by OSH professionals and employers. Using the BCRSP and BCSP certification schemes and their years of collective expertise in delivering competency assessments, this thematic paper will explore some of the concepts and developments as they relate to the certification of OSH professionals. Particular attention is paid to the validation survey process and how this research supports the certification process, the use of competency-based examination models and the importance of validity and reliability measures within the context of certification, and how the psychometric analysis of examinations is useful to certification organizations.

2.0 WHAT IS CERTIFICATION AND WHY DOES IT MATTER?

Certification is defined as a "voluntary process by which a non-governmental entity grants a time–limited **recognition** and use of a credential to an individual **after verifying that he or she has met predetermined and standardized criteria**. It is the vehicle that a profession or occupation uses to differentiate among its members, using standards, sometimes developed through a consensus-driven process, based on existing legal and psychometric requirements." (Knapp, J., et al 2006) Certification differs from certificate programs in that certification programs are designed to meet very different needs.

Certification programs are a voluntary process in which a professional is evaluated against an established standard which is set through a defensible, industry-wide process (job analysis/role delineation) that results in an outline of required knowledge and skills. Certification programs award the use of a certification mark that is time-bound, and they require continuing professional development be reported on a set-cycle and to a defined minimum requirement.

In contrast, a certificate program generally results from an educational process, is an indication of completion of a course or series of courses with a specific focus, is an end result (no continuing professional development required to maintain), and assessment tools are typically not set through a standard setting process, rather they are established by the program instructor to measure knowledge of listed program outcomes.

The Institute for Credentialing Excellence (ICE) also refers to the assessment scope of a certification program typically being broad versus a certificate program which may be narrow in focus. (ICE, 2015)

3.0 VALUE OF CERTIFICATION

Certification programs, which adhere to industry best practices, provide professionals, consumers, and government agencies an assurance of competency in a constantly changing world. In general, certification programs raise the bar within a profession and provide a benchmark of professionalism. For the professionals, there are a number of benefits typically identified and there are an increasing number of research studies being conducted on the value of certification to a profession.

ICE has developed a theoretical model supporting certification that outlines the conditions necessary for value to be equated to the certification program.

Necessary conditions related to objectivity, rigor, professional ethics and discipline, and continuing competence, if developed and communicated effectively, lead to observable value by certificants and by others.			
		Value	
Necessary Conditions	**Communication**	**Seen by Certificants**	**Seen by Externals**
· Objectivity · Rigor · Ethics/discipline · Recertification · Market need	· Responsibilities to stakeholders · Marketing to stakeholders · Annual report · Candidate handbook · Directory	· Greater confidence in professional competence · Increased autonomy in the workplace · Enhanced marketability · Employability, and opportunity for advancement · Improved monetary factors · Heightened job satisfaction	· Required for employment · Required for advancement · Justifies salary differential · Investment to attain/retain certification · Better compliance with regulations and conditions of third-party payers · Raised public opinion · Lowered risk · Greater scope of practice

Figure 1 *ICE Theoretical Model Supporting Certification (Henderson, J , 2012)*

In 2011, the BCRSP undertook a research study on the *Perceived Value of Certification* amongst OSH Professionals. The findings in this research study are consistent with the ICE report. The key value statements identified by Canadian Registered Safety Professionals (CRSP) are that certification:

- Is an indication of professional growth,
- Enhances professional credibility,
- Provides evidence of professional commitment,
- Enhances employability and mobility, and
- Increases earning potential. (ASI/BCRSP, 2011)

Organizations that engage professionals that hold BCSP certifications reported benefits such as:

- Improved competence in safety decisions,
- Improved quality of safety inspections and audits,
- Improved trust and confidence from clients in the ability to manage safety at job sites,
- Continued professional development.

The increased earning potential of certified professionals is also supported through salary survey data collected by both the BCRSP and BCSP. Employers recognize the value of certification and this is reflected through increased salary, internal recognition and/or promotion.

Many employers prefer or require applicants for OSH positions to be certified particularly for mid-career or senior level positions. Certification of OSH professionals provides employers and the public with the assurance that certified individuals possess the necessary skills, knowledge, and experience to perform competently. A pre-requisite for certified OSH professionals is also used as part of the procurement process for contractors and sub-contractors both in the private and public sector.

With a robust, quality certification program there is also an opportunity for the profession to be able to achieve recognition within legislation to perform certain OSH functions. One example of this is the British Columbia WorkSafeBC - OHS Regulation – Part 9 Confined Space where the holder of either a CRSP or CSP are recognized as having adequate training and experience in the recognition, evaluation and control of confined space hazards.

4.0 STANDARD SETTING & EXAMINATION DEVELOPMENT

In North America, the certification of OSH professionals through the use of a standardized assessment tool (multiple choice examination) has been utilized for more than 40 years.

The development of a quality credentialing or licensing program must follow logically sound and legally defensible procedures when developing examinations.

Standardized tests ensure a consistent method of scoring/assessment and ensures legal defensibility. To achieve this, there are a number of steps undertaken during the psychometric process in order to establish a measurement tool that will objectively measure the skills and knowledge of the individuals being assessed.

The examination development process includes the following key steps.

- Role delineation
- Validation Survey
- Item Development
- Cut Score
- Statistical Analysis
- Continuous Improvement

4.1 Role Delineation

Before an examination is developed, the scope of what is to be tested must be set. This process known as the role delineation or practice analysis process is the initial undertaking usually by a group of representative (geographically, industry and demographically dispersed) subject matter experts (SMEs) who are able to review and/or determine the domains, tasks, knowledge and skills required to practice in a field. In both Canada and the USA, for the OSH profession, this process is undertaken every five years by the BCRSP and BCSP respectively, to ensure that the competencies identified as critical to practice within the certification are reflective of the current practice of OSH professionals.

At a global level, a similar exercise has been undertaken by the International Network of Safety & Health Practitioner Organisations (INSHPO) in the development of the *Global OSH Competency Framework*. The Global Framework defines the tasks, roles, and functions of the OSH professional from a global perspective. Once the INSHPO framework is finalized, it will require further validation to ensure it is reflective of the global profession and free of any country or region specific bias.

4.2 Validation Survey

The second stage, which is critical to the examination development process, is the validation survey. A representative sample of professionals in the field reviews and validates the work of the role delineation panel. This is typically conducted by survey in which the importance, criticality and frequency of each task is rated. The results of the validation survey are aimed to provide guidance for the development and setting of the examination structure, such as the percentage ranges for examination questions within various domain areas.

Once the competencies to be tested have been finalized, and the structure of the examination has been determined, the certification examination can be developed. An *examination blueprint* typically provides information on the structural parameters of an examination as well as a listing of the domains and competencies that may be tested. The final blueprint is then approved by the board or a committee authorized to do so.

4.3 Examination and Item Development

The development of an examination relies on the structural parameters within an examination blueprint to direct its creation. In addition to the examination blueprint, items in the examination bank may have statistical information associated with them from previous use which may be factored into the examination development process. Certification boards may also place 'experimental' items on an exam that will not be scored but are statistically evaluated to determine future usability.

Another ongoing part of the examination development process is the item development process. This process ensures that new items undergo initial review to ensure they are representative of current industry practice, and are fair and relevant to the profession. Items are written by SMEs utilizing applicable globally recognized resources and references, and these references are documented for each item. Items undergo multiple levels of review to confirm that the item is relevant, grammatically correct, and linked to the examination blueprint. During item review, it is also confirmed that the item is applicable to a global audience.

In instances where a certification examination is being administered in more than one language, the item translation process may involve multiple steps to ensure there is no impact related to translation on examination candidates. In Canada, the CRSP certification examination is delivered in both English and French. The BCRSP is utilizing multiple stages within the translation process to minimize any impact of the translation. These steps include: initial translation completed by a professional translator; a review process by multiple bilingual SMEs in consultation with another professional translator; and finalization of the translation. Items are also reviewed during the initial item development stage to ensure that there are no perceived issues with translation related to the initial question content. Translation of questions can be challenging due to variations in technical terminology and grammatical structure as well as the non-existence of some technical terms in some languages.

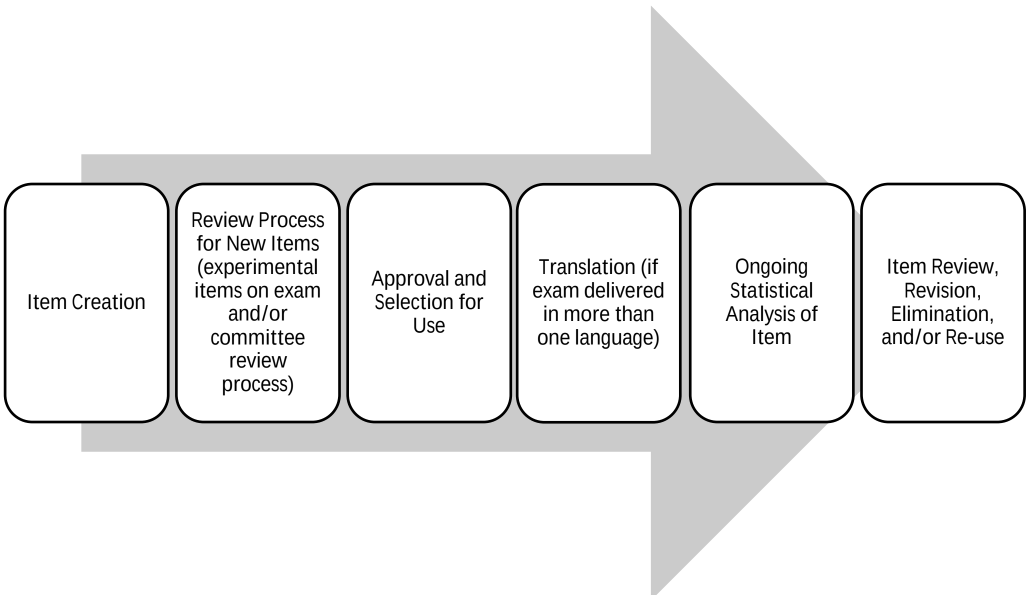

Figure 2 *Item Development Process*

4.4 Cut Score
Every examination form goes through a cut-score setting process. The standard or pass mark is set in reference to the content and the difficulty of the examination questions. A generally accepted best practice for certification or licensure examinations for setting the cut score is the Angoff Method or Modified Angoff Method. A major advantage of using a (Modified) Angoff approach is that the determined pass mark is based on the content of the examination and not on group performance.

Using these methods, a panel of representative content experts from various areas of practice reviews each examination question and produces ratings based on a common understanding of a competent professional who has met the minimum eligibility requirements of the certification board. The ratings are averaged for each item and then summed to obtain a panel-recommended raw cut score. A variable on this is to instruct the SMEs to take the test and rate each item with the performance levels of the test candidates in mind. SMEs are then asked to provide estimates for each question of the proportion of borderline or "minimally acceptable" participants that they would expect to get the question correct. There are typically procedures in place in order to reach consensus on the rating of a question should the independent judging of an item range significantly.

In addition to these ratings, a variety of relevant data (for example, information on the preparation of candidates, data on results from previously administered examinations) are carefully considered to ensure the standard that candidates must achieve on the examination is valid and fair. Based on this information, an appropriate standard or pass mark is set. This procedure is repeated for every newly-created examination form. The final cut score for the examination is then approved by the board or a committee authorized to do so.

A number of factors contribute to the successful implementation of these standard-setting methods. An effective training session is essential in orienting the SME to the concept of the minimally competent candidate. As well, discussion and modification of extreme ratings help ensure that a defensible and valid cut score is established.

4.5 Statistical Analysis
One of the cornerstones of competency assessment examinations is the reliance on the statistical analysis not only of the exam forms but each individual item. A key determinant in the overall performance of a certification examination is the annual statistical report which is produced by a psychometrician and includes information on the reliability and validity of the examination forms, as well as other information regarding the overall health of the certification examination process (e.g. item bank statistics, program activities/initiatives undertaken towards process improvement, recommendations based on industry best practices, etc.). The importance of reliability and validity of assessment methodology is also a key component within the ISO/IEC 17024 Standard. Clause 9.3.5 of the standard requires that "appropriate methodology and procedures shall be documented and implemented in order to reaffirm, at justified defined intervals, the fairness, validity, reliability and general performance of each examination, and that all identified deficiencies are corrected." (ISO/IEC 17024, (2012)

Reliability is defined as an indicator of the extent to which examination scores are consistent across different examination times and locations, (ISO/IEC 17024 (2012), Clause 3.18) and validity is defined as evidence that the assessment measures what it is intended to measure, as defined by the certification scheme. ISO/IEC 17024 (2012), Clause 3.17)

Put into context, both the BCRSP and BCSP produce annual reports that measure the validity and reliability of their respective certification examinations. Validity is whether the inferences being made about a candidate's knowledge and skills in OSH are accurate. For reliability, while there are several ways to quantify reliability, the most commonly used method for certification examinations, and the method used by both the BCRSP and BCSP is *internal consistency.* Internal consistency is a measure based on the correlations among different items on the same test. It measures whether several items that purport to measure the same general construct produce similar scores.

4.6 Continuous Improvement

The examination development process is an ongoing process in which the certifying body is constantly monitoring, measuring, and analysing key processes. Standardized review periods for the examination blueprint, ongoing item bank development and maintenance, and policy review cycles help ensure that the certification remains reflective of current professional practices. Certification bodies may also benchmark their policies and procedures to like organizations and certification industry best practices as published by organizations such as ICE or the Association of Test Publishers (ATP).

5.0 ISO/IEC 17024 – INTERNATIONAL ACCREDITATION STANDARD

Both the BCRSP and BCSP are accredited to the ISO/IEC 17024 standard through ANSI and SCC respectively. Released in 2003, ISO/IEC 17024 is designed to harmonize the personnel certification process worldwide, In the European Union ISO/IEC 17024 replaced EN 45013 (1989), which was published in the UK as BS 7513:1989.

The BCSP obtained accreditation in 2003 and the BCRSP obtained accreditation in 2005. ISO/IEC 17024 is generally recognized as the highest standard in personnel certification accreditation. The standard used by ANSI and SCC to accredit certification bodies is an international standard. Accreditation to an international standard is extremely important for certification bodies that have global operations or aspirations. Both ANSI and SCC follow an internationally recognized process for accrediting organizations.

The accreditation process requires that the certifying body be able to prove compliance to the standard through an initial accreditation assessment including both material/documentation and on-site assessment as well as annual surveillance audits and a full reaccreditation audit every four (Canada) or five (USA) years.

The key issues that ISO 17024 tackles can be summarized as:

- Defining what it is you examine (the competencies - knowledge, skills, abilities) and standardized eligibility requirements
- Examination must be independent from training/training providers
- Examination must be a valid and reliable assessment tool
- Certification scheme must safeguard impartiality
- Effective Management System must be in place

Accreditation to an international standard helps drive continuous improvement of the certification schemes both through the internal and external audit process as well as through changes instituted to the ISO/IEC 17024 standard itself. In 2012 a new version of the ISO/IEC 17024 standard was released. The changes to the standard required both the BCRSP and BCSP to review their existing certification schemes to ensure compliance with the new version of the standard. As a result of the changes, the BCRSP and BCSP conducted a complete review of the standard against their systems and identified any process gaps that required addressing. The challenge of continually ‘raising the bar’ requires organizations to respond accordingly within their own programs.

The internal audit requirement also creates an opportunity to generate continuous improvement initiatives and should be viewed as a tool to assist an organization in improving its processes and procedures.

6.0 CERTIFICATION STANDARDS AND THE IMPACT ON THE PROFESSION

Both the BCRSP and BCSP have a long history of setting the standard for the certification of OSH professionals in Canada and the USA respectively. There is evidence that the certification schemes may influence the practice of safety and health, as well as curricula of OSH educational programs.

In the United States, the *ANSI/ASSE Z590.2-2003 (R2012) Criteria for Establishing the Scope and Functions of the Professional Safety Position* (2012) draws a correlation between the description of the professional safety position outlined in the standard and the BCSP’s comprehensive job analysis study of professional safety practice.

In Canada, the *CRSP® Examination Blueprint* has been utilized by a number of educational institutions as a roadmap for developing course curriculum. When an updated examination blueprint is released, the BCRSP has seen program modifications occur at colleges and universities with OSH offerings. While no OSH program level accreditation exists in Canada, eligibility of program graduates for certification is a market driver for programs to ensure graduates from the programs will meet the minimum formal education requirements as defined by the BCRSP. The BCRSP hosts a *National Education Symposium* that has been developed for OSH educators/program managers and is aimed at developing a network to foster continuing dialogue between the BCRSP and academic institutions through the sharing of ideas, concerns, and solutions to challenges facing students in OSH programs and identifying core subject matter essential to the development of sound OSH practices and principles.

Similarly, in the USA, BCSP works with colleges and universities wishing to prepare their graduates to achieve certification. Certain Qualified Academic Programs (QAPs) exist in these institutions that are accredited by the Accreditation Board for Engineering and Technology (ABET). Graduates of these programs earn a designation that serves as their first step toward certification.

Each time the BCSP produces a new blueprint for a certification, the BCSP goes through a rigorous process of re-evaluating the curriculum of each QAP to determine whether or not it still substantially matches the new blueprint. Those that do are allowed to keep their QAP status. However, those institutions whose academic programs do not substantially match the new BCSP blueprint must either modify their educational offering to come into compliance, or forfeit their QAP designation.

In both Canada and the USA certification is often cited by employers, recruiters, and clients as a requirement for employment as an OSH professional. Employers view certification as a way to ensure that the individual they are hiring has proven their expertise in the field by demonstrating their competency through the certification process, is committed to continual learning, and is committed to compliance to a Code of Ethics. In Canada, preliminary research suggests that up to 70% of career advertisements for OSH professionals require or prefer a certified professional.

Both the BCRSP and BCSP require their certificants to agree to and adhere to a Code of Ethics or Rules of Professional Conduct, and this practice of setting an ethical standard is common amongst certification boards. The purpose of Codes of Ethics is to provide guidance to ensure that each certificant adheres to high standards of integrity and professional competence. These Codes are fully enforceable through robust complaints and discipline processes and individuals who are found to have breached the Code of Ethics may have their certification revoked. Typically Codes of Ethics cover areas such as acting within the limits of ones' competence, integrity and confidentiality, respect of others and other professionals, and compliance with the rules of the certification scheme. These codes contribute to the public's view of the profession and the trustworthiness of the professionals involved.

7.0 CERTIFICATION STANDARDS AND LIFELONG LEARNING OF THE OSH PROFESSIONAL

As outlined earlier in this paper, one of the principle elements of a certification program is the requirement for continuing professional development to be reported on a set-cycle and to a defined minimum requirement. Continuing competence programs are an effective and well-recognized method of recertification. They should provide a meaningful and relevant process that demonstrates certificants remain current in their field. Otherwise, the knowledge and skill determined at the time of initial certification would become outdated and, therefore, diminish the value of the certification to the public, employers, and certificants. (ICE Research & Development Committee , 2015, p.5)

Both the BCRSP and BCSP have requirements for certified professionals to report every five years on their continuing professional development activities. Both programs require a similar minimum 'point' total be achieved within the five year cycle and accept professional development activities across a number of activity areas including completion of additional training, achieving additional certifications or degrees, and professional activities. Failure to comply with continuing competence program generally leads to suspension or withdrawal of certification of the individual. As many individuals have worked hard to achieve the initial certification, they will continue to work hard to maintain the certification in question. Through the requirements of these continuing competence programs, certification standards promote lifelong learning of the OSH professional.

8.0 TRANSPORTABILITY AND INTERNATIONAL INFLUENCE

As industry becomes more global and as OSH professionals continue to move more widely and rapidly between countries, transportability and comparability of credentials becomes of paramount importance.

International transportability of credentials takes the value of certification a step further. International transportability allows professionals who have earned a certification or met a competency standard in one country to practice in another country based on the certification or credential from the original country. International transportability of credentials is effective when a credential from one country is recognized as substantially equivalent and sufficient to qualify for practice in another country and to compete equally with someone holding a credential from the other country. (Brauer, Roger L , 2006)

Organizations who certify professionals are able to analyse and equate their systems of certification (particularly if also accredited to the ISO/IEC 17024 standard) and develop memoranda of understanding (MOUs) to create opportunities for certified professionals to become certified in other jurisdictions. The BCRSP and BCSP have an MOU which provides for a streamlined process for individuals to become certified by the other organization.

Due to the similarities between the structure of the certification schemes in both Canada and the USA, it is relatively easy to map processes, develop agreements, and determine the appropriate paths for individuals to obtain certification ‘across the border’ as well as around the world through MOU agreements with other OSH professional certification boards.

Both the BCRSP and BCSP participate in the International Network of Safety and Health Practitioner Organisations (INSHPO). INSHPO is the global voice for the OSH profession. INSHPO provides an international forum for engagement on OSH-related matters and advancing the OSH profession through the exchange of evidence-based practices and the development of a harmonized framework for the profession. Its member organizations include OSH professional bodies from Canada, the USA, United Kingdom, Italy, Australia, New Zealand, the Russian Federation, Singapore, Korea and Mauritius. Through participation in INSHPO, and projects such as the *OSH Professional Competence Framework*, the BCRSP and BCSP are contributing internationally to the advancement of the OSH profession.

9.0 CONCLUSION

Using the BCRSP and BCSP certification schemes and the years of collective expertise in delivering competency assessments, this thematic paper has explored a number of concepts including the value of certification, the certification and standard-setting process, the impact of accreditation on the certification standards and how certification standards impact industry, the professional, transportability and international influence. Accredited certification programs not only add value for the professional, but also continually raise the bar for the profession.

10.0 REFERENCES

American Education Research Association, American Psychological Association & the National Council on Measurement in Education. (2014). Standards for educational and psychological testing. Washington, DC

Assessment Strategies Inc., (2014). *Competency Validation Report*, Board of Canadian Registered Safety Professionals, Mississauga, Ontario

Assessment Strategies Inc. (2011). *Report on the Perceived Value of Certification Survey*, Board of Canadian Registered Safety Professionals, Mississauga, Ontario

Assessment Strategies Inc., (2014). *Technical Report for the Canadian Registered Safety Professional Examination (CRSPEX)*, Board of Canadian Registered Safety Professionals, Mississauga, Ontario

Board of Canadian Registered Safety Professionals, (2015). *Blueprint for the Canadian Registered Safety Professional Examination (CRSPEX)*, Board of Canadian Registered Safety Professionals, Mississauga, Ontario

Board of Certified Safety Professionals (2014). *CSP Examination Blueprint*, Board of Certified Safety Professionals, Champaign, Illinois

Brauer, Roger L., *International Transportability of Safety Credentials Presentation* (2006). Presented October 21, 2006, 30 Anniversary Celebration, Ottawa, Ontario, Canada to the Board of Canadian Registered Safety Professionals. Retrieved July 24, 2015, from http://www.bcsp.org/Portals/0/Assets/PDF/Articles_PPT/InternTransCred.pdf

Henderson, J, Biel, M., Harman, L., Wickett, J., Young, P., (2012). *A Look at the Value of Professional Certification* Institute for Credentialing Excellence, Washington, DC.

Knapp, J., Fabrey, L., Rops, Mickie, McCurray, N. (2006). *Basic Guide to Credentialing Terminology*, Institute for Credentialing Excellence, Washington, DC.

Institute for Credentialing Excellence Research & Development Committee, Continuing Competence Task Force, (2015). *Utilizing a Process Framework to Build an Effective Continuing Competence Program for Certification,* Institute for Credentialing Excellence, Washington, DC.

Institute for Credentialing Excellence, *Certificate vs. Certification: What's the Difference,* Washington, DC, Retrieved July 20, 2015 from http://www.credentialingexcellence.org/p/cm/ld/fid=4

ISO/IEC 17024 (2012). *Conformity Assessment – General requirements for bodies operating certification of persons,* 2nd edition, ISO, Switzerland.

WorkSafeBC *OHS Regulations*, Part 9, Retrieved July 20, 2015 from http://www2.worksafebc.com/publications/OHSRegulation/Part9.asp#SectionNumber:9.11

Developing a conceptual framework for anticipating and mitigating risks of injury and illnesses in Brazilian and Canadian Pork Industries

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Abstract

Occupational health and safety exposures and incidents have been studied in several sectors and contexts in order to identify multiple types of risk and interventions that could minimize the impacts of work on the health of workers and on the operation of workplaces. The pork industry is growing globally due the high demand from customers while the production has become more concentrated into larger and more intensive operations. Likewise, one of the strategies used by companies around the world has been migrating from developed countries to developing countries in order to minimize general costs such as labor, logistics and installations. In fact, developing countries present lower operating costs, availability of feed, land, water, as well as less restrictive environmental policies. (KUNZ et al, 2008). Knowing that the pork industry has complex and dynamic operations, correlating high scale production and high potential to generate risks to health and safety, it was possible to evaluate that there is a lack of information about ways to manage the risks that influence the health of workers and the flow of the pork production despite the fact that increased corporate management has intensified the need to determine the variables that, directly or directly, may result in occupational accidents and trauma to workers and interfere with the performance and the quality of performed activities. Therefore, this paper seeks to address this gap in the literature by providing a framework that can be used for systematic analysis of risk in the sector in order to predict situations that can result in accidents, hazards and potential traumas to people in all steps of the production (from breeding to slaughtering). Methodologically, the research draws on insights from conceptual models that have been developed and applied to identifying and investigating sources of risk in other industrial sectors: the models created by Lipscomb et al (2006), Embrey (1992) and Windle et al (2008) to help identify the potential indirect and direct occupational hazards and risks which impact on the security of work, and the model elaborated by Attwood et al (2006) and applied to the oil and gas industry with a focus on how to define occupational hazards in specific environments or layers and how to understand the relationship between them as well. The model proposed by Attwood et al (2006) was adapted with input from the other models to create a conceptual approach that can be used to predict accident frequency through examination of potential factors that can generate risk in different segments of the industrial (as opposed to family-operated) pork industry. Knowing that the pork industry can take different forms in different countries and present different characteristics in the same country as well, this paper developed a framework through a review of the literature that incorporates elements of diverse characteristics of pork industries located in Brazil and Canada in order to identify the main and potential parameters that might affect occupational health and safety standard, the corporate safety culture and the management of organizations between the two countries.

Keywords: Pork Industries; OHS procedures; Risk management; Occupational accidents

1. INTRODUCTION

Around the world, the pork industry has been increasing production due to expanding demand from new and current customers and technological and other innovations. The conscience of improving a safe environment through occupational health and safety parameters has been addressed as a crucial decision to mitigate consequences (injuries and illnesses) in all industrial contexts. Indeed, occupational safety guidelines can cause important changes in several scenarios: as Attwood (2006) mentioned, OHS outcomes are correlated to improvements directly connected to workers and their workplaces. Consequently, these modifications which are related to optimize health and safety on workplaces will also affect the quality of production (productivity), the performance of work and the growth of profits.

With the necessity of producing in large scale (in order to reach the required demand) the companies have been trying to minimize the costs of production and logistics migrating from developed to developing countries. In fact, developing countries present lower operating costs, availability of feed, land, water, as well as less restrictive environmental policies. (KUNZ et al, 2008).

In Brazil, for example, swine production is an important activity representing the fourth largest production sector, fourth largest export and the sixth largest consumer product inside the country (IBGE, 2006). In Canada, the number of hog farms is decreasing whereas the total number of pigs produced is increasing, indicating an overall trend of concentration of pork production into larger barns and fewer operations (TRASK et al, 2013).

There are multiple and changing occupational health and safety risks associated with intensive pork production. Silveira et al (2008) pointed out that several risk factors are present in Brazilian swine houses can affect the health of workers: heavy work operations, repetitive jobs, intensity of dust and gases and manipulation of toxic residuals can influence the capacity of workers and quality of work. Some of these can also affect the health of animals due the favorable breeding ground for pathogenic agents that affect them such as brucella, streptococcus, influenza virus and hepatitis E. With this situation the labor context is also affected by intensity of tasks in which workers must fulfill in order to follow the rhythm of production.

In Canada, a research done in Saskatchewan and Quebec by Trask et al (2013), has demonstrated an increase of occupational diseases and accidents due to an increase in the amount of tasks per worker and the high rate of risk during the execution of each task. Respiratory diseases, high concentration of toxic substances, musculoskeletal symptoms are related in these studies as the most common diseases and injuries found in pork industry due the nature of work and lack of internal structure.

A review of the literature on OHS in the pork industry and on the current situation with Pork Industry Management in key countries reveals a lack of information about the potential variables that can affect OHS outcomes as well as inform planning to reduce risk within organizations. This report seeks to address this gap in the literature. It provides a framework that can be used for systematic analysis of risk in the sector in order to predict situations that can result in accidents, hazards and potential risks to OHS in the pork industry. The frameworks draws on insights from several conceptual models developed in other industrial sectors and contexts including in poultry processing in North Carolina by Lipscomb et al (2006), by Windle et al (2008) for understanding risk in fisheries and by Embrey (1992) for evaluating an accident causation using hierarchical influence network. It seeks to visualize the direct and indirect factors that influence risk in the pork industry and the iterative effect (consequences) that sources of risks cause in this sector. The main model used was (created by Attwood et al (2006) and applied to an analysis of the risk of injury in oil and gas industries in Canada and the United States. This model presents a conceptual approach that can be used to predict accident frequency through examination of the potential factors that can maximize or generate risk. All these factors are allocated in three levels or layers: the direct layer, corporate layer and external layer. Together, the three layers can be used to evaluate the real impact of all variables which affect OHS outcomes in different sectors and contexts such as the pork industry.

2. MATERIALS AND METHOD

This study is based on a literature review on the risks involved in swine production companies in Brazil and Canada, as well as variations existing between them and the rest of the world, as concern the OHS management policies. The literature studied was restricted to scientific articles from Brazil, Canada and United States including master's theses and doctoral dissertations where the use of international standards and safety standards is a basic premise for the assessment and / or implementation of new safety methodologies.

All the literature that depicts the pig industry in Canada was obtained during a probationary period developed at the Research Centre for Occupational Safety and Health of the Memorial University of Newfoundland, located in the province of Newfoundland and Labrador, Canada. The bibliographic references of Brazilian pig production industries were collected partly in Brazil (through sources and the library of the Federal University of Campina Grande) and elsewhere in Canada.

Based on a bibliographical approach, the results of the application of the occupational safety system in Brazil and Canada were collected, analyzed and compared to the creation of the proposed model. The model present work deals with results from an adaptation of the model

previously designed by Attwood et al (2006) in this area of study and connected with other SST models created and applied in several areas of foreign companies.
The study is also characterized as a descriptive analysis, since as Almeida (1996) states, the descriptive evaluation is done through observations, records and ordering of data, without the interference of the researcher (manipulation). In this sense, the central focus was to discover that a particular sequence does occur, its nature, characteristics, among others, in which case, the observation about the risk parameters and their behavior on swine production companies in Brazil and Canada.

3. RESULTS AND DISCUSSION

3.1 Occupational Risk analysis based on Attwood's model: External, Corporate and Direct layers

Attwood et al (2006) has developed a model which presents a different concept about how to define occupational hazards in specific environments or layers and understanding the relationship between them as well. To the author, all the occupational risks can be created through a set of factors which allow the occurring of other occupational risks in a different environment (e.g. external risks might influence corporate decisions and occasioning in an occupational accident subsequently). Indeed, the risk can be generated externally the company and influence severity on its planning, which occasionally involves other problems in the process itself and finally affecting the worker in his workplace.
The model explained by Attwood et al (p.210; 2006) suggests that:
"Occupational accidents occur through a direct (unsatisfactory) interaction between worker and workplace, it is the basic premise of the presently proposed model that worker's behaviors are influenced by corporate culture, and their workplace environment and procedures are controlled corporately. Furthermore, corporate decisions and actions are, in turn, influenced by external elements."
The schematic model is shown below:

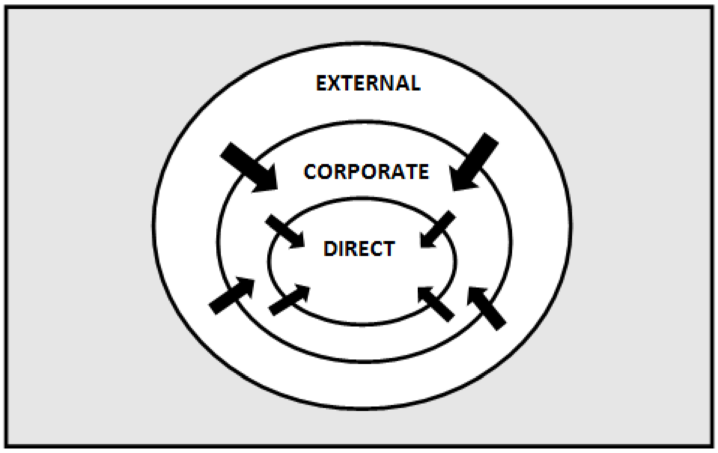

Figure 1- Basic Schematic of model. Adapted from Attwood et al (2006)

The following sections will describe the details of each layer and the subsequent interaction in a pork industry.

3.1.2 The Direct Layer

In a pork industry, it's common to observe the extreme interaction between the worker and the workplace. Several farms present a standard layout with segments which allow possible accidents or injuries which need to be carefully evaluated. In order to address the environment inside a pork industry through occupational guidelines it is necessary firstly evaluate the physical arrangement and the facilities behind the process. Thus, it will be possible to diagnostic the level of influence between the human activities (performed tasks) and the production, enabling a holistic view over the possible occupational risks and hazards which affect directly the industry. According to Attwood (2006), the direct layer considers the factors which affect accident likelihood. Analyzing the factors addressed over the two countries, it may be possible to describe the following specific elements considered in this model:

- Quality of personal protective equipment (PPE): all the personal equipment supplied by the company such as tools, boots, cloves, masks, aprons, waterproof paints, safety glasses and earplugs.
- Quality of equipment and safety design – takes into account the level of safety design in all equipment utilized by workers during their work time.
- Layout and Infrastructure: the correct disposition of the equipment and tools in order to guarantee the correct utilization of the space destined to the work (evaluation about the distances between workplaces, sequence of process, takt-time and lead-time).
- Ventilation System: Current situation of ventilation inside the industry to minimize the concentration of gases during the breeding, farrowing and slaughtering.
- Level of confinement: Degree of confinement and exposure to dust and gases inside the company.
- Motivation at work: takes into account the safe manner of producing the product through the current management and supervisors (corporate level) trough means of positive reinforcement and penalties.
- Attitude at Work: can be defined as the use of good safety attitudes in which can produce direct benefits and general improvement of overall safety culture. Evidently, attitude can be increased through corporate decisions and actions.
- Weather (referring to the changing of the seasons): The condition of the weather during the production process may affect according to the changing of the seasons. Cold seasons combined with uncontrolled ventilation system may generate an increase the amount of gases potentially toxics. During the warm seasons, the greater risk to animals and workers from ventilation failure is heat stress from elevated temperature and humidity (DONHAM, 2010)
- Physical Capability: Physical capability integrates the level of coordination, fitness and lack of fatigue. All of them are correlated with the performing of the tasks. In pork industry, could be observed an intense necessity of coordination during the breeding and a high pick of fatigue from the workers in the slaughter process.
- Mental Capability: It is related to the industrialization of animal farming systems and to the drastic intensification of work. It demands high level of knowledge about the tasks and intelligence as well. Through the literature review, it was evaluated that the major part of workers in Brazil and Canada are presenting symptoms of mental disorders such as: having strong feeling of anger, major changes in eating and sleeping habits, a growing inability to cope with daily problems and activities, feelings of extreme highs and lows, spending more time alone or avoiding others and so on.
- Moral Capability: Moral capability refers to the situations connected to the work which affect morally the employees. Some of these situations such as the problem of smelling are examples of a profound cause of suffering that can only be partly relieved.
- Level of occupational hygiene procedures: The intensity of occupational hygiene procedures is a relevant and crucial manner to minimize the impact of biological diseases inside the industry. The incorrect use of decontaminants and a lack of regular safety and hygiene maintenance in the workplace may increase the chance of contaminations in workers and animals.
- Social Vulnerability: This parameter refers to the current influence of gender and age on the division of labor in the production. In a pork industry, some tasks need to be performed by specific workers (the major part of the tasks during the housing and the slaughtering are performed by young men) and tasks related to evaluation and quality of the product are executed by women. Actually, some of these characteristics have not been followed by several companies around Canada and Brazil which intensity the generation of risk due incompatibilities between the task and the capacity of the employers.

The specific elements mentioned above are listed in the figure 2:

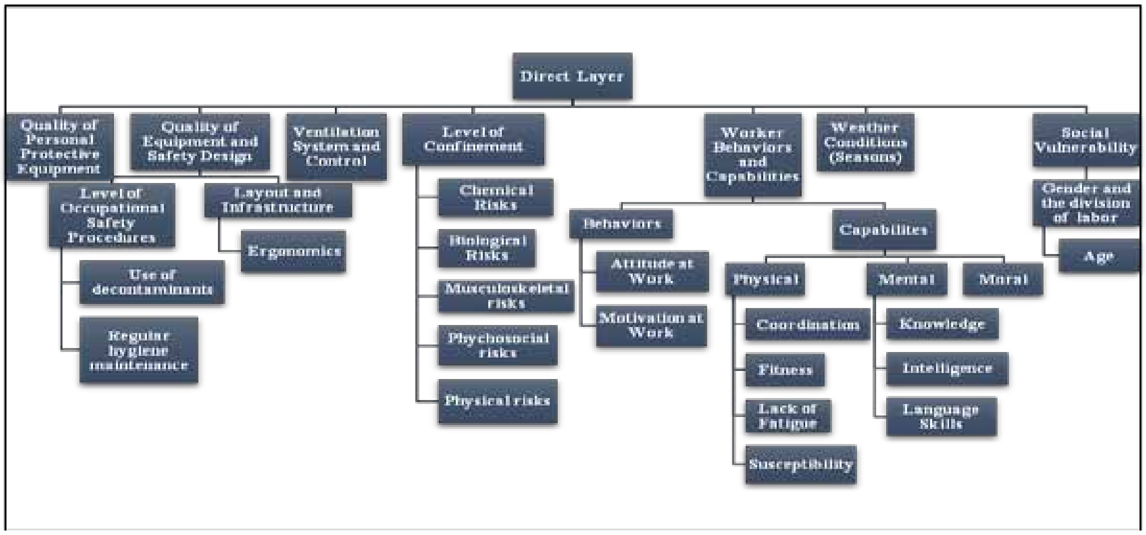

Figure 2 - Elements corresponding to the Direct Layer in Pork Industries. Adapted from Attwood (2006)

3.1.3 The Corporate Layer

Around the world, the pork production management has been evaluated by the capacity of producing in a large quantity, faster and with more quality. Indeed, through the review of the literature it was possible to note the intense preoccupation in producing as much as possible in order to attempt the overall consumers. As characterized as a stress type of work, Porcher (2010) pointed out that several diseases are presented because farmers and workers have to manage lean production.

For example, in order to maximize equipment utilization, workers inseminate more sows than there are places available in the “maternity ward” in anticipation of insemination failures. By the corporate level, the workers has received the orientation to produce as much tonnage as they can – it’s important to observe the major part of employers ask their employees to think in terms of kilograms of meat produced by sows, not in terms of animals (PORCHER, 2010). At the same time, influenced by other external elements such as governmental guidelines and regulatory regimes, farmers are also asked to care for the animals “well-being” and to consider them as “sensitive” beings.

These contradictory demands cannot be reconciled, which gives workers the painful feeling of never doing enough for the animals. Thus, based on the review of the literature, it was possible to analyze that most part of the countries in North and South America present methods to prevent the amount of occupational diseases and risks. Sequentially, other injuries are more equally distributed between short-term and long-term employees, suggesting these injuries may be prevented through instruction and training in animal handling and injection technique. (COLE et al, 2008).As the main problems detected into the four steps in the production process are the respiratory diseases, it is up to the employer try to implement a sequential prevention program in order to maintain the employees away from the risk. According to Ruth et al (2010), engineering and management practices may decrease the levels of gases, dust and contaminants. Some of the procedures related by the author are presented below:

- Lower animal stocking densities to reduce airborne dust and bioaerosols;
- Feeding systems enclosed as much as possible to decrease the amount of dust discharged into the building;
- Delivery of feed into covered feeders rather than dropping it to the floor;
- Feeders designed to allow animals easy access to the feed;
- Oil sprinkled in barn to reduce dust, endotoxin, ammonia, and hydrogen sulfide levels;
- Provide approved dust masks, or other respiratory protective equipment for employees to be used during tasks where elevated exposures may occur, such as feeding and animal handling.
- Therefore, combining the model proposed by Attwood (2006), the guidelines which can be placed in a corporate layer are:
- Corporate Safety Culture – The safety culture is created by the organization and managed by the employers. The company has to optimize its environment in order to

minimize the impacts of occupational diseases. The application of safety programs to eradicate the hazards as well as the consolidation of operational parameters (as described above) and evaluations inside the workplace may be crucial to workers' health. Application of occupational health and safety committee has been crucial in order to manage OHS regulations, policies and legislations as well as recognize effectively hazards, possible accidents, injuries and illnesses before they occur.

- Safety Training – As reported by Attwood (2006), the safety training must be oriented during the first days of the workers at work. It's necessary to maintain regular training sessions in order to professionalize all the workers and, consecutively, diminish the generation of risks.
- Procedures to minimize the risk – The total amount of procedures created by the company to minimize any types of risks. As mentioned by Ruth et al (2008) a prevention program based on education and industrial hygiene consultation has shown to be effective in improving producer knowledge of health and safety risks, and shifting attitudes towards protecting themselves and their employees.
- Investors: The influence of investors and shareholders in pork industries has been increasing due the transition of the production from family farmers to big corporations. All the corporate decisions are being evaluated and controlled by a team and not by individual manager. Attwood et al (2006) pointed out that the pressure which comes from the shareholders is related to the degree to which the organization feels pressure from its owners to improve bottom line performance.
- Shift Rotation: It is related to the way in which the corporation manages the execution of the tasks proportionally between the number of employees and the workplaces in order to minimize occupational hazards through rotation of the jobs and the work time available. On shift rotation other variables such as payment system, employment system, and seniority system and labor wage rates also affect OHS outcomes and need to be evaluated.

Therefore, the specific elements which are present in the corporate layer are presented below hierarchically:

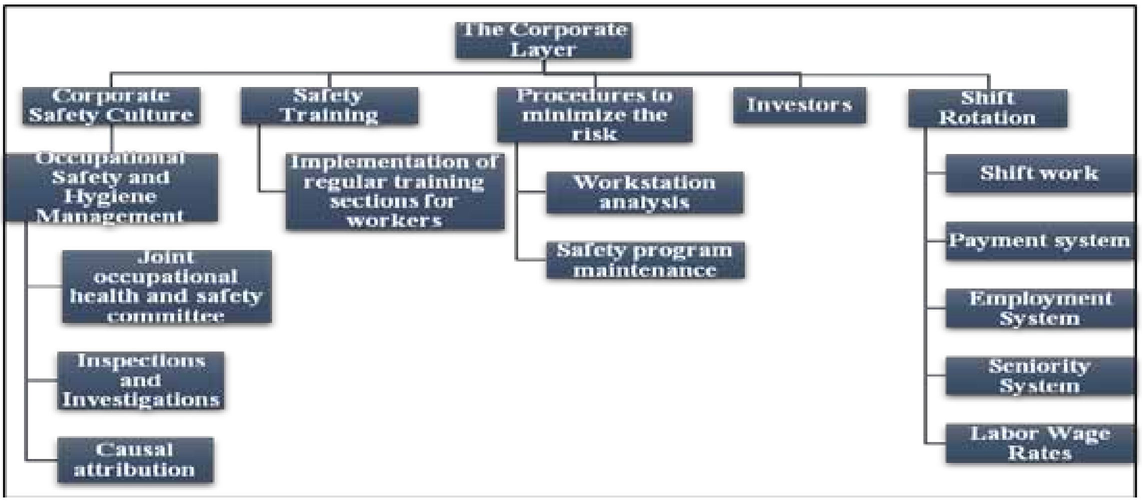

Figure 3 - Elements corresponding to the Corporate Layer in Pork Industries. Adapted from Attwood (2006)

3.1.4 The External Layer

As Attwood (2006) pointed out in his paper, there are several situations which can influence corporate decisions. These situations are connected by influences of external environment or contexts which impact all the other layers of the model. One of these influences, as surveyed by Steinsfeld et al (2006) is the increasing of human populations which demand for animal-source food products.

The intensification of pork production has been occurred because people who live in countries such as Brazil, Canada, United States and China have derived their dietary protein intake from food of livestock origin. The FAOSTAT (Food and Agriculture Organization of the United Nations) presented an overview which shows the intense raising of pork production from 2007 to 2011 in tonnes:

Table 1 - Production of pork (pig meat) from 2007 to 2012 in tonnes. Source: FAOSTAT (accessed July 2015)

Production/ year (in tonnes)	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Brazil	2,990,000.00	3,015,000.00	3,130,000.00	3,195,000.00	3,369,616.00	3,464,520.00
Canada	1,898,000.00	1,947,830.00	1,943,420.00	1,925,930.00	1,968,880.00	1,998,430.00
China	43,933,037.00	45,804,252.00	47,924,755.00	49,581,462.00	49,396,351.00	50,003,628.00
USA	9,951,360.00	10,598,959.00	10,441,699.00	10,185,748.00	10,330,808.00	10,555,203.00

Along the years, the ample growth for demanding pork products exerts pressures on the industry sector, mainly because the necessity of sub products to maintain the large-scale production. Another influence has been detected by the increase of grain prices (due the low level of crop production and international economic variances such as the inflation) which impacts directly the livestock production in overall sectors. The table 2 shows the increasing of pork producer prices (in USD/ton) between 2007 and 2011 in Canada, United States and China (FAO has not enabled the current situation in Brazil):

Table 2 - Producer price (in USD/ton) to meat live weight from 2007 to 2011. Source: FAOSTAT (accessed July 2015)

	Producer Price (USD/ton) – meat live weight				
Canada	1,040.10	1,016.90	913.9	1,205.50	1,439.40
China	1,814.50	1,761.50	1,765.70	1,561.30	1,733.70
United States of America	1,027.00	1,036.00	917	1,193.00	1,440.00

The strength of the inflation has also been affecting developing countries. Due the growth of inflation, livestock productions in Brazil, Argentina and Colombia are constantly presenting higher Producer Price Index (PPI) compared with other developed countries such as United States, United Kingdom, Spain and Canada. Based on the United States Department of Labor, the producer price index (PPI) is the first indicator of inflation annually or monthly. It is a measure of wholesale prices at the producer level for consumer goods and capital equipment. The influence of inflation occurs over the PPI when the grade reaches values beyond 100.

Table 3 - Analysis of Producer Price Index (PPI) in developed and developing countries. Source: FAOSTAT (accessed July 2015)

Countries	**2007**	**2008**	**2009**	**2010**	**2011**
Argentina	118.76	144.25	142.1	216.14	257.94
Brazil	103.53	107.7	108.54	104.51	122.31
Canada	89.41	84.36	81.22	97.03	111.4
Colombia	108.22	130.17	129.13	129.78	129.63
Spain	74.79	81.9	78.9	79.66	87.24
United Kingdom	92.15	113.57	130.44	124.1	123.14
United States of America	96.04	99.77	85.94	111.56	134.66

According to Tripp et al (2008), the pork production businesses only increase in size to remain competitive. There are socioeconomic pressures to keep costs down and to produce a uniform high quality product, as well as political pressures which can add to the costs of production. Variables such as feed prices, energy costs, labor wage rates, workers' compensation insurance, taxes and tough environmental regulations can all impact the costs of hog production.

Indeed, the process of slaughtering has potentially increased along the years in the main countries which produce pork. In the table 4, the total amount of pork production (animals/slaughtered: head) is showed with 8% of growing in Brazil, 15,23% in China and 4,5% in United States. In Canada and Portugal the number of slaughtering along the years remained slightly constant.

Table 4 - Production of pork slaughtering in the main countries (Head (animals/slaughtered)). Source: FAOSTAT (accessed July 2015)

Countries	2007	2008	2009	2010	2011	2012
Brazil	33.110.000,00	32.700.000,00	33.510.000,00	34.290.000,00	34.873.154,00	35.979.434,00
Canada	21.269.100,00	21.706.300,00	21.806.500,00	21.296.500,00	21.262.200,00	21.282.600,00
China	576.375.226,00	602.225.970,00	624.914.822,00	677.242.926,00	672.141.183,00	679.960.975,00
Portugal	5.777.716,00	5.977.054,00	5.920.892,00	5.965.601,00	5.887.915,00	5.541.933,00
USA	108.138.000,00	116.558.400,00	113.733.800,00	110.367.000,00	110.956.300,00	113.257.600,00

Taking into account that pork production is inserted in feed quality management, the pressure due the food quality regulations also affect directly occupational health and safety outcomes. It's important to note that these regulations are evaluated through the combination of other external parameters such as the customer pressure and the governmental policies. The specific elements considered to conclude the external layer are showed below:

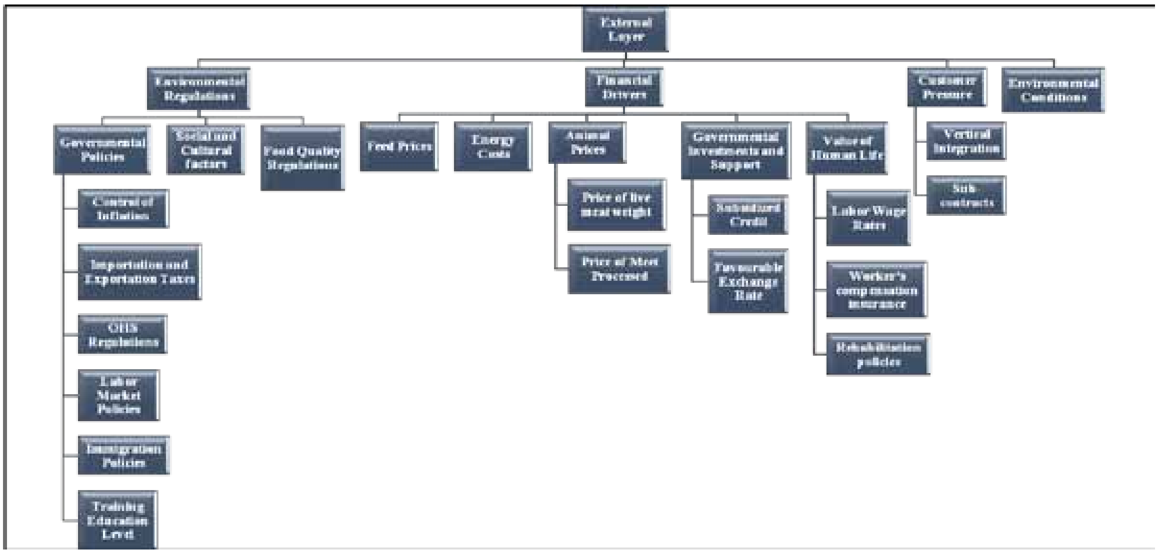

Figure 4- Elements corresponding to the External Layer in Pork Industries. Adapted from Attwood (2006)

4. CONCLUSIONS

The pork industry has been getting relative importance to occupational health and safety society. The major part of the farms and companies need to improve their knowledge about the real external and internal impact of accidents and injuries on production and management of products due the intensification of the demand from the consumers.

This study focused on finding all variables which can affect OHS outcomes as well as the results planned by the managers in order to predict, through safety management, sources of risks. However, it is truly necessary to measure the influence of each parameter in terms of financial, social and environmental damages. Future researches can apply this model in different regions or countries in order to determine ways to improve the implementation of safety and health outcomes through similarities and correlations (strengths and weaknesses on applying OHS guidelines) between them.

Moreover, this report shows the consequences from the external to direct layer by linear model where the intensification of damages from the top (external environment) can affect characteristics present on the bottom of the structure (direct influences on the workplace). It is also necessary to evaluate if some of these variables can influence OHS outcomes and regimes through different directions, creating feedbacks and correlating causes and consequences as Windle et al (2008) pointed out in his paper (a model which describes a dynamic effect between indirect and direct consequences over occupational health and safety in several contexts).

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The three layers integrated can evaluate and address the potential about how occupational health and safety guidelines can mitigate illness and injury throughout the pork industries system management. Orienting the OHS conceptions over the external, corporate and direct levels (focused on minimizing the consequences due the nature of work), it might be possible to describe how social, environmental and financial drivers behave inside this sector and others as well.

Therefore, the complete structure of the model (presenting all layers and the connections between them) is showed below:

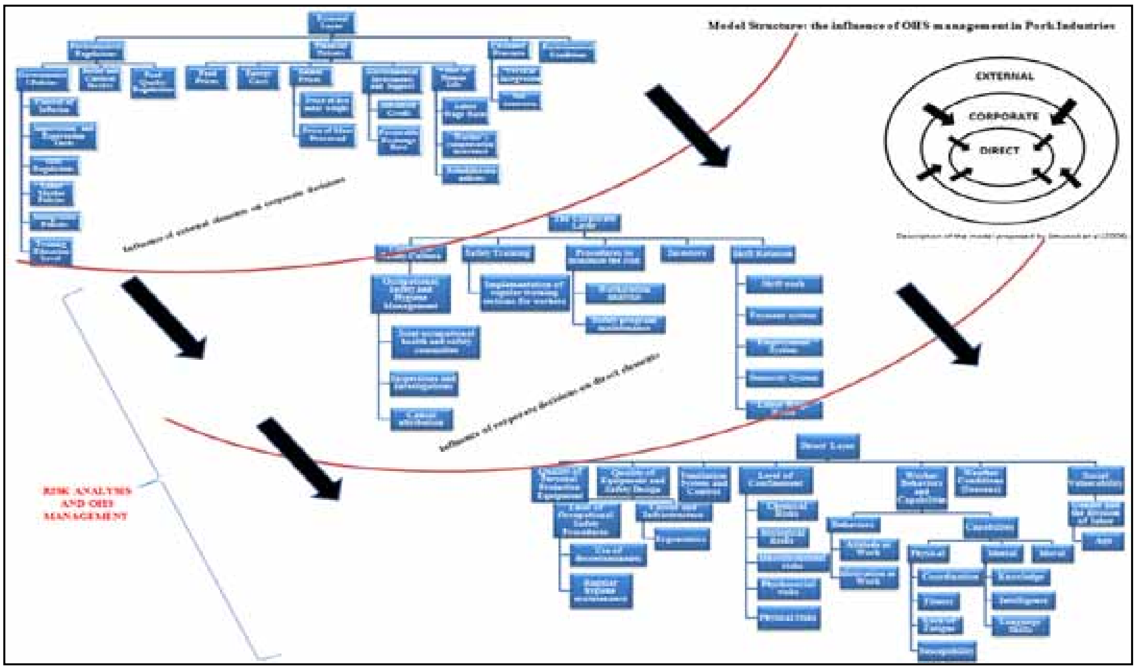

Figure 5 - Model structure. Adapted from Attwood et al (2006)

5. REFERENCES

Attwood D, Khan F, Veitch B. Can we predict occupational accident frequency? Institution of Chemical Engineers. 2006; Trans IChemE, Part B, 84(B3): 208-221

Attwood D, Khan F, Veitch B. Validation of an offshore occupational Accident Frequency prediction model – a practical demonstration using case studies.American Institute of Chemical Engineers. 2006; 25(2): 160-171

Binkley M, Bigney K, Neis B, Bornstein S. Lessons from Offshore: Challenges and opportunities in linking data to promote understanding of accidents and injuries among Newfoundland and Labrador fishers 1989- 2001. Marine Policy 2008; 32(6): 905-912

Cole, Dana, Lori Todd, and Steve Wing."Concentrated swine feeding operations and public health: a review of occupational and community health effects."Environmental health perspectives 108.8 (2000): 685.

Donham KJ. Community and occupational health concerns in pork production: a review. J. Anim. Sci. 2010; 88(E. suppl.):E102-E111. Doi: 10.2527/jas.2009-2554

Embrey, David E. "Incorporating management and organisational factors into probabilistic safety assessment." Reliability Engineering & System Safety 38.1 (1992): 199-208.

Fávero, Jerônimo Antonio, and Claudio Bellaver."Produção de carne de suínos." Congresso Brasileiro de Ciência e Tecnologia de Carnes. Vol. 1. São Pedro eSP: ITAL, Instituto de Tecnologia de Alimentos, 2001.

Frank, J et al. Disability resulting from occupational low back pain, Part I: what do we know about preliminary prediction? A review of the scientific evidence on prevention before disability begins. 1996. Spine 21(24): 2908-17

Hallqvist J, Diderichsen F, Theorell T, Reuterwall C, Ahlbom A. Is the effect of job strain on myocardial infarction risk due to interaction between high psychological demands and low decision latitude? Results from the Stockholm heart epidemiology program (SHEEP). Social science and medicine. 46(11): 1405-15.

Hurley TM, Kliebenstein JB, Orazem PF. An analysis of occupational health in pork production. Amer. J. Agr. Econ. 2000. 82. p: 323-333

Kunz, A., M. Miele, and R. L. R. Steinmetz. "Advanced swine manure treatment and utilization in Brazil." Bioresource Technology 100.22 (2009): 5485-5489.

Langley R. Occupational Hazards on Swine Farms. North Carolina healthy hogs seminar. Duke University, NC, 1998.

Leigh J and Miller T. Ranking Occupations based upon the costs of job-related injury and diseases. Journal of Occupational and Environmental Medicine. 1997; 39(12): 1170-1182.

Lipscomb, Hester J., et al. "A conceptual model of work and health disparities in the United States." International Journal of Health Services 36.1 (2006): 25-50.

Mayhew C, Quinlan M, Ferris R. The effects of subcontracting/outsourcing on occupational health and safety: survey evidence from four Australian industries. Safety Science 25(1-3):163-178

Perdomo, Carlos Cláudio, Gustavo JMM de Lima, and Kátia Nones. "Produção de suínos e meio ambiente." Sistema 1995 (1990): 2000.

Pickrell J. Hazards in confinement housing – Gases and dusts in confined animal houses for swine, poultry, horses, and humans. Vet. Hum. Toxicol. 1991; 33: p. 32-39

Porcher, Jocelyne. "The relationship between workers and animals in the pork industry: A shared suffering." Journal of agricultural and environmental ethics24.1 (2011): 3-17.

Silveira NA, Naas IA, Moura DJ, Salgado DD, Silva, RBTR. Labor activities and occupational health in Brazilian swine production - a case study. Agricultural Engineering International: the CIGR Ejournal. Vol X. 2008

Steinfeld, H., T. Wassenaar, and S. Jutzi. "Livestock production systems in developing countries: status, drivers, trends." Rev. sci. tech. Off. int. Epiz 25.2 (2006): 505-516.

Sullivan T and Frank J. Restating disability or disabling the state: four challenges. In: Injury and the new world of work. 2000. UBC Press.

Trask C. Preliminary ergonomic evaluation of barn tasks in intensive swine production. Journal of Agromedicine 2013; 32(4): 368-378.

Vilela, Rodolfo Andrade de Gouveia, Ildeberto Muniz de Almeida, and Renata Wey Berti Mendes. "From surveillance to work-related accident prevention: the contribution of the ergonomics of the activity." Ciência&SaúdeColetiva 17.10 (2012): 2817-2830.

Windle MJS, Neis B, Bornstein S, Binkley M, Navarro P. Fishing occupational health and safety: A comparison of regulatory regimes and safety outcomes in six countries. Marine Policy 2008; 32(4): 701-710

MercoPress: South Atlantic News Agency. Available at: (http://en.mercopress.com/). Accessed at June 20th 2014)

Donham KJ. Pork industry health and safety training – Seminars and online courses. 2009. Available at: (*http://www.pork.org/FileLibrary/ResearchDocuments/07-226-DONHAM-UofIA.pdf)* Accessed Jun. 2, 2014.

Food and Agriculture Organization of the United Nations (FAO) (2014) – FAO statistical databases. Available at: http://faostat3.fao.org/faostat-gateway/go/to/download/P/PI/E. Accessed on 15 July 2014)

Taylor G, Roese G. Understanding the pork industry. NSW department of primary industries.Primefact 105. 2006. Available at: (*http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/62916/Understanding_the_pork_industry-Primefact_105-final.pdf)* Accessed Jun 06, 2014.

Oliveira NAS, Iguti AM, Monteiro I. Work conditions in a brazilian swine production unit. NES2012 Proceedings. 2012. Available at: (*www.nes2012.se/documents/Proceedings/Scientific/Oliveira_NAS.pdf)* Accessed Jun 5, 2014.

How quantitative are “semi-quantitative” risk assessment methods?

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Abstract
This paper intends to promote discussion on the way the term “semi-quantitative” is currently being applied to risk assessment (RA) methods. For decades, RA approaches had been classified within two major categories: quantitative and qualitative. The paper starts with a brief historical review on both categories, explaining the evolution of techniques and associated concepts. After such introductory review, the author focuses on certain scored techniques and the ever more frequent term “semi-quantitative”. The use of such classification, however, is not consistent in terms of meaning and definitions. Just as it happened with other safety concepts in the past, this calls for common understanding and clarification. This paper encourages the debate among safety professionals and researchers, by setting out the question “how quantitative are “semi-quantitative” risk assessment tools?”. It also offers a possible answer to the question, by proposing that a fundamental notion behind the concept “quantitative” is that numbers, whenever used, need to have a mathematical or statistical real meaning associated with them. Otherwise, when numbers are assigned only to establish a scale or order (scores), the assessment would better be considered as a qualitative one, in which subjectiveness is still a relevant part of the scale.

Keywords: risk assessment tools, risk matrix, scored methods, risk terminology

1. INTRODUCTION

The general term “risk assessment” (RA) has a wide scope and it embraces an endless field of application, ranging from complex, highly technological systems to the simpler day-to-day risks of working places. In both cases, however, national and international legal systems require that all kinds of risks be assessed and controlled, i.e., be kept at an acceptable level. Over time, this legal pressure has helped to promote change and to improve safety practices in all organisations. It also meant that assessing and “measuring” risk level became widespread and a routine activity in most organisations. Simultaneously, there has been a fast popping out of many proposals for new methods on how to perform risk assessments. As a result, the traditional categorisation into qualitative or quantitative methods is not enough to embrace all the new proposals. New concepts and new terminology appeared in the literature classifying certain methods as “hybrid”, “semi-quantitative”, etc. Such progression in the RA lexicon, however, is not consistent in terms of meaning and definitions, as they often depend on the (individual) interpretation and experience of their author(s). Just as it happened with other safety concepts in the past, this calls for common understanding and clarification.
Discussing unclear concepts, encouraging debate and reducing potential confusion among the interested parties (e.g.: safety professionals, researchers, legislators, law enforcement agents, etc.) became the chief motivation for this paper, which frames de question: *How quantitative are “semi-quantitative” risk assessment tools?*

2. HISTORICAL BACKGROUND AND EVOLUTION

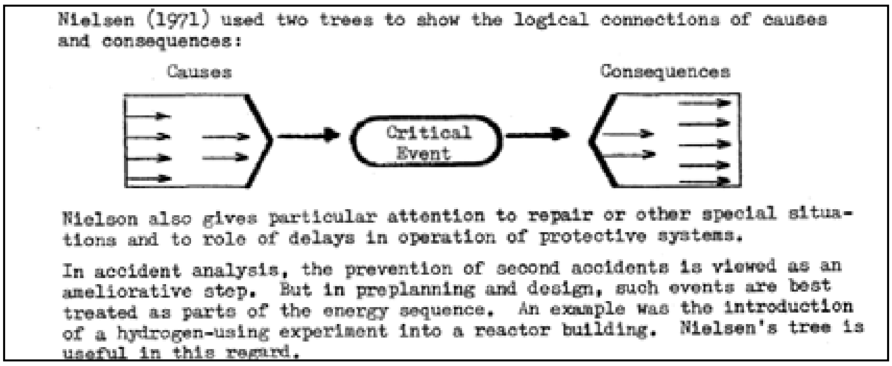
Countless risk analysis and assessment techniques can easily be found in the literature. For such reason, sections 2 and 3 are not intended to give a comprehensive review on such techniques, but rather be a short summary of the most relevant and best known, especially those that have survived the test of time. This brief historical background is intended to facilitate the distinction between strictly “quantitative” and “qualitative” approaches and give support to the discussion held here. The case with the “semi-quantitative” will be discussed later, towards the end of the paper.

2.1 Risk assessment within industrial settings

There is abundant evidence in the literature showing that assessment of industrial risk has been closely associated with reliability and that this relationship was intensified during World War II (e.g.: Hammer, 1989; Cox & Tait, 1991; Villemeur, 1992). Towards the end of the 19th Century, science had begun to make use of statistical and probabilistic techniques. These probabilistic approaches entered the safety and reliability fields during the war on a large-scale basis, as

attempts were made to operate electronic armament (Cox & Tait, 1991). During the following decades such techniques have multiplied and have been applied to other fields, such as civil aviation and the process industry, where larger and more hazardous chemical reactors became the first centre of attention; spatial, nuclear and the offshore oil industry followed immediately.
In the 1950s reliability became a discipline in its own right, as a branch of engineering, and underwent rapid development particularly in the electronics field. The next decade witnessed the rise of new reliability and safety techniques as well as a wider variety of their applications; Fault Tree Analysis (FTA) and Failure Modes and Effects Analysis (FMEA) are examples of these new developments, which have been extensively used ever since (Villemeur, 1992). According to Villemeur, up to the end of the 1960s, these methods were intensively used, but only in a few "high-tech" industries. However, during the same decade, the Japanese industry made a significant effort to integrate quality and reliability concepts and methods, which led to Japan's economic success in the 1970s.
In contrast with the probabilistic tree-diagram techniques of the 1960s - 1970s, such as Fault Tree Analysis (FTA) and Event Tree Analysis (ETA), a couple of qualitative techniques (usually using tables to display results) were also developed for the analysis of industrial / technical systems, focusing on systems' reliability or on their safety and operability condition. In the case of reliability, a well-known and surviving technique is Failure Modes and Effects Analysis (FMEA), which was further developed to FMECA (Jonhson, 1973, p.251; Villemeur, 1992; ISO/IEC/FDIS 31010, 2009); in the extended version FMECA, the "C" letter stands for "Criticality" [of the effects] and it adds the ability of ranking risk through a scoring system incorporated in the analysis; although also qualitative, FMECA allows ranking / categorisation into "severity classes" for prioritising intervention. The latter concerns the HAZOP technique (Hazard and Operability Studies), which it was developed in ICI Petrochemicals Division in 1963, UK. The first published paper on HAZOP was from Herbert G. Lawley, in 1974 (IChemE, 2002; p.24). HAZOP was developed for application in the process industry and is well documented by Kletz (1983 and after); this technique has survived the test of time and is still widely used as a qualitative approach in a variety of chemical and petrochemical plants.
During the 1970s and 1980s, the nuclear industry became an important contributor to the innovations introduced into industrial risk assessments. The first extensive risk assessment of an industrial site (two nuclear power plants in the USA) was published in 1975 and Professor Rasmunssen directed the study (Villemeur, 1992; Reason, 1990). This risk assessment included the human element for the first time. From this milestone onwards, the number of comprehensive (and costly) probabilistic risk assessments increased dramatically in high-tech industries, especially in nuclear power plants. During this period, the qualitative assessments of the past quickly shifted to the powerful quantitative (probabilistic) techniques of Quantified Risk Assessment (QRA), also called Probabilistic Risk Assessment (PRA).
Up to the late 1970s it was the era of the so-called "safety systems engineering". In this epoch, reliability and safety science would typically be focused on hardware failure and, at most, on man-machine direct interface. The occurrence of several major industrial accidents during the late 1970s and 1980s, called for the need to improve safety and reliability, particularly in complex technical systems, through consideration and inclusion of all aspects of socio-technical systems. The 1980s marked this gradual transition from the technical/engineering to the socio-technical approaches. The study of human aspects in systems' reliability, through the psychological sciences, ergonomics and human factors engineering, has grown considerably since the 1980s (Rasmussen et al, 1987; Cox & Tait, 1991). Reason (1990) maps the development of cognitive science in this area and the probabilistic risk assessments of the 80s started to include the human element, i.e., the modelling of (probabilistic) Human Reliability Assessment (HRA) (Kirwan, 1996).
After the "official" arrival of the safety culture concept in 1986, there have been calls for new assessment methodologies, which should include failures related to organisational factors, safety management and safety culture. Advances in the 1990s, accounted not only for the inclusion of more factors into the analysis i.e., the socio-technical factors, but also for new developments at the level of mathematical modelling. By definition, risks are associated, to a greater or lesser extent, with uncertainty. Mathematical modelling deals with this uncertainty in an attempt to improve the confidence of prediction techniques. The advances in this field comprise further developments on both non-probabilistic (i.e. "possibility") and probabilistic methods. Regarding the first category, Wang et al (1995; p.104) stated *«the last decades have seen an explosion in research in the areas of non-probabilistic theories and their applications».* These included Bayesian modelling with imprecise prior probabilities and the use of Fuzzy Sets

theory for the identification of hazards and modelling of risk, especially in complex technological systems.
Both Bayesian and Fuzzy Sets methodologies use expert (subjective) opinions and provide a useful alternative in those situations where the distribution of variables, for use in probabilistic risk studies, is difficult or impossible to obtain (Wang et al, 1995; Coolen, 1996). Since the 1980s, Bayesian models have been widely used in safety analysis for the assessment of rare events, such as catastrophic occurrences in complex technical systems (Coolen, 1996; Aven and Pörn, 1998). Quantified risk analysis of rare events is very difficult because there is not enough data on failures to calculate relative frequencies; hence the use of experts. More recently, another way of getting in-depth information is through the use of Bayesian Belief Networks (BBN). This is a useful tool for the analysis of complex systems with many interactions between their components or functions (Jensen, 2001). The graphical network representation shows explicitly the dependence structure between the random variables considered in the system, which this brings a better understanding of the phenomena under analysis. Such characteristics led to a rapid expansion of this technique for the assessment and quantification of risks in various industrial contexts. A key advantage of BBN approaches is to allow the assessment based on historical data, expert opinion or a combination of both. The use of this technique has seen substantial increase (Trucco et al, 2008; Rizzuto et al, 2010).
On the other hand, the use of fuzzy logic seems promising, as this approach does not require probabilistic data. Fuzzy Sets theory originated in 1965 as a result of the work of Zadeh (1965; 1973), who also conceived many of its applications, the first of which was in the area of industrial controllers. Since then, fuzzy sets and fuzzy logic underwent a steady growth in other fields of application such as engineering, operational research, mathematics, and especially in computer science, for the development of “expert systems” (Sinha & Gupta *(eds)*, 2000). Around 2000, fuzzy theory entered the field of risk and safety assessment (Wang, 2000; Sii et al, 2001). Subsequently, it has been recognised that application of fuzzy reasoning provides a systematic tool to deal with risk uncertainty, a reason why fuzzy theory has been increasingly used for risk quantification (e.g.: Zimmermann, 2004; Markowski et al, 2009). An updated guidance on quantitative risk assessment and methods to deal with uncertainty is given by NASA (2011).
The turn of the millennium marks a new milestone for probabilistic techniques, when the Shell Group developed a new approach under the name of Hazard, Effect and Management Process (HEMP), which became known internally, and internationally, as the “bow-tie diagram” (Zuijderduijn, 1999). This concept gained popularity, as it offers a good overview of the different accident scenarios under analysis. The bow-tie technique combines FTA with ETA and it gives a graphical representation of the critical event (central nod), its causes (the fault tree on the left) and its possible consequences (the event tree on the right).
In fact, the fundamental idea behind today’s bow-tie, i.e., the combination of tools in such a logical sequence (FTA – Critical Event – ETA), was proposed several decades earlier, as shown in the original MORT Manual (Johnson, 1973), of which an extract is presented in Figure 1.


Nielsen (1971) used two trees to show the logical connections of causes and consequences:

Nielson also gives particular attention to repair or other special situations and to role of delays in operation of protective systems.

In accident analysis, the prevention of second accidents is viewed as an ameliorative step. But in preplanning and design, such events are best treated as parts of the energy sequence. An example was the introduction of a hydrogen-using experiment into a reactor building. Nielsen's tree is useful in this regard.

Figure 1- The embryo of the bow-tie diagram in 1971 explained in MORT (reprint, Jonhson, 1973, p.252)

With regard to the modern bow-tie approach of the 2000s, an important feature is that its diagram depicts safety barriers as well; thus it allows performing a barrier analysis, helping to identify missing or ill-designed barriers, which is a key-issue in today’s risk management. The bow-tie visibility has increased with the ARAMIS Project (Accidental Risk Assessment Methodology for Industries), in the framework of Seveso-II Directive (Delvosalle et al, 2003); a new integrated risk assessment methodology was created (Delvosalle et al, 2006), by

combining the strengths of different methods currently used in the European Countries. Such methodology, under the acronym of MIMAH (Methodology for the Identification of Major Accident Hazards), is supported by the bow-tie approach and the assessment of safety barriers and it focuses on industries within the framework of Seveso directives, i.e., on major industrial accidents. The bow-tie model is essentially a probabilistic technique, but in time it has developed in different versions, depending on the system under analysis. There have been attempts to combine the bow-tie diagram with fuzzy logics for the quantification of risk (e.g.: Markowski et al, 2009).
Overall, it is apparent that modern systems' approaches to industrial risk and global safety assessments require full integration of reliability concepts and its mathematical modelling, with human and organisational factors, management procedures and social/cultural values. Moreover, within complex industrial settings, the prevalent methods used are *quantitative techniques*, based on mathematical modelling of risk. A variety of such quantitative techniques often incorporate distinctive logic diagrams, e.g.: Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Bow-Tie, or Bayesian Belief Networks (BBN), to name a few (Fig. 2).

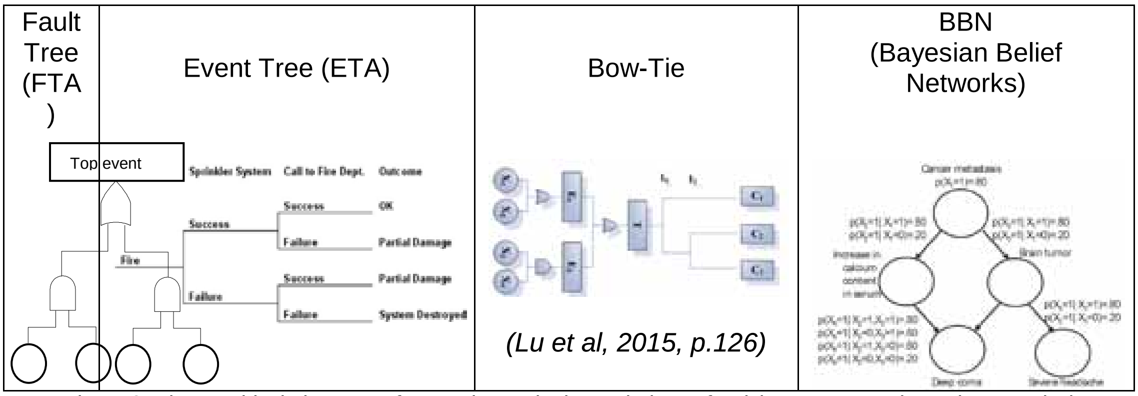


Figure 2- The graphical elements of several quantitative techniques for risk assessment (generic examples)

Despite the techniques illustrated above had been developed either as probabilistic or possibility tools (hence quantitative) the diagram feature can be used "per se" to help the analytical step, and to depict important relationships, even if the quantification step is not performed. Within the context of the current discussion, however, it is worth mentioning that such "partial application" of the techniques does not change the tools, i.e., it does not turn them into something else, neither "qualitative" nor "hybrid" tools. The technique is the same and its origin and nature remains the same, even though some analysts decide to use only part on the original technique.

2.2. Assessment of occupational risk

The debate on work conditions is perhaps the oldest one in safety science and yet it still is a central point of today's agenda, under an ever-increasing social pressure towards prevention of accidents and ill-health. Although many risk assessment techniques have been originally designed for risks arising from high-tech systems, some of these methods (mentioned previously) are considered adequate to assess all kinds of risk, even those associated with "minor hazards", which are common in any type of workplace or activity. This new section focuses the attention on methods that are commonly used for the assessment of occupational risk.
Work environment have been a long-standing preoccupation. In and around 1920, for instance, at the time of Taylor's "scientific management approach", the precursor of JSA (Job Safety Analysis) was simply called Job Analysis (JA) or Task Analysis. Glenn (2011) made a historical review of JSA and explains how Heinrich, in his well known book of 1931, used the term JSA as a way of emphasizing the safety benefits of JA to support employee selection (Glenn, 2011, p.49), i.e., to select the *«men best fitted to the peculiarities of the work»* as a means to reduce unsafe acts and enhance performance. JSA is a qualitative approach using a table to display results; the method is still in use by today's community of safety professionals, and its procedure is well covered in the several editions of "Accident Prevention Manual for Industrial Operations", printed by the US National Safety Council (e.g.: NSC, 1955 and newer editions).
Since these early attempts, many approaches have emerged to assess workplace safety. Harms-Ringdahl (1993; 2013) described many methods, specifically to show how safety

analysis can be applied in the field of occupational safety. It is argued that certain methods, such as FMEA (Failure Modes and Effects Analysis) and HAZOP (Hazard Operability Studies), in their original state, are not well suited to assess workplace hazards. FMEA, for instance, is much focused on hardware component failure, although it can be of use when assessing risks arising from machine operation (Harms-Ringdahl, 1993). With regard to the HAZOP technique, just as FMEA, it has limited usefulness in many working activities, since it is very much process-oriented for the chemical industry. However, Harms-Ringdahl (1993; p.108) defends that HAZOP can be applied to batch production, in which case the analysis "can be structured so as to follow job procedures rather than different parts of an installation"; some of the guide-words, however, may need to be re-formulated as appropriate. In both cases, as already mentioned, these techniques use text descriptors, their results are displayed in a text table and they are qualitative by nature.

In contrast with the above specifically-oriented techniques, other strictly qualitative but broader approaches were developed for use in occupational safety. The most popular are perhaps Energy Analysis and Deviation Analysis. The first appeared in the early 1960s and its origin and philosophy are well documented in relevant safety text books (e.g.: Hammer, 1989; Harms-Ringdahl, 1993, 2013). The Energy Analysis approach is used essentially to identify hazards (hazardous energies) that may cause harm by "transference of energy" to the system or worker. This technique provides a structured check-list to assist the analyst; the final results are presented in an organised table, which relates the hazard (type of energy), its potential consequence (injury or loss) and the recommended barriers for controlling risk: either by avoiding the energy release, and/or by reducing the magnitude of the consequence.

The Deviation concept, on the other hand, originated in Sweden for application to accident investigation and analysis (Kjellén, 1984), but it was later adapted by Harms-Ringdahl (1993) to the field of occupational risk analysis. The last version brings new details, namely the inclusion of "latent failures" within deviations (Harms-Ringdahl, 2013, p.117). This technique also includes a guidance check-list, this one organised into the THO fashion (Technical, Human and Organisational) risk factors. The main idea underlying the deviation analysis is that all systems can have deviations (from the standard procedure, or expected performance) that may, on certain occasions, lead to increase risk; therefore, all dangerous deviations need to be identified and dealt with. The basic concept of deviation is also present in FMEA or HAZOP, and therefore, the results are presented in relatively similar tables with qualitative information.

The diagram tree techniques, e.g.: FTA (Fault Tree Analysis) and Event Trees, can also be very useful in the assessment of occupational risks, although they are more difficult to use as their construction requires training and expertise skills. Because they clearly show the relationship between causes and consequences, these two techniques have been successfully used in the workplace, not only for risk analysis, but also for post-accident analysis (Hammer, 1989; Harms-Ringdahl, 1993). However, in occupational risk, the use of the diagram(s) to support the analysis is much more common than its probabilistic application.

Different types of quantitative assessments are found in occupational settings, despite being less frequent than the simpler qualitative analysis. It should be noted that quantifying the risk of occupational accidents is becoming increasingly important since the output of such assessments must be used to prove that risk acceptance criteria is met. A study carried out by Kjellén & Sklet (1995, p.225) concluded that *«there are no combinations of types of acceptance criteria and risk analysis methods that cover the full range of occupational accidents»*. As a consequence, they argue, it will be difficult to meet the requirements of risk analysis regulations in the area of occupational accidents. To fill this gap, Kjellén (1995) proposed a new risk assessment method called "Comparison Analysis", which allows the prediction of the quantified LTI-rate (Lost-Time Injury rate), although the author recognised that improvements were still needed.

The use of Fuzzy theory is another alternative and its practical application has entered occupational risk areas after 2000, where there is not a well-marked frontier between what is the "safe" and "unsafe" side regarding occupational exposure to a specific hazard. Examples of quantified applications are the use of fuzzy sets within occupational health risks (Nunes, 2007), or within occupational accident risks (Dağdeviren et al, 2008; Pinto et al. 2012).

Even more recently, the bow-tie probabilistic model has also reached the field of occupational safety, through the European project WORM (Workgroup for development of the Occupational Risk Model), intended to decrease occupational accident rates in the Netherlands (Hale et al, 2005). This workgroup uses the bow-tie approach to quantify risks of occupational accidents with the purpose of introducing a risk-based thinking into occupational safety. The project has

already produced ample evidence of progress by the work of, for instance, Hale et al (2007), Papazoglou & Ale (2007), Aneziris et al (2008); further evidence is given by Papazoglou et at (2015, online).
Overall, it can be established that both qualitative and quantitative assessments are used in the field of occupational safety, but application of qualitative techniques prevail, as they are easier to learn and to apply and do not require quantified data for the assessments. Finally it should be noted that, preferably, methods can be grouped and combined, profiting from their individual focus and strengths; the combination is likely to provide a better holistic approach to the whole process. A summary of methods and a grouping strategy (Fig. 3) has been proposed by Harms-Ringdahl (2013).

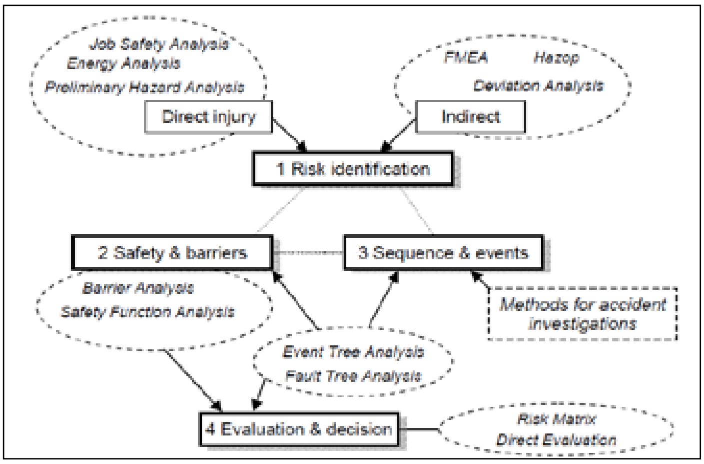


Figure 3 – Alternative grouping of methods proposed by Harms-Ringdahl (2012, p.59)

The figure maps four stages of a risk assessment process and pinpoints the method(s) best fit for each stage. Many were already mentioned in Sections 1 and 2 of this paper. The fourth group is concerned with evaluations and decisions, for which Risk Matrices are considered a good option. Matrices are very popular among safety professionals and are well covered in the literature. Sometimes are classified "qualitative", other times are "semi-quantitative" and quite often both terms are used interchangeably, without clear distinction. This is the point where the pertinent question arises: *how quantitative are "semi-quantitative" risk assessment tools?*
Since the question is also the focus of this paper, risk matrices will be discussed in a section of their own (Section 4), only after some debate on the concepts of Risk Assessment *versus* Risk Management and on how the new standard ISO 31000:2009 defines quantitative, qualitative and semi-quantitative risk assessment approaches.

3. RISK ASSESSMENT *VS* RISK MANAGEMENT – THE WHOLE PROCESS

All risk perspectives, however different, have at least one common element: the distinction between reality and mere possibility (future occurrence). Almost all definitions comprise three elements: uncertainty (probability of occurrence), outcomes that have an undesirable effect (consequences) and a formula, or reasoning procedure, to combine both (Renn, 1998). These three elements, in turn, provide the basis for the concept of **risk assessment**, which can be defined as:*«the scientific process of defining the components of risk in precise, usually in quantitative terms (…) In technical risk assessments this means specifying what is at stake, calculating the probabilities for unwanted consequences, and aggregating both components»* (Renn, 1998; p.52). This definition, then, suggests a quantified probabilistic procedure.
A simpler qualitative definition for application within occupational risk is: «*the process of identifying hazards and evaluating the risks to health and safety arising from these hazards taking account of the existing risk controls (or, in the case of a new activity, the proposed risk controls)*» (BS 8800, 2004; p.4). **Risk management**, in turn, refers to the process of reducing risks to a level deemed tolerable by the organisation or society and to ensure its control, monitoring and communication (Renn, 1998). A generic framework for illustrating the whole process of risk management (Fig. 4) is the one provided by the International Standard IEC 60300-3-9 (Rouhiainen and Gunnerhed, 2002).

More recently, the ISO 31000 (2009) adopts the same terms and definitions given in ISO/IEC Guide 73, and establishes eleven key principles (2009, pp.1-2) for risk management. This new standard provides general guidance and brings higher visibility to human and cultural risk factors, to the dynamic nature of risk management and puts great emphasis on the continuous improvement principle. An interesting particularity of the new standard is that it does not include the term hazard within its general procedure; instead of hazard within the first stage of risk identification, it uses the term «*sources of risk*» (p.11).

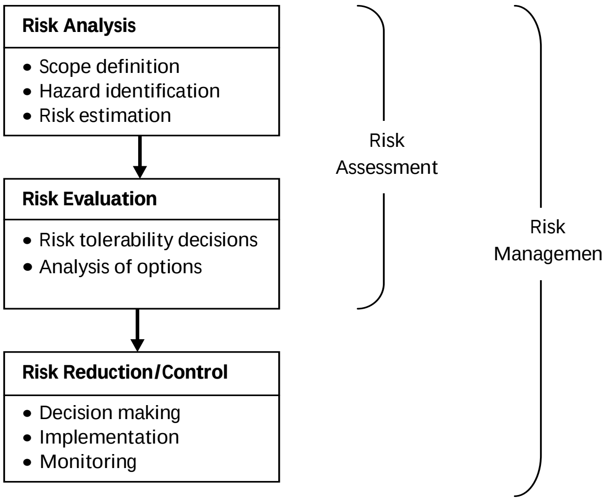


Figure 4 - Relationship between Risk Assessment and Risk Management (IEC 60300-3-9, cited by Rouhiainen and Gunnerhed, 2002; p.62)

When it comes to the stage of ***risk analysis***, the standard states explicitly «*Risk analysis can be undertaken with varying degrees of detail (…) analysis can be qualitative, semi-quantitative or quantitative, or a combination of these, depending on the circumstances*» (p.12). It suggests application of qualitative analysis as the first step to obtain an overall view, but also advises «*when possible and appropriate, one should undertake more specific and quantitative analysis of the risks as a following step*» (p.12). Risk analysis also means that «*consequences can be expressed in terms of tangible and intangible impacts. In some cases, more than one numerical value or descriptor is required to specify consequences for different times, places, groups or situations*» (p.12).

Of particular interest for this discussion are the formal definitions given by the associated standard ISO/IEC/FDIS 31010 (2009, p.13). The key definitions are replicated below.

Qualitative assessment defines consequence, probability and level of risk by significance levels such as "high", "medium" and "low"; may combine consequence and probability, and evaluates the resultant level of risk against <u>qualitative criteria</u>.

Semi-quantitative methods use <u>numerical rating scales</u> for consequence and probability and combine them to produce a level of risk using a formula. Scales may be linear or logarithmic, or have some other relationship; formulae used can also vary.

Quantitative analysis estimates practical values for consequences and their <u>probabilities</u>, and produces values of the level of risk in <u>specific units</u> defined when developing the context.

In the latter case, the standard also states (p.13) that full quantitative analysis may not always be possible or desirable due to insufficient information, lack of data, influence of human factors, etc., or even because the effort of quantitative analysis is not warranted or required. In such circumstances, they say, a comparative semi-quantitative or qualitative ranking of risks by specialists, knowledgeable in their respective field, may still be effective.

From these definitions it becomes apparent that all techniques using scores (numerical ratings) can be classified as being semi-quantitative. There is no apparent distinction between scores/rates given by (merely) subjective judgments and scores based on quantified evidence, or underlying numerical data expressed in a specific unit; in the latter case the scores still hold a quantified meaning, although they are categorised in interval scales, to accommodate uncertainty.

Despite availability the formal definitions, there is still room for different interpretations of what a "semi-quantitative" analysis really means; the next section of this paper will discuss how some of these diverse interpretations are quite old, whereas others arise from relatively new developments.

4. SCORED SYSTEMS AND RISK MATRICES

Amongst the oldest techniques using scored systems are FMECA, and "Mathematical Evaluations for Controlling Hazards", also known as the Fine method (Fine, 1971; Fine and Kinney, 1971). The first was already discussed in Section 1; it was designed for reliability analysis of technical systems and it uses a *risk index* (RPN – risk priority number) to establish priorities. Considering the definition given by the ISO/IEC/FDIS 31010 (2009, p.81), "risk index" is «*a semi-quantitative measure of risk which is an estimate derived using a scoring approach using ordinal scales*» (p.81); the standard also states that «*Risk indices are essentially a qualitative approach to ranking and comparing risks. While numbers are used, this is simply to allow for manipulation*» (p.81), and the recommendation is that in certain cases, «*where the system is not well known, or not able to be represented, it is better to use a more overtly qualitative approach*» (p.81). Astonishingly, one reads in two consecutive paragraphs (p.81) that a "risk index" is a semi-quantitative measure of risk and also that risk indices are essentially qualitative approaches. On this basis, it is difficult to know which term is best suited for risk index.

The Fine method (Fine, 1971), in contrast, was aimed specifically at analysing safety, with the purpose of determining priorities. The Fine technique, which is also explained in the original MORT manual (Johnson, 1973, p.210), has gained visibility and became popular among safety professionals. It survived the test of time and this approach is currently part of the Technical Norms for Prevention (NTP 330) issued as guidance by the Spanish National Institute for Safety and Health at Work (INSHT, 1993).

The original Fine report (Fine, 1971, p.1), states that *«a formula is presented to calculate the risk due to a hazard, or to quantitatively evaluate the potential severity of a hazardous situation»*, which means that, at the time, this was viewed as a "quantitative" method. The referred formula is given by (Fine, 1971, p.4):

«Risk Score = Consequences x Exposure x Probability, or, in its abbreviated translation: R = C x E x P»

In fact, at least two variables of this "formula" (or evaluation rule) have rating scales based (at least partially) on "quantities", either expressed in monetary units for losses ($US, for Consequences), or in time units (e.g.: daily and weekly; for Exposure). Other ratings, however, represent the translation of nominal values, such as *«extremely serious injury (amputation, permanent disability)»* that are worth 50 points in the consequence scale [1-100], or «*disabling injuries*», worth 5 points in the same scale. The scale Probability rated [0.1-10], also uses nominal values and text descriptors, such as «*is the most likely and expected result = 10 points*» or «*would be an unusual sequence or coincidence = 3 points* » (Fine, 1971, pp.4-6). Based on such formula, Risk Score may vary from 0.05[1] to 10 000 scores and its "action sheet" hierarchy comprises three main levels of intervention (p.16). The 1971 Fine method also provides a formula to determine (economic) justification recommended for corrective action(s). Once again, the variables used are expressed in either monetary units (Cost), or in relatively subjective criteria (Degree of Correction), and then translated into ratings to estimate the final score for Justification.

On the other hand, the Spanish Norm NTP 330 proposes a final score for Risk Level within a scale [20-4000], which is associated with four levels of intervention ranging from "no intervention" to "correction is urgent". The Spanish authorities state that «*this methodology allows quantifying the magnitude of risk and, as a consequence, to establish a rational hierarchy for correction*» (INSHT, NTP 330, 1993, p.2).

The point taken is that both William Fine (in 1971) and the Spanish Institute (currently) classify this technique as "quantitative", even though it uses ratings within an ordinal (interval) scale for grading risk. In the light of the definition provided by the new ISO/IEC/FDIS 31010 (2009, p.13), this method would be better classified as "semi-quantitative", given that it relies on scores. Moreover, it is worth highlighting that, within the Fine Technique, these ratings/scores may, or may not have a "quantity" underlying them, or simply be given upon text descriptors and subjective criteria.

Risk Matrices, on the other hand, may be based as well on rating systems and are of paramount importance in this discussion. They are frequently called "qualitative", or "semi-quantitative", or even "quantitative" tools for assessing risk. This is perhaps the area in which terms and opinions seem to be ever imprecise and call for clarification and harmonisation.

A very ample description on the general Risk Matrix process is given in Harms-Ringdahl's most recent book (2013). Apparently, for this author, the risk matrix is *«a semi-quantitative method»* but he also acknowledges that the matrix *«is applied in many different areas, and consequently the terminology and methodology vary quite a lot»* (p.76). Moreover, Harms-Ringdahl (2013, p.87) draws attention to several critical problems associated with the use of matrices; to cite but a couple, 1) most users rely on implicit assumptions, which they presume to be shared by

[1] R = CxExP; lower limit score (0.05=1x0.5x0.1); upper limit score (10 000=100x10x10)

everyone (without even referring to any guidance), and 2) the lack of, or absent meaning of the scales for probability and consequence, and their origins.
In fact, the design, interpretation and detail of risk matrices vary immensely, to a point that it can create the false illusion of "quantification", simply because numbers are often used, even if such numeric values are not associated with any quantity or unit. The ISO/IEC/FDIS 31010 gives a detailed description of this technique in its Annex B.29, in which it explains that *«the consequence/probability matrix is a means of combining qualitative or semi-quantitative ratings of consequence and probability to produce a level of risk or risk rating (…) it is commonly used as a screening tool»* (ISO/IEC/FDIS 31010, 2009, p.82). Despite this, it is still unclear in which cases matrices can be adequately classified as "semi-quantitative" tools, or when they should remain "qualitative", even when ratings are used. Apparently, only matrices using exclusively qualitative text descriptors are universally accepted as qualitative. The best known example of strictly qualitative is provided by the British Standard BS 8800 (BSI, 2004), illustrated in Figure 5. This British standard provides nominal values (text descriptors) for the several levels of "likelihood" and "consequence", thus allowing for five levels of risk (ordinal scale) to establish the hierarchy of control measures.

Likelihood of harm (see Table E.2)	Severity of harm		
	Slight harm	Moderate harm	Extreme harm
Very unlikely	Very low risk	Very low risk	High risk
Unlikely	Very low risk	Medium risk	Very high risk
Likely	Low risk	High risk	Very high risk
Very likely	Low risk	Very high risk	Very high risk
NOTE These categorizations and the resulting asymmetry of the matrix arise from the examples of harm and likelihood illustrated within this British Standard. Organizations should adjust the design and size of the matrix to suit their needs.			

Figure 5 – Matrix 4x3 applying strictly qualitative criteria for ranking risk; 5 levels of risk (BS 8800:2004, p.26)

On the opposite side of strictly qualitative, it is also clear that «*Rating scales and a matrix may be set up with quantitative scales. For example, in a reliability context the probability scale could represent indicative failure rates and the consequence scale the dollar cost of failure*» ISO/IEC/FDIS 31010 (2009, p.85). In this case, it is obvious that ratings are not merely ordinal entities for comparative purposes; these ratings establish specific interval scales with intrinsic meaning, because certain "quantities" (and units) are associated with each level of the scale. So, is this a semi-quantitative or a strictly quantitative approach?
The problem: What happens in-between these two extremes? i.e., when rating scales use numerical values merely to set up a ranking/order for risk-level? The question is: in which case should matrices be considered "semi-quantitative" tools? The same question applies to risk indices based on ratings or to any other scored approach. Apparently, the trend in the literature is to call "semi-quantitative" to scored matrices in general, regardless of their numeric scores/rating scales having, or not, an underlying mathematical meaning or an associated quantity.
A recent study by Carvalho & Melo (2014; 2015 in press) also classifies ranked Risk Matrices as "semi-quantitative" tools, even when the rated scales are nominal. The study was designed at measuring the reliability of these tools when applied by different analysts. To this purpose the authors asked around 40 people to use four semi-quantitative risk matrices (in two different moments) to estimate and assess six occupational risks identified in two tasks associated with the production of Airbags. The Krippendorff's Alpha coefficient (α-K) was the agreement measure selected to evaluate both inter-rater and intra-rater agreement. It was found that, in general, there was little agreement (αK < 0.6), which means low inter-rater reliability. This study demonstrates that different analysts can attain varying results (risk rates) and draw contradictory conclusions, due to difficulties in making objective judgements, which supports the recommendation that estimates should be made within team work. In the past decade, the advice of using risk matrices "with caution" seems to be consensual amid many authors; perhaps the strongest signal comes from Cox (2008), who claims that under certain circumstances *«(…) the results can sometimes be 'worse than useless' leading to worse-than random decisions»* (Cox, 2008, p.497).
In the past decade much has been said on the use and misuse of Risk Matrix approaches (e.g.: Woodruff, 2005; van Duijne et al, 2008; Cox, 2008; Jacinto et al, 2010; Ni et al, 2010; Al-Anbari et al, 2015; Duijm, 2015; Lu et al, 2015). Regardless of being "pro" or "against", most authors pinpoint the same type of advantages and similar limitations as well. Among the most referred

advantages are the following: a) Easy to use, b) Promote robust discussion, with the discussion often being more useful than the actual rating, c) Allow decision makers to focus on the highest priority risks. In what concerns relevant limitations, the most frequent criticisms are: a) Difficult to define the scales unambiguously, b) There is a risk of semantic confusion of the names that are used for value labels on a scale, and c) It is difficult to combine or compare the level of risk for different categories of consequences.

Possible solution: The above mentioned limitations provide strong motivation towards more objective criteria, preferably based on some measurable quantities. In other words: numbers assigned to scales should have a quantifiable meaning; in turn, this calls for a better discrimination between qualitative and semi-quantitative assessments.

5. FINAL ARGUMENTS

This paper provided evidence that confusing terminology appears in the literature classifying certain risk assessment methods as "hybrid", "semi-quantitative", etc. Such evolution in the safety lexicon, however, is not consistent in terms of meaning and definitions. Just as it happened with other safety concepts in the past, this calls for common understanding and clarification.

This paper intends to encourage the debate among safety professionals and researchers, by setting out the question "*how quantitative are "semi-quantitative" risk assessment tools?*"

As a basis to start discussion, the author suggests that a fundamental notion behind the concept "quantitative" is that numbers, whenever used, need to have a mathematical or statistical real meaning associated with them. Otherwise, when numbers are assigned only to establish an ordinal scale (ranking scores), the assessment would better be considered as a qualitative one, in which case subjectiveness and individual interpretation are still a relevant part of the scale.

As a consequence, it is also suggested that the term "semi-quantitative" be used only in situations where the scores can be associated to some kind of quantity, with measurable units. This principle applies to risk matrices and to all other methods using scored systems. Examples of quantified criteria for ranking scales are suggested in Table 1, some of which have already been used in studies using a risk matrix, sometimes in combination with other techniques (e.g.: Woodruff, 2005; Jacinto and Silva, 2010; Ni et al, 2010).

Table 1 – Examples of quantified criteria (intervals of values) for rating probability/consequence matrices

Probability / Likelihood (interval scales)	Consequence (interval scales)
Failure rates of equipment Accident rates (for a specific activity or sector), e.g.: incidence rate per 10^5 workers; frequency rate per 10^6 hours	Monetary units (e.g.: cost of damage and losses; % impact on budget)
Accident distribution – relative frequency Number of occurrences – absolute frequency	Days lost (absence from work due to accidents); accident ratios to fatal
Time intervals (e.g.: exposure frequency, mean time between failures)	Time intervals, Downtime (e.g.: recovery time of environmental damage in years; business interruption (hours)

The metrics suggested in Table 1 are not exempted of errors and misjudgements; ranking probability/consequence scales based on quantified intervals is likely to reduce subjectiveness of the assessment, but only if each scale takes into account the specific risk scenario under assessment, i.e., the criteria (and quantities, intervals) established need to be representative of the situation, or activity in which the specific risk is being considered.

To support this proposal, Figures 6 and 7 illustrate a couple of examples, in which the concept "semi-quantitative" matrix approach is associated with scales for probability and seriousness based on some kind of "quantity", i.e., based on measurable units, with a mathematical meaning.

The first example (Fig.6) depicts an approach to assess occupational accident risk in the activity sector "ship building and repair". The risk level was estimated using a Risk Matrix with real accident data of the mentioned activity sector. The likelihood/probability scale was established using the relative frequency distribution of accidents (variable contact), whilst severity of harm (consequence scale) was based on the variable days lost.

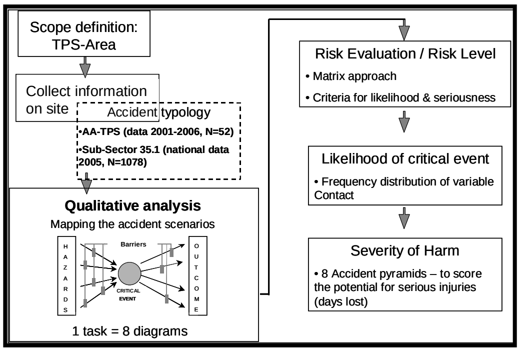


Figure 6 – Combined use of Bow-Tie with a "semi-quantitative" matrix (Jacinto & Silva, 2010, p.975)

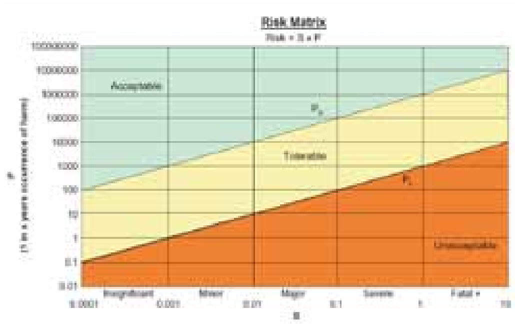


Figure 7 – A risk matrix using tolerability limits proposed by Woodruff (2015, p.348)

In the second example (Fig.7), also within occupational accident risk, the Risk Matrix was built using the British HSE upper and lower tolerability limits for risk resulting in fatal injury to individuals, to which have been assigned values of 1 in 1000 per annum and 1 in 1,000,000 per annum respectively. Woodruff (2005, p.352) claims that for most organisations it is sufficient to estimate risks based on a simple 3 level scale of high, medium and low, and that calculation of the absolute value of risk is unnecessary even if it were possible.

The application of quantified criteria for establishing scored probability / consequence scales (inputs) is the main reason for calling these examples "semi-quantitative" approaches, as their original authors did. Naturally, if used in the wrong context, or in the wrong way, the results may be GIGO (Garbage In, Garbage Out), but when properly used in the specific context for which they had been assigned, then subjectiveness is expected to decrease and inter-rater reliability (agreement between different analysts) is likely to increase.

The virtues of "qualitative" matrices (scored or not) are not at stake in this discussion; they have recognised and important benefits when adequately applied. The case made with this discussion regards solely the terminology, suggesting a way to discriminate more clearly between qualitative and semi-quantitative approaches with regard to risk matrices and other scored methods as well. Matrices, in particular, are currently so popular, and so widely used, that one can consider they have reached a maturity stage. The next improvement may well be an effort to establish harmonised terminology.

6. REFERENCES

Al-Anbari, S., Khalina, A., Alnuaimi, A., Normariah, A., Yahya, A. (2015). Risk assessment of safety and health (RAHS) for building construction. *Process Safety and Environmental Protection*, 94, 49–158.

Aven, T. and Pörn, K. (1998). Expressing and interpreting the results of quantitative risk analysis. Review and discussion. *Reliability Engineering & System Safety*, 61, 3–10.

BSI - BS 8800 (2004). Guide to occupational health and safety management systems (2nd Edition). British Standard Institutions, UK.

Carvalho, F. & Melo, R.B. (2014). Semi-quantitative Approach in Risk Assessment: Inter and Intra-rater Reliability. In *Advances in Safety Management and Human Factors*, P. Arezes & P. Carvalho (Eds.), pp. 246–257. AHFE'2014.

Carvalho, F. & Melo, R.B. (2015, in press). Stability and reproducibility of semi-quantitative risk assessment methods within the occupational health and safety scope. *WORK: A Journal of Prevention, Assessment, and Rehabilitation* (In Press). doi:10.3233/WOR-141878.

Coolen, F.P. (1996). On Bayesian reliability analysis with informative priors and censoring. *Reliability Engineering & System Safety*, 53(1), 91–98.

Cox, L.A. (2008). What's Wrong with Risk Matrices? *Risk Analysis*, 28(2), 497–512.

Cox, S.J. & Tait, N.R.S. (1991). Reliability, safety and risk management: an integrated approach. Butterworth Heinemann, Oxford, UK.

Dağdeviren, M, Yüksel, İ, Kurt, M. (2008). A fuzzy analytic network process (ANP) model to identify faulty behavior risk (FBR) in work system. *Safety Science*, 46(5), 771–783.

Delvosalle, C., Fievez, C., Pipart, A., Debray, B. (2006). ARAMIS: A comprehensive methodology for identification of reference accident scenarios in process industries. *Journal of Hazardous Materials*, 130(3), 200–219.

Delvosalle, C., Fiévez, C., Pipart, A., Fabreg, J.C., Planas, E., Christou, M., Mushtaq, F. (2003). ARAMIS Project: Identification of reference accident scenarios in SEVESO establishments. In *Safety and Reliability*, Bedford and Van Gelder (Eds), ESREL 2003, pp. 479–488.

Duijm, N.J. (2015). Recommendations on the use and design of risk matrices. *Safety Science,* 76, 21-31.

Fine, W.T. (1971). Mathematical Evaluations for Controlling Hazards. Naval Ordinance Laboratory, White Oak Maryland (NOLTR 71-31), USA. Document Retrieved from: http://handle.dtic.mil/100.2/AD722011

Fine,W.T. & Kinney,W.D. (1971). Mathematical evaluation for controlling hazards. *Journal of Safety Research*, 3(4), 157–166.

Glenn, David D. (2011). Job Safety Analysis – Its Role Today. American Society of Safety Engineers, *Professional Safety*, 56(3), 48–57.

Hale, A. R., Ale, B. J., Goossens, L. H., Heijer, T., Bellamy, L. J., Mud, M. L. 2007. Modelling accidents for prioritizing prevention. *Reliability Engineering & System Safety*, 92(12), 1701–1715.
Hale, A., Ale, B., Bellamy, L., Whiston, J., Mud, M., Papazoglou, I., Bloemhof, B., Post, J., Oh, J. (2005). Best Practice in Risk Assessment: Work Accidents. European Consumer Safety Association Conference, Edinburgh 20-21 Apr.
Hammer, Willie. 1989. Occupational Safety Management and Engineering (4th Edition). Prentice Hall, Englewood Cliffs, New Jersey.
Harms-Ringdahl, L. (1993). Safety Analysis – Principles and Practice in Occupational Safety (1st Edition). Elsevier.
Harms-Ringdahl, L. (2013). Guide to safety analysis for accident prevention. IRS Riskhantering AB, Stockholm.
IChemE – Institution of Chemical Engineers (2002). Herbert G. Lawley – Obituary. IChemE Loss Prevention Bulletin No165, June 2002, UK, p.24.
INSHT, Spain (1993). NTP 330: Simplified Method for evaluating Accident Risks. Spanish National Institute for Safety and Hygiene at Work (INSHT). Technical Norms for Prevention, Ministry of Labour, Spain (*in Spanish*).
ISO 31000 (2009). Risk management – principles and guidelines. ISO - Inter. Organization for Standardization. Geneva.
ISO/IEC/FDIS 31010 (2009). Risk management — Risk assessment Techniques. ISO-International Organization for Standardization and IEC- International Electrotechnical Commission.
Jacinto, C. & Silva, C. (2010). A semi-quantitative assessment of occupational risks using bow-tie representation. *Safety Science*, 48(8), 973–979.
Jensen, F. (2001). *Bayesian Networks and Decision Graphs*, Springer-Verlag, New York.
Johnson, W.G. (1973). *MORT- The Management Oversight and Risk Tree*. SAN 821-2, US Atomic Energy Commission. Available at the NRI website: http://www.nri.eu.com/SAN8212.pdf
Kirwan, B. (1996). Safety management assessment and task analysis – a missing link?. Paper presented at NeTWORK Workshop, Bad Homburg, 20-22 June 1996.
Kjellén, U. & Sklet, S. (1995). Integrating Analysis of the Risk of Occupational Accidents into the Design Process. Part I: a review of types of acceptance criteria and risk analysis methods. *Safety Science*, 18(3), 215–227.
Kjellén, Urban (1984). The Deviation Concept in Occupational Accident Control – Part I – definition and classification. *Accident Analysis and Prevention*, 16(4), 289–306.
Kjellén, Urban (1995). Integrating Analysis of the Risk of Occupational Accidents into the Design Process. Part II: Method for prediction of the LTI-rate. *Safety Science*, 19(1), 3–18.
Kletz, Trevor A. (1983). *Hazop & hazan: notes on the identification and assessment of hazard*. Institution of Chemical Engineers (IChemE), Rugby, UK.
Lu, L., Liang, W., Zhang, L., Zhang, H., Zhong, L. and Shan, J. (2015). A comprehensive risk evaluation method for natural gas pipelines by combining a risk matrix with a bow-tie model. *Journal of Natural Gas Science and Engineering*, 25124–133.
Markowski, A. S., Mannan, M. S., Bigoszewska, A. (2009). Fuzzy logic for process safety analysis. *Journal of Loss Prevention in the Process Industries*, 22(6), 695–702.
NASA. 2011. *Probabilistic Risk Assessment Procedures Guide for NASA Managers and Practitioners*. (2nd Edition). Doc. NASA/SP-2011-3421, December 2011, NASA Headquarters, Washington, DC.
Ni, H., Chen, A., Chen, N. (2010). Some extensions on risk matrix approach. *Safety Science*, 48, 1269–1278.
NSC - National Safety Council (1955). *Accident prevention manual for industrial operations*. (3rd Edition). Chicago.
Nunes, I.L. (2007). Knowledge acquisition for the development of an upper-body work-related musculoskeletal disorders analysis tool. *Human Factors and Ergonomics in Manufacturing*, 17(2), 149–162
Papazoglou, I.A. & Ale, B.J.M. (2007). A logical model for the quantification of occupational risk. *Reliability Engineering & System Safety*, 92(6), 785–803.
Papazoglou, I.A., Aneziris, O., Bellamy, L., Ale, B.J.M., Oh, J.I. 2015 (on line, in press). Uncertainty Assessment in the Quantification of Risk Rates of Occupational Accidents. *Risk Analysis* 02/2015.
Pinto, A., Ribeiro, R.A., Nunes, I.L. (2012). Fuzzy approach for reducing subjectivity in estimating occupational accident severity. *Accident Analysis & Prevention*, 45, 281–290.
Rasmussen, J., Dunkan, K. Leplat, J. (eds) (1987). *New Technology and Human Error*. John Wiley & Sons, Chichester.
Reason, J. (1990). Human Error. Cambrige University Press, UK.
Renn, O. (1998). The role of risk perception for risk management. *Reliability Engineering & System Safety*, 59, 49–62.
Rizzuto, E., Teixeira, AP., Guedes Soares, C. (2010). Reliability assessment of a tanker in grounding conditions. The 11th International Symposium on Practical Design of Ships and other Floating Structures. Spaier, Estefan, Pasqualino (eds.), Aped – Apoio e Produção Ltd., Vol. 2, pp.1446–1458.
Rouhiainen,V. & Gunnerhed,M. (2002). Development of international risk analysis standards. *Safety Science*, 40,57–67.
Sii, H.S., Ruxton, T. Wang, J. (2001). A fuzzy-logic-based approach to qualitative safety modelling for marine systems. *Reliabilty Engineering & System Safety*, 73(1), 19–34.
Sinha, N.K. & Gupta, M.M. (eds) (2000). *Soft Computing & Intelligent Systems: theory and applications*. Academic Press. ISBN: 0-12-646490-1.
Trucco, P., Cagno, E., Ruggeri, F., Grande, O. (2008). A Bayesian Belief Network modelling of organisational factors in risk analysis: A case study in maritime transportation. *Reliability Engineering & System Safety,* 93(6), 845–856.
van Duijne, F.H., van Aken, D., Schouten, E.G. (2008). Considerations in developing complete and quantified methods for risk assessment, *Safety Science*, 46(2), 245–254.
Villemeur, A. (1992). *Reliability, Availability, Maintainability and Safety Assessment*. Vol1-2, John Wiley & Sons, NY.
Wang, J., Yang, J.B., Sen, P. (1995). Safety analysis and synthesis using fuzzy sets and evidential reasoning. *Reliability Engineering & System Safety*, 47(2), 103–118.
Wang, J. (2000). A subjective modelling tool applied to formal ship safety assessment. *Ocean Engineering,* 27, 1019–1035.
Woodruff, J.M. (2005). Consequence and likelihood in risk estimation: A matter of balance in UK health and safety risk assessment practice. *Safety Science*, 43, 345–353.
Zadeh, L. (1965). Fuzzy Sets*. Information and Control*, 8, 338–353.
Zadeh, L. (1973). Outline of a New Approach to the Analysis of Complex Systems and Decision Processes. *IEEE Transactions on Systems, Man and Cybernetics*, 3, 28–44.
Zimmermann, H. J. (2004). *Fuzzy set theory and its applications*. USA: Kluwer Academic Publishers.
Zuijderduijn, C. (1999). Risk management at Shell Pernis Refinery/Chemicals - Implementation of SEVESO-II based on build up experiences, using a Hazards & Effects Management Process. In *Proceedings of the Seveso 2000 European Conference*, Athens, Greece, 10-12 Nov 1999. Retrieved March 2015 from: http://mahbsrv.jrc.it/Proceedings/Greece-Nov-1999/B4-ZUIJDERDUIJN-SHELL-z.pdf.

Personal Constructs Concerning Safety and Atmosphere

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Abstract
Industrial production organisations have transformed from single company organisations into multi-organisational networked systems. Hence, it is assumed that shared multi-organisational workplaces aggregate a wider repertoire of personal cognitive constructions about safety and organisational atmosphere than single company organisations. The increased complexity of the modern workplace poses new challenges for safety management. For this study, the researchers elicited the most common personal constructs about working in a large industrial park and the effects of its constructions to the safety and organisational atmosphere in the shared workplace. The study is based on the Personal Construct Theory (PCT) and the Repertory Grid Technique (RGT). The personal construct theory states that all individuals view their world, process information and make corresponding decisions on a purely personal basis. People model the world with personal constructs, which consist of comparisons of real-world events and items. Due to the personality of constructs, all people seek their own understanding of the world, and these constructs can be elicited only through personal interviews. Researchers applied the Repertory Grid Technique (RGT) to interview 73 persons in five different companies in an industrial park. The interviewees were asked to compare changes that had occurred in the park, in their organisation and in the personal level of their work. During the interviews, researchers gathered 689 constructs. In addition, the interviewees specified the importance of each personal construct by evaluating the construct's influence on safety and atmosphere. The most common safety and atmosphere related constructs were: clarity of work, working methods and attitudes towards work, professional skills, working methods and habits, responsibilities, investments for safety and managers' commitment to safety, listening to employees and involving them in decisions, personal development, hurry, infrastructure and working environment, team spirit and cooperation, working hours, off-duty hours and distribution of work, information flow, fairness, equality and the same rules for all, confidence, acknowledgement and closeness to employees. The strongest positive safety impact was related to the high levels of investments in safety and managers commitment on safety. The most important positive effects on the atmosphere were related to the good team spirit and co-operation, confidence, acknowledgement and closeness to employees. The results also show that the industrial park reached positive development in safety and atmosphere, especially in managers' commitment on safety and in the personal development.

Keywords: Personal Construct Theory (PCT), Repertory Grid Technique (RGT), safety culture, organisational atmosphere.

1. INTRODUCTION
Industrial production organisations have transformed from single company organisations into multi-organisational networked systems. Hence, it is assumed that shared multi-organisational workplaces aggregate a wider repertoire of personal cognitive constructions about safety and organisational atmosphere than single company organisations. The increased complexity poses new challenges for safety management. Safety research has traditionally been based on assessing predefined features, and the results inevitably involved only those predefined features. However, psychological and cognitional research have widely accepted that worldviews and corresponding behaviours are highly personal. We are constantly observing the surrounding world and making our own personal interpretations of it. We observe the world with our sensory system, and all information we gain must filter through our senses. Our mind then interprets this sensory data. From these observation-based interpretations, we make personal generalisations, which we use as guidelines when operating in the world. This way of making "rules of thumb" from the world and conducting our behaviour accordingly is considered a fundamental aspect of human behaviour (Nurius & Macy, 2012, p. 130). Berger and Luckman called this model of behaviour "habitualization" (1966, p. 70), by which they mean that any action, when repeated frequently, becomes cast into a pattern. However, because our previous

experiences affect our interpretation, two different people draw different personal interpretations, even from same event (Adams-Webber, 2003, pp. 52–53). Because all human behaviour is personal, each person's ideas of safety and safety behaviour are also personal. This research paper will concentrate on the personal side of safety and reveal peoples' personal constructs about safety.

In a previous research project, the researchers completed inquiries at ten organisations and interviewed personnel in five different organisations in a large-scale industrial park, which comprises one of the biggest chemical industry complexes in Finland. The research was conducted from 2008–2013 and the aim was to find ways of diminishing accident rates while considering the special characteristics of the industrial park, where a group of independent organisations work in close co-operation. Because the organisations may have had connections through their manufacturing processes, auxiliary systems, supplies, manufacturing areas or by some other activity, there was the possibility of common working areas and communal systems, such as sewage systems or power production. Those special characteristics require safety. Our research covered all the major companies within the area. A questionnaire was distributed to ten companies with 794 employees total as potential respondents. The researchers received 407 answers, making the response rate 51.3%. From the respondents' answers, researchers defined a collective understanding of each organisation's safety culture and created a picture of the safety culture of the entire area (Porkka, Mäkinen, & Vanharanta, 2013; Porkka, Salo-Pihlajamäki, & Vanharanta, 2010).

Our analyses showed that, according to respondents, the companies had addressed safety issues quite well (Porkka et al., 2013). The safety management systems, protective equipment and safety instructions were in good shape. Some safety related interventions were initiated according to the results of the questionnaires. In this phase, the participating companies wanted to deepen their knowledge about the employees' own personal view of the safety and atmosphere in the companies. In this study, the researchers elicited the most common personal constructs about working in a large industrial park and the effects of the constructions to the safety and organisational atmosphere in the shared workplace.

1.1 Personal Construct Theory (PCT)

Kelly (1955) developed the Personal Construct Theory (PCT), which revolutionised ideas about the nature of being human (Fransella, 2003a). At the centre of this theory, the individual is working as a person and an active actor who makes his own interpretation from the world in order to operate in it. The PCT has a fundamental postulate—"*A person's processes are psychologically channelized by the ways in which he anticipates events*" (Kelly, 2003, p. 7)—and eleven corollaries to illuminate the theoretical implications. To fulfil the fundamental postulate, a person requires means for anticipation. The construction corollary of the theory states that a person anticipates events by construing their replications (Kelly, 2003, p. 9). By using the term *anticipate*, Kelly cuts PCT free of the stimulus-response determinism (Kelly, 2003, p. 8), where all people have the same response to the same stimulus. In the PCT, the psychological initiative is a property of the person. Therefore, in this sense, the PCT also has adhesion to cognitive-behavioural theories. The construed replications of reality are called constructs. A construct of a real world event is not the event itself, but how the person construes it. A construct is the meaning we give to the real world event. The construct is also a dimension of time because the meaning we ascribe to it is anchored in its antecedents and consequences (Kelly, 2003, p. 4). In short, the PCT states that people use personal constructs to anticipate events and these constructs affect our future behaviour.

The constructions are simplifications from the real world and, as such, are basic elements of the individually experienced world. To operate in the first place, the individual must form simplifications of the surrounding world. The reality of the individual is based on the constructions, and the individual acts according to how he/she interprets phenomena and events through his constructions. The constructions affect the observations and in turn the observations to the constructions; therefore, the construction system is in a constant state of change. Furthermore, the constructions can be located in both the conscious and unconscious mind (Bannister 1977).

The individuality corollary states that all persons differ from each other in their constructions of events (Kelly, 2003). The experience corollary states that a person's construction system varies. Our experiences of the world around us, including events that take place or our understanding of people, including ourselves, are open to an immense variety of interpretations. Kelly argued that no one construct is a final or definitively accurate way of grasping the world (2003). Instead, we can always create alternative constructs to better explain or represent that which we observe. A revised construct can increase our ability to comprehend the world around us and help us feel that we can predict or control it. Furthermore, Kelly (1969) remarked that the same events can strengthen several different constructions, and even the different incompatible events may strengthen the same constructions.

In the PCT, several different data collection methods, all of which are based on some kind of questioning and interviews, may be used for eliciting personal constructs to fit different purposes. Kelly was sceptical of traditional psychologic tests, most of which were either objective or projective. "*When the subject is asked to guess what the examiner is thinking, we call it an objective test; when the examiner tries to guess what the subject is thinking, we call it a projective device*." (Kelly, 1969). He suggested that, if you want to know something about a person, then ask and the person may tell you. Construct eliciting methods include the repertory grid technique (RGT), self-characterization sketches, bow-ties, the lying game, illuminative incident analysis, interviews about instances, snakes and rivers, metaphors and artefacts (Denicolo, 2003, pp. 125–131).

1.2 Repertory Grid Technique (RGT)

The Repertory Grid Technique (RGT) is probably the most widely known construct elicitation method (Bell, 2003, p. 95). It has been described as the key instrument of personal construct psychology (Denicolo, 2003, p. 123). The fundamental postulate of the PCT underpins the RGT. In the postulate, "*the ways*" refer to the constructs and the "*anticipated events*" are elements (Bell, 2003). The use of the RGT involves defining a set of real world elements, which are then compared. After eliciting a set of constructs that distinguish among these elements, each construct divides the elements into two different groups. According to Kelly (2003, p. 10), a construct is the basic contrast between two groups. The construct refers to the nature of the distinction between elements, and it enables us to put elements into arrays or scales. The PCT assumes that the reality is based in the opposites, not from absolute matters (Jankowicz, 2004). Kelly (2003) emphasised that the construct differs from the concept by being bipolar, whereas the construct is unipolar. The concepts can be used to describe events; however, the construct refers to similitudes or differences between the events. Thus, a construction can be used as a scale or indicator, to which the individual projects the events perceived by it. To define significance of the construction and the element it refers to, both ends of the construction must be known (Duck, 1994). Two individuals assessing "customer service" with the constructs "good – inadequate" and "good – bad" will offer significantly different views on the topic. Eden and Jones (1984, p. 779) clarified the matter: "*We construe situations by seeking to differentiate them from others see them as similar to others; it is only through such a process that we give meaning to events, that they have significance, and so may become psychologically defined as problematic.*" Comparison of real world elements or events is the key to achieving personal constructs.

The repertory grid technique can be characterised as a semi-structured interview, where the respondent is in charge of producing both constructs and their rankings, while the interviewer's role is to assist. Every grid consists of four components (Jankowicz, 2004, p. 10): 1) *topic* restricts the realm of discourse, and it is the only one the interviewer is responsible for, 2) *elements* are (usually) real world items, which are to be compared, 3) *constructs* are the personal structures, with which we construe the elements and 4) *ratings* express how constructs define the elements.

The repertory grid can have one or more stages (Easterby-Smith, Thorpe, & Holman, 1996, p. 5). Firstly, the interviewer must decide on the grid's focus. The focus restricts the number of constructs and must be within the focus of the research. Secondly, there must be a set of elements. The elements can be set by the interviewer, by the interviewee or the two can select the elements together. According to Fransella (2003, p. 21), the interviewer usually chooses both the topic and the elements. According to the personal construct theory, the constructs are defined as construals that people use to differ and group elements.

The third stage is to elicit constructs from the elements by comparing elements and providing two words or phrases that best describe the different poles of the found difference. For example, Ilkka and Jouni are "effective" and Pasi is "a bit lazy". As in the example, the comparison is usually made with the triad of elements (Easterby-Smith et al., 1996), by finding out a property which two of the elements share and the remaining third does not hold. While it is also possible to compare two elements (dyads), some differences were found in construct organisation measures compared to the triad (Caputi & Reddy, 1999). There were more variations in construct type using the triadic method, and constructs produced with the dyadic method were less complex. However, for some people, it is easier to use dyads as children (Jankowicz, 2004, p. 53). There is nothing sacrosanct about triads; one must use the most appropriate method (Fransella et al., 2003).

The fourth step is to link constructs to the elements. This is usually done with a grid or table. Elements are written in the top margin over the columns. On the side margins of each row, there are the “positive” and “negative” poles of each found construct. All the elements are then evaluated against the constructs. There are three ways to complete the evaluation. Elements can be grouped into two groups in such a way that all elements belong to either pole of the construct. This is simply a 2-point rating scale (Jankowicz, 2004, p. 54). Rating with a larger number, such as a 5-point scale, is the most common in evaluations. Ranking is possible when all the elements are ranked according to the construct. However, the ranking may make the comparison of different grids difficult if the rankings used are not equal (Jankowicz, 2004, p. 56).

The fifth and final step is to elicit more constructs and go back to the third step. The elicitation of constructs continues as long as the interviewee can produce them.

The PCT was originally developed to study mental disorders; therefore, it focuses solely on a person’s internal psychological factors. The PCT and RGT have been used in clinical psychological research successfully for over 50 years. In the 1980s, research in cognitive psychology made significant progress in understanding human expertise (Simon, 1991, p. 129), and the focus from purely behavioural stimulus-response theories turned to cognitional-behavioural theories. The PCT has a major dissimilarity to cognitional-behavioural theories in that it focuses on a person’s internal actions, while cognitional-behavioural theories focus on external actions, namely behaviour. However, the PCT has the role of solving internal cognitions (constructs) that may reside behind the behaviour. The RGT has since been used in several branches of science and research. The RGT has been deployed in artificial intelligence research, education and learning. In management science, research has been conducted in several disciplines including policy dynamics, strategy, personal classification (Wright, 2006), marketing, making tacit knowledge explicit (Björklund, 2008), user experience (Karapanos & Martens, 2008), employee selection (Anderson, 1990) and business in general as well as in a safety context in reckless driving research (McNally & Bradley, 2014).

2. MATERIALS AND METHODS

This research took place in a Finnish large-scale industrial park, which is utilised by the metallurgical and chemical industries. The park is one of the biggest chemical industry complexes in Finland, with 17 different companies operating in the area, five of which participated in the research. Of the five participating companies, two were main producers and the remaining three included maintenance, service and engineering companies. Interviewees from all the companies consisted of both workers and managers.

The researchers chose the Repertory Grid Technique (RGT) to elicit constructs. The fundamental idea in the RGT is not only to find out answers to questions, but also to achieve an understanding of the true meanings of the words the interviewee used. This can be achieved only by asking. The RGT offers a powerful way of quantifying people’s attitudes, feelings and perceptions (Easterby-Smith et al., 1996, p. 3).

Researchers elicited 689 constructs from 73 different individuals during the interviews. The demographics of the interviews can be seen in Table 1.

Table 1 - Number of interviews, constructs elicited and distribution according to company

		Company ID				
	All	**1**	**2**	**3**	**4**	**5**
Interviewees	73	10	12	19	21	11
Constructs	689	96	96	141	244	112
Avg. of constructs	9.45	9.60	8.00	7.42	11.62	10.18

The number of respondents varied from 10 to 21, according to the size of the company. The average number of constructs per person was 9.45, which was rather normal. On a company level, the variation was from 8.0 to 11.6, where the greater amount belonged to companies with more highly educated personnel.

2.1. Repertory grid of this study

The focus of our study was to find out the materialised changes in the organisations and to survey their impact on the employees on a personal level. Therefore, the researchers defined the main RGT elements: "past – now". The actual time of the change was not recorded. The researchers elicited the constructions by giving the interviewees certain broad discussion topics (Table 2). In addition, they asked the interviewees to define any changes they have experienced within the subject.

Table 2 - Discussion topics used in the grid

SID	Discussion topics	Description, example
1	Industrial Park	Comparison of two companies from the park
2	Respondent's company	Changes in own company, timescale past – now
3	Respondent's own work	Changes in own work, organisational changes
4	Respondent's ways of working	Changes in own working habits, changes in person
5	Co-workers' ways of working	Changes in co-workers working habits
6	Management	Actions of management, managers as individuals
7	Other – respondent's own choice	Anything the respondent wants to compare

When the eliciting process concerned the comparison of different companies from the industrial park (first row of Table 2), the eliciting process was conducted in a traditional manner, as described in chapter 1. The RGT elements were the companies from the park, and the constructs were elicited by comparing different companies. However, in the ranking phase, the researchers were not interested in how other companies could be ranked according to the construct. Instead, the researchers asked the interviewee to describe the effects of the construct for both the safety and organisational atmospheres.

All other subjects from Table 2 were elicited by comparing a single RGT element in the timescale "past –now". The researchers were interested in how the elements had changed in previous years. The timescale was not restricted to any given values, so it varied from months to several years. The elicited constructs were the poles of possible changes. Notably, neither poles elicited needed to happen. The changes were real, but the poles could express the biggest possible change the interviewee could imagine. This possibility was used, especially when defining the positive pole. As was the case in the comparison of companies, all other elicited constructs were assessed by the interviewee for their effect on safety and atmosphere.

2.2 Interviews

The interviewer's role must be minimal to discover the true constructs of the interviewee (Fransella, 2003b, p. 106); however, the interviewer must guide and help the interviewee to elicit the constructs. Our interviewees were asked to look back and recall changes within the subjects. In the beginning of the interview, the table was totally empty, shown as as row 0 in Figure 1. The first subject, "industrial park", was different from the other subjects because there was no timescale involved when the interviewee compared two companies. The researchers asked the interviewee the question, "What kinds of differences are there in various companies?" In the example grid in Figure 1, rows one and two present answers to this question. The interviewee found that company A's "*operation patterns*" were "*more free*" compared to company B, where there was more "*supervision*" and the "*mode of action was restricted*". The words and terms are actual definitions made by the interviewee, and in the interview process, the grid was projected on the wall, with the interviewee seeing all that was written. On several occasions, the interviewee returned to a previously elicited construct and refined what he/she meant.

				Catalysts		Element-in-Time			Inhibitors		
#	SID	Name of construct	Positive	S+	A+	Past	+/-	Now	S-	A-	Negative
0											
1	1	Operation pattern	More free (Company A)	0	4				0	1	Supervision, mode of action restricted (B)
2	1	Activity at work	Initiavity, commitment (C)	0	3				0	3	Passivity (D)
3	2	Orientation to work	More learning-by-doing	3	4	5	-3	2	4	3	Too school-oriented
4	2	Tools' safety	Resources to tools and safety equipment	5	3	2	3	5	4	2	Less resources
5	3	Course of action	Designers responsible for their work	1	3	4	-2	2	1	4	Main designers' role increased
6	4	Culture of action	Self-direction increased	0	4	1	2	3	3	2	Bosses take responsibility and guide
7	6	Concern management	Local management has more power	1	3	3	-1	2	0	1	Situation bad, local managers' roles diminished
8	1	Occupational safety	People hold to the promise	3	4	1	2	3	2	3	Promises and actions conflict

Figure 1 - Example grid with real data

In Figure 1, rows 3 to 8 consist of constructs where time is relevant. The interviewee explored and defined the kind of change the construct had gone through in time. Therefore, the interviewee gave values for the “Element-in-Time” columns “Past” and “Now”. The positive pole has a value of 5, and the negative pole a value of 1. In row 3, “*Orientation to work*” has a value of 2, so it is near the negative pole. It used to have a value of 5, meaning there was much “*more learning by doing*” in the past. In the middle column, between “Past” and “Now”, are the amount and direction of the change, which is the intersection of “Past” and “Now”. In the case of “*Orientation to work*”, the interviewee felt that it had a negative impact on the power of the three units. In row 4, the construct named “*tools´ safety*” shows that the progress has been positive; therefore, there are now enough “*resources to tools and safety equipment*”.

The interviews were carried out in two phases. First, the interviewees and interviewers elicited and described the constructs and both poles of the constructs. Second, the interviewees rated the constructs. Studies have shown that constructs need not be symmetric; therefore, the interviewees were asked to evaluate both poles individually. The numeric values in this evaluation were from 0 (no affect at all) to 5 (significant affect). The interviewee rated the significance of the construct to safety (S) and atmosphere (A). The interviewee was given guidance to the rating “*If the positive side of the construct would hold, what would be its impact on safety on a level of 0 to 5, where 0 is no effect at all and 5 would diminish accidents significantly”*. On the negative side, a value of 5 meant that it would increase accidents significantly. The asymmetric characteristic of the constructs can be seen in all elicited constructs. In row 6, the element “*culture of action*” and “*increased self-direction*” have no effect on safety, but the negative pole, where “*bosses take responsibility and guide*” can increase accidents, according to the interviewee. Almost all interviewees also verbally validated the given number and provided explanations for choosing that given value.

3. RESULTS AND DISCUSSION

The elicited constructs are extremely personal. However, to gain general results, some kind of synthesis must be achieved. According to Denicolo (2003, p. 125), the RGT produces a mass of rich, yet unstructured, data that requires skill to make it manageable through the identification of key themes, categories and patterns that are meaningful to all engaged in the task. Researchers classified the constructs into seven different main categories and several subcategories according to the content (or researchers interpretation) of the constructs. Categorization in psychology binds people into a strict concept and is therefore criticized (Warren, 2003, p. 392). It has been used in the PCT to classify the various constructs elicited, deriving several categories (Pope, 2003, p. 307). However, in this study, it is merely finding similarities in highly personal constructs. The researchers attempted to increase the validity and trustworthiness of our findings by deploying more than one investigator in the collection and analysis of data (Rothbauer, 2008, p. 893). Triangulation is a well-known method used to increase validity in safety research (Eeckelaert, Starren, Scheppingen van, Fox, & Brück, 2011, p. 27; Haavik, 2014).

The classification did not follow the categories of the discussion topics for the interview, as presented in Table 2. The reason for this was the uneven distribution of elicited constructs. Three classes from categories of subjects, “*respondent’s own work*”, “*respondent’s ways of working*” and “*co-workers’ ways of working*” were united in the classification phase into one class called “*Personnel*”. “*Information and its flow*” and “*Safety*” rose from the constructs and were classified into their own classes. Industrial park, company, management and other were the same in the subject category and in the classification. Some constructs that the interviewee positioned into the subject class management were in the classification phase and relocated into the class "*Company*". Only constructs concerning personal features were classified into the class management. Table 3 gathers some properties of the chosen classes.

Table 3 - Classification of constructs (constr) and their impact on safety (S) and atmosphere (A)

Class #	**Class**	**# subclasses**	**# constr**	**% constr**	**S+5**	**S-5**	**A+5**	**A-5**
1	Industrial Park	14	157	22.8	41	29	33	32
2	Company	10	157	22.8	20	12	44	28
3	Management	8	119	17.3	8	5	31	22
4	Personnel	6	113	16.4	19	12	33	18
5	Safety	5	73	10.6	32	21	16	9
6	Information and its flow	3	36	5.2	-	2	9	4
7	Other	-	34	4.9	8	5	8	2
	Total	46	689	100.0	128	86	174	115

As we can see from Table 3, the distribution of constructs into classes is not even. The classes "*Industrial Park*" and "*Company*" hold the biggest number of both subclasses and constructs. The next two classes, which contain more constructs, relate to personal aspects of personnel, management and supervisors. Almost 10% of all constructs were directly related to safety. The lesser constructs were classified into "*Information*" and "*Other*".

The last four columns of Table 3 express the number of 5 values given by the interviewees to positive (+) and negative (-) poles of their given constructs. The number 5 was the highest value the interviewee could give to a pole of a construct. The column S+5 indicates the number of constructs, where the positive pole would happen and it would have a significant impact on preventing accidents. Column S-5 refers to constructs, where negative poles would happen and would increase accidents significantly. Letters S and A denote safety (S) and atmosphere (A). Therefore, the last four columns express the distributions of the most significant constructs in both preventing and increasing safety and atmosphere.

Table 3 clearly shows that the constructs elicited may be, and some of them certainly are, asymmetric from their poles. If the constructs were symmetric, the number of positive and negative values would be same. Symmetry indicates that a construct would have the same effect on both positive and negative poles; therefore, the numbers should be the same. It should be noted that only 18 of the constructs related to "*Industrial Park*" (class #1) had a value of 5 in both their positive and negative poles. However, in the industrial park related constructs, there were 41 positive and 29 negative values of 5. Hence, 23 (41–18) constructs were positively asymmetric, meaning they had the positive side stronger than the negative, and 11 (29–18) were negatively asymmetric, having a stronger negative side than a positive one.

According to Kelly (2003, p. 10), we should not consider a construct as another term for a concept. A concept can be defined as "*an idea of what something is or how it works*" (Merriam-Webster's, 2015). A concept is a definition, but the true personal meaning is built in everyone's own mind. When concepts are assessed with a questionnaire and Likert-scale, the scale is always given by the researcher and is symmetric. Symmetry is presumed in interviews when the research focuses on concepts. Therefore, in this study, the researchers analysed the symmetry of all the constructs in more detail. The results show that only 46.1% of the constructs elicited were symmetric in safety and 38.1% were symmetric in atmosphere. In safety, 33.0% were positively asymmetric and 20.9% were negatively asymmetric. In atmosphere, there were twice as many positively asymmetric constructs (42.4%) as negatively asymmetric constructs (19.5%).

The main idea of classification is to compile pieces of data into a more condensed form. Therefore, the researchers presented those subclasses that had the greatest number of constructs in Table 4. Fourteen subclasses had more than 20 constructs in them. In Table 4, the subclasses are ordered by the number of constructs they include, and the first column is the order of the class. The second column indicates the main class that includes the subclass. The third column includes the name of the subclass, followed by the number of constructs included in the subclass. The total number of interviewees was 73, and the fifth column indicates the percentage of all interviewees that had a construct, which was included in the corresponding subclass. Finally, we presented the column "Element-In-Time" (EIT), which indicates the average of change of the elements “Past” and “Now”, the corresponding constructs in the subclass reference. The positive values indicate a positive change, and the negative values indicate undesirable change. Because the interviewees evaluated the change on a scale from 1 to 5, the values in this column can vary from -4 to 4.

Table 4 - Subclasses with the most constructs

#	Main Class	Subclasses	# of constr.	% of resp.	EIT
1	Company	Clarity of work: supervision of work, responsibilities, structures	53	72.6	-0.58
2	Personnel	Working methods and attitudes towards work	35	47.9	0.50
3	Other	Other	34	46.6	0.61
4	Industrial Park	Professional skills, working methods and habits, responsibilities	33	45.2	-1.50
5	Safety	*Investments for safety and managers commitment to safety	30	41.1	2.05
6	Management	Listening of employees and involving them in decisions	27	37.0	1.10
7	Personnel	Personal development	25	34.2	1.79
8	Company	Amount of personnel vs. workload (hurry)	25	34.2	-1.19
9	Industrial Park	Infrastructure and working environment	22	30.1	0.50
10	Personnel	**Team spirit and co-operation	22	30.1	0.88
11	Company	Working hours, off-duty hours and distribution of work and	22	30.1	-0.89
12	Information	Information flow	21	28.8	0.40
13	Management	Fairness, equality and same rules to all	20	27.4	0.30
14	Management	***Confidence, acknowledgement and closeness to employees	20	27.4	0.91

*$S_{Average}$ = 4.13 (If company invests in the safety and managers commit on safety, it has positive effect on safety)
**$A_{Average}$ = 4.23 (Good team spirit and co-operation have positive effect on atmosphere)
***$A_{Average}$ = 4.05 (Confidence, acknowledgement and closeness to employees have positive effect on atmosphere)

The greatest number of constructs was a collected to subclass “clarity of work”, which included supervision of work, responsibilities it holds and structures it has. Table 4 also shows that 10 out of the 14 subclasses changed positively over time. The result suggests that the industrial park reached positive development in safety. Especially, the subclasses “Investments for safety and managers commitment on safety” (EIT=2.05) and “Personal development” (EIT=1.79) changed substantially. The strongest positive impact on safety was related to the high level of the subclass “Investments for safety and managers commitment to safety” ($S_{Average}$=4.13). The most important positive effects on the atmosphere were related to high levels of “Team spirit and co-operation” ($A_{Average}$ = 4.23) and “Confidence, acknowledgement and closeness to employees” ($A_{Average}$ = 4.05).

4. CONCLUSIONS

The aim of this study was to elicit the most common personal constructs about working in a large industrial park and the effects of the constructions to the safety and organisational atmosphere in the shared workplace. From the methodological point of view, it is notable that the researchers did not give the construct to the interviewees. Instead, the interviewees built up their own constructions and the researchers captured the constructs to the repertory grid. Researchers classified the constructs and identified the most common safety and atmosphere related subclasses of the constructs:

- clarity of work
- working methods and attitudes towards work
- professional skills
- working methods and habits
- responsibilities, investments for safety and managers’ commitment to safety

- listening to employees and involving them in decisions
- personal development
- number of personnel vs. workload (hurry)
- infrastructure and working environment
- team spirit and cooperation
- working hours, off-duty hours and distribution of work
- information flow
- fairness, equality and same rules for all
- confidence, acknowledgement and closeness to employees.

The strongest positive impact on safety was related to the high levels of investments in safety and managers commitment on safety. The most important positive effects on the atmosphere were related to the good team spirit and co-operation, confidence, acknowledgement and closeness to employees. The results also show that the industrial park reached positive development in safety and atmosphere, especially in managers' commitment on safety and in the personal development.

The results of this study deepen the understanding about individual differences and similarities of personal constructions about factors that affect safety and organisational atmospheres. The new results will be especially beneficial when companies develop their safety training and organisational atmosphere. In the future, the researchers will further analyse the differences of the constructions between the companies. In addition, the researchers will analyse how the constructions differ (if at all) from good safety management principles.

5. REFERENCES

Adams-Webber, J. (2003). Research in Personal Construct Psychology. In F. Fransella (Ed.), *International Handbook of Personal Construct Psychology* (p. 474). John Wiley & Sons Ltd.

Anderson, N. (1990). Repertory Grid Technique in Employee Selection. *Personnel Review*, *19*(3), 9–15.

Bell, R. C. (2003). The Repertory Grid Technique. In F. Fransella (Ed.), *International Handbook of Personal Construct Psychology* (pp. 95–103). John Wiley & Sons Ltd.

Berger, P. L., & Luckmann, T. (1966). *The Social Construction of Reality - A Treatise in the Sociology of Knowledge*. Penguin Books.

Björklund, L. (2008). The Repertory Grid Technique: Making Tacit Knowledge Explicit: Assessing Creative Work and Problem Solving Skills. *Researching Technology Education: Methods and Techniques*, 46–69.

Caputi, P., & Reddy, P. (1999). A comparison of triadic and dyadic methods of personal construct elicitation. *Journal of Constructivist Psychology*, *12*(3), 253–264.

Denicolo, P. (2003). Elicitation Methods to Fit Different Purposes. In F. Fransella (Ed.), *International Handbook of Personal Construct Psychology* (pp. 123–131). John Wiley & Sons Ltd.

Duck, S. (1994). *Dynamics of relationships*. Thousands Oaks (Calif.) : SAGE. Retrieved from

Easterby-Smith, M., Thorpe, R., & Holman, D. (1996). *Using repertory grids in management*. *Journal of European Industrial Training* (Vol. 20).

Eden, C., & Jones, S. (1984). Using Repertory Grids for Problem Construction. *Journal of the Operational Research Society*, *35*(9), 779–790.

Eeckelaert, L., Starren, A., Scheppingen van, A., Fox, D., & Brück, C. (2011). *Occupational Safety and Health culture assessment - A review of main approaches and selected tools*.

Fransella, F. (2003a). Introduction. In F. Fransella (Ed.), *International Handbook of Personal Construct Psychology*. John Wiley & Sons Ltd.

Fransella, F. (2003b). Some Skills and Tools For Personal Construct Practitioners. In F. Fransella (Ed.), *International Handbook of Personal Construct Psychology* (p. 480). John Wiley & Sons Ltd.

Fransella, F., Bell, R., & Bannister, D. (2003). *A Manual for Repertory Grid Technique* (2nd Edition). Wiley.

Haavik, T. K. (2014). On the ontology of safety. *Safety Science*, *67*, 37–43.

Jankowicz, D. (2004). *The Easy Guide to Repertory Grids*.

Karapanos, E., & Martens, J.-B. (2008). The quantitative side of the Repertory Grid Technique: some concerns. In *UXEM workshop in CHI'08, April 6th, 2008*.

Kelly, G. A. (1955). *The Psychology of Personal Constructs: A Theory of Personality*. New York: Norton.

Kelly, G. A. (2003). A Brief Introduction to Personal Construct Theory. In F. Fransella (Ed.), *International Handbook of Personal Construct Psychology* (pp. 3–20).

McNally, B., & Bradley, G. L. (2014). Driving construals: Personal Construct Theory in a reckless driving context. *Transportation Research Part F: Traffic Psychology and Behaviour*, *24*, 71–82.

Merriam-Webster's. (2015). Merriam-Webster's online dictionary. Retrieved from http://www.merriam-webster.com/dictionary

Nurius, P. S., & Macy, R. J. (2012). Cognitive-Behavioral Theory. In C. N. Dulmus (Ed.), *Human Behavior in the Social Environment: Theories for Social Work Practice* (p. 552). John Wiley & Sons.

Pope, M. (2003). Construing Teaching and Teacher Education Worldwide. In F. Fransella (Ed.), *International Handbook of Personal Construct Psychology* (p. 474). John Wiley & Sons Ltd.

Porkka, P. L., Mäkinen, E. P., & Vanharanta, H. (2013). Safety Culture Research in a Finnish Large-Scale Industrial Park. *Chemical Engineering Transactions*, *31*(1), 361–366.

Porkka, P. L., Salo-Pihlajamäki, M., & Vanharanta, H. (2010). Proactive vision for the safety culture in a Finnish chemical plant. In W. & S. Karwowski G. (Ed.), *Proceedings of the 3rd International Conference on Applied Human Factors and Ergonomics (AHFE)*.

Rothbauer, P. (2008). Triangulation. In L. M. Given (Ed.), *The Sage Encyclopedia of Qualitative Research Methods* (pp. 892–894). SAGE Publications, Inc.

Simon, H. A. (1991). Bounded Rationality and Organizational Learning. *Organization Science*, *2*(1), 125–134.

Warren, B. (2003). Pragmatism and Religion: Dewey's Twin Influences. In F. Fransella (Ed.), *International Handbook of Personal Construct Psychology* (p. 474). John Wiley & Sons Ltd.

Wright, R. P. (2006). Rigor and Relevance Using Repertory Grid Technique in Strategy Research. In D. J. Ketchen & D. D. Bergh (Eds.), *Research Methodology in Strategy and Management* (Vol. 3, pp. 289–341). Emerald Group.

The Toolbox training program for Danish construction foremen - initial process evaluation

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Abstract

A Danish *Toolbox training* program aims to improve construction foremen's knowledge and communication skills in regards to current work tasks and their related health and safety risks on site. The overall goal of the training program is to reduce physical attrition and improve injury and accident prevention, health and safety culture. The purpose of this article is to describe the study protocol and initial process evaluation results in this on-going study. The study is based on 32 foremen who participated in the training in three different groups during 2014 and 2015. The process evaluation utilized questionnaires, interviews, and participant observations. The process evaluation investigated: (1) whether the expected target population was reached; (2) if the program was implemented as intended; (3) how the participating foremen experienced the program; and (4) which contextual factors influenced the implementation.

Participants received five *classroom training* days carried out over nine weeks and delivered by an external training consultant (100% dose-delivered). Initial results provided evidence that the training topics were relevant and useful for the foremen in their everyday interaction with their crews, colleagues, leaders, customers and other construction professions. Inclusion of health and safety in their daily planning and communication was seen as giving added value to their work and their projects. The foremen's knowledge regarding health, attrition and communication increased and participants experienced a higher awareness to their role as foremen. However, not all training tools and skills were implemented as intended. The most common factors which hindered the implementation were lack of time, tight production schedules, lack of interest and high turnover among work crew members, language barriers and individual attitudes towards the *Toolbox training*. In conclusion, the program has the potential to add noticeably to developing vocational training for construction foremen and increasing safety communication as well as safety culture in the Danish construction industry.

Keywords: Toolbox meetings, Toolbox talks, Tailgate meetings, safety training, safety communication

1. INTRODUCTION

Accidents at work and physical attrition continue to be major problems in the construction industry, and provide many challenges in implementing initiatives in prevention and safety culture (1, 14). Construction project *Start-up* meetings and *risk evaluations* are often carried out prior to engaging in projects and tasks, which include a focus on improving safety. However, the daily communication between a foreman and his work crew, colleagues, leaders, customers and other construction professions mainly addresses production issues and deadlines (8, 12). *Toolbox meetings* (Toolbox talks, Tailgate meetings, etc.) are a popular tool used in construction in many countries (9, 11), and a *Toolbox training* program is currently being developed in Denmark with focus on improving construction foremen's knowledge and communication skills in regards to current work tasks and their related occupational safety and health (OSH) risks on site. Involving employees (colleagues, leaders, customers and other construction professions) in the daily planning process is a key element in the training and in the Nordic safety culture. The purpose of this paper is to describe the content and aims of the training program, as well as the design, methods and results of the process evaluation.

1.1. Aims and content of the training program

Unlike *Toolbox meetings*, which involves a foreman's preparation and delivery of a specific OSH topic with his crew (e.g. safe use of machines, PPE etc.), we developed a *Toolbox training* program which focuses on improving foremen's knowledge and skills in safety communication, not only with their crew members, but also with their colleagues, leaders, other professions and customers. The overall goal of the training program is to reduce physical attrition & improve injury/accident prevention, OSH culture for all parties, while improving planning and safety communication at the same time.

More specifically, the hypothesis of this study is that the approach will promote safety communication on a daily basis among the various parties. This will raise risk awareness among the various parties especially that of the work crew members, and increase their individual participation in OSH dialogue. Participation is proposed to then increase influence on planning and safety procedures, which improves the prevention of work accidents, health and safety culture on construction sites (see Figure 1) – and subsequently results in improved business.

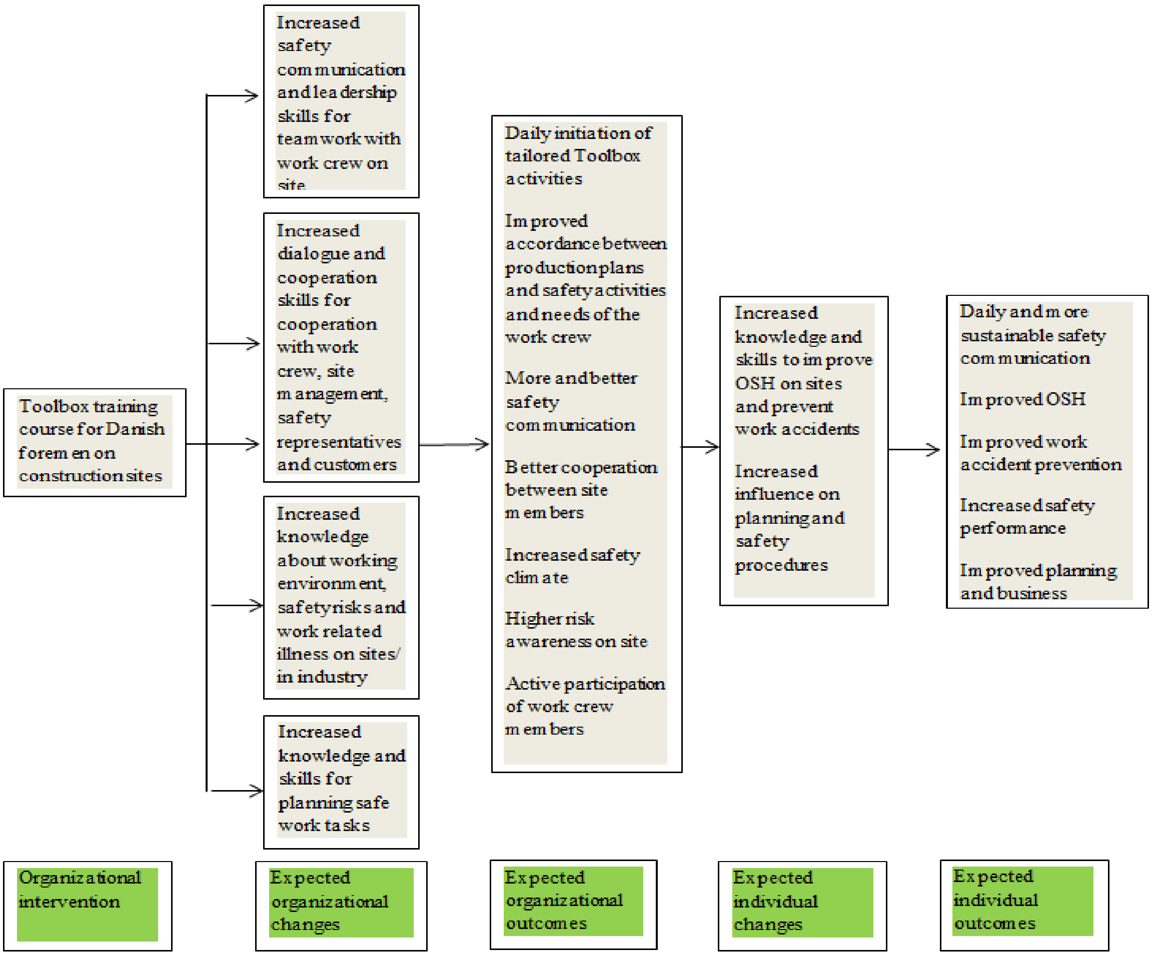


Figure 1-Toolbox-training: Core elements and expected pathways to improve occupational safety and health (OSH) and business.

2. MATERIALS AND METHOD

2.1. Study population

The study is based on 32 foremen who participated in the training in three different groups during 2014 and 2015. The foremen represented eight different construction companies covering two geographically different regions in Denmark (Jutland and Zealand), and who worked in various construction trades (e.g. earth and concrete, masonry, carpentry, scaffolding, demolition).

2.2. Toolbox training course

A 22½ hour classroom program was developed by the project team and was carried out over nine weeks. It included two weeks of *on-site training* between each of the five *classroom training* days (4½ hours each day). The training included topics such as: foreman roles and responsibilities, communication (verbal and non-verbal), conflict management, planning systems, leadership and cooperation, prevention of injury and work related disease, as well as improving OSH on construction sites. Training was provided by an external training consultant and consisted of a mixture of theoretical lectures, practical casework and role-play, as well as assignments to be carried out during the two weeks between each classroom session. Training focused on the central role of the foreman and the importance of dialogue, influence and involvement of employees (and other parties) to improve the daily OSH communication and planning of specific and future tasks and the managing of work related OSH risks. Forman were to use the new skills and knowledge in their daily activities with their work crew. Two project researchers (authors 1 and 2) followed the training course and visited selected participants throughout the program period to facilitate the implementation.

2.3. Aims and design of the process evaluation

The study includes a detailed process evaluation of the training program which serves both a formative and a summative purpose. The formative purpose involves a continuous use of process data and feedback from the participating foremen for optimizing training through learning. The aim of the summative purpose is to determine whether the training was implemented as intended, and to provide guidance for future interventions.

The process evaluation follows the framework introduced by *Saunders and colleagues (2005),* which is based on work by *Steckler and Linnan (2002), Baranowsky and Stables (2000)*. According to the above-mentioned framework the following components are recommended to be included in process evaluations: *fidelity* (quality), *dose-delivered* (completeness), *dose-received* (exposure), *satisfaction*, *reach*, *recruitment*, and *context* (barriers and facilitators).

We defined the process evaluation components used in this study as follows:
Fidelity was the extent to which the intervention was implemented as planned. In this study participants were to implement the training tools themselves during the two-week *on-site training* between each of the five *classroom training* days. Additionally, two project researchers followed the implementation process throughout the training period to facilitate implementation. *Dose-delivered* was the proportion of the *Toolbox training* days which was provided by the training consultant to the participating foremen. In this study five *classroom training* days were provided to each of the three training groups. *Dose-received* was the proportion of participants showing up for the training days. *Satisfaction* was defined as the foremen's opinions and attitudes towards the *Toolbox training*, which was evaluated based on the level of satisfaction on a 3-point scale. *Reach* was defined as the proportion of foremen who were approached for participation in the *Toolbox training*. In the present study the intended audience was Danish construction foremen with staff management responsibilities (e.g. to lead a work crew), and a certain level of financial as well as operational authority. *Recruitment* was defined as the sources and procedures used to approach and attract foremen for participation in the *Toolbox training*. All foremen were informed about the main objective and content of the research project and participated voluntarily. The course was free, and foremen participated during their working hours. Finally, *Context* was defined as factors which either hindered or facilitated the implementation of *Toolbox training*.

We summarized the seven elements into four main research questions for the process evaluation:
(1) Was the expected target population reached? (reach, recruitment), (2) Was the program implemented as intended? (fidelity, dose-delivered, dose-received), (3) How did the foremen and their work crews experience the training? (satisfaction), and (4) How was the implementation influenced by contextual factors? (context).

By documenting all of these aspects of the implementation process we were to asses to what extent the implementation was successful. In the case of a successful implementation, we examined if our hypothesis (Figure 1) can be confirmed, that is, if the organizational intervention of the training program led to the expected organizational and individual changes and intermediate outcomes. To carry out this process evaluation we used three data sources: short questionnaires for all participating foremen before and after the training, semi-structured interviews with selected foremen and their work crew members (and where relevant - leaders and colleagues) before, during and after the training and participant observations during the training days and on site. The information from these data sources were used to assess the implementation according to the above-mentioned framework. In the following, the main data sources for the process evaluation are explained more in-depth.

2.4. Questionnaires for participating foremen

We distributed a short online questionnaire to 25 participating foremen before and after the training (training group 2 and 3). The baseline questionnaire prior to the start of the training included questions about the respondents' occupational experience and role, their knowledge about certain training topics and contextual factors, which influence OSH communication on site. The follow-up questionnaires were distributed directly at the end of the fifth training day, and assessed to what degree the participants gained new knowledge, new skills and to what degree the different training tools were experienced as useful on site. Additionally, the training consultants answered questions about the content and structure of the training course, and usability of methods and materials in order to optimize the program.

2.5. Individual interviews with participating foremen

Individual semi-structured interviews (about 19) with selected foremen were conducted before and after the training course (4 interviews with selected foremen). We assessed to what degree and why different training tools and skills were utilized, to what degree the foremen were satisfied with the training course, and whether the implementation was influenced by contextual factors. We asked to what degree the training materials were used and why, to what degree training knowledge and skills were transferred to crew members, how often foremen talked to their crew members, which topics they discussed and to which extent the foremen experienced a change in the communication, team work and OSH behavior of their work crews.

2.6. Individual interviews with selected work crew members

Individual semi-structured interviews (about 36) with selected work crew members were conducted before and after the training course. The data collection is still ongoing. We asked the selected crew members to which degree they felt involved in decisions, whether they had influence on their daily work tasks and whether they experienced a change in the foremen's OSH communication and behavior. The interviews investigated whether crew members were sufficiently informed about OSH, to which degree they were satisfied with OSH communication and team work on site and if they recognized new information material (e.g. training templates) posted in the on-site hut.

2.7. Participant observation

The formative purpose of the process evaluation involved a continuous use of feedback from the participating foremen. We involved all participants and used their feedback to develop and optimize the content and length of the training course. During the five training days we observed foremen's participation, engagement, behavior and attitude towards the training. We documented their feedback on the duration of the training, which training elements of the day were experienced as valuable, and which tools they said they would use the day after the training and during the 2-weeks break. We documented to what degree foremen completed their assignments, based on interviews and observations.

As a supplement to the questionnaires and the interviews, two project researchers conducted observations on site before, throughout and after the training course. Prior to the start of the training we observed selected foremen's *Toolbox meetings* between them and their work crew. We assessed the degree of safety communication, which materials (e.g. leaflets, copies) were distributed to the work crew and which type of communication was used. During the follow-up observation we investigated whether communication type (e.g. dialogue) and content had changed (e.g. safety and health topics), whether foremen used training tools on site and we linked foremen's behaviour during the five training days to this utilization (*dose-delivered* to work crew members).

Table 1-Toolbox-training: Process evaluation data sources.

	Before *Toolbox-training*	Throughout *Toolbox-training*	After *Toolbox-training*
Questionnaires to participating foremen	25		25
Individual interviews with participating foremen	19		4
Individual interviews with selected work crew members	36		4
Participant observation in classroom		32	
Participant observation on-site	4	15	4

3. RESULTS AND DISCUSSION

3.1. Recruitment, reach, dose-delivered, and dose-received

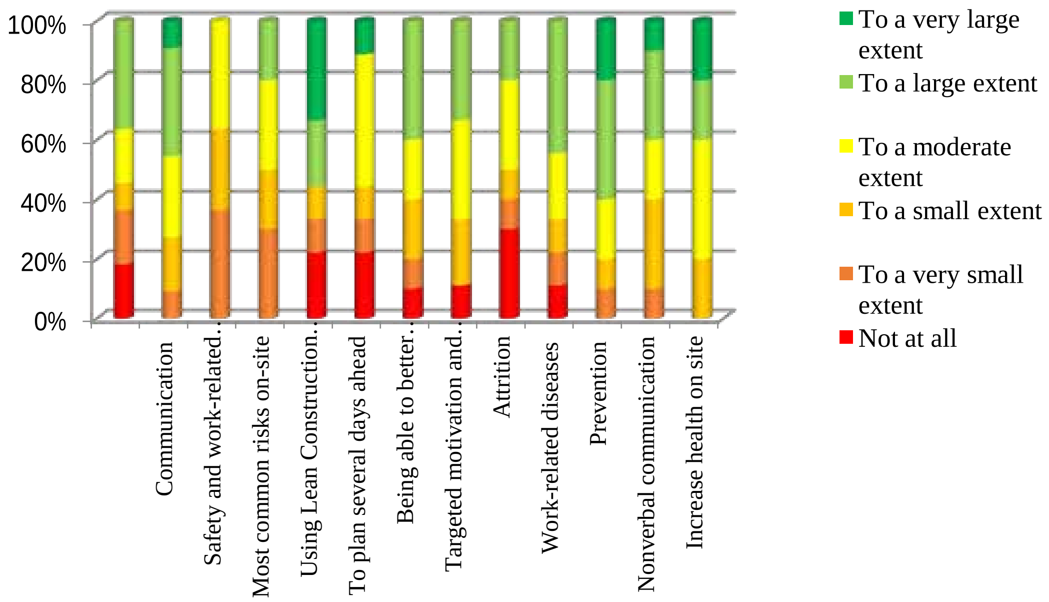
Recruitment consisted of direct contact to several construction companies covering two geographically different regions in Denmark (Jutland and Zealand) and various construction trades (e.g. earth and concrete, masonry, carpentry, scaffolding, demolition). The research group approached the companies QHSE directors (Quality, Health, Safety and Environment), who distributed information onwards to construction site managers and their foremen. We used flyer for distribution and an article in a trade specific paper to attract participants. Eight out of fourteen companies sent foremen to participate in the *Toolbox training* course. Thus, reach was 57%. Dose-delivered was 100%; that is, a training consultant delivered all five training days to each of the three training groups. Dose-received was 80% for the first group (7 out of 9); 100% for the second group (12 out of 12) and 90% for the third group (13 out of 14); that is, three participants only showed up for one or two training days.

3.2. Fidelity, satisfaction and context

High fidelity was given, if participants gained more knowledge, new skills and training tools were experienced as useful on site. The training and data collection are still on-going, however the initial results provided evidence that the training topics were relevant and useful for the foremen in their everyday interaction with their crews, colleagues, leaders, customers and other construction professions. Inclusion of OSH in their daily planning and communication was seen as giving added value to their work and their projects. Foremen were to a high or very high degree satisfied with the *Toolbox training* course. The preliminary results show that the degree of knowledge regarding health, attrition and communication increased, and that participants attention to their role as foremen and assignments of responsibilities increased from before to after the training (Table 2).

One foreman responded during the training as follows:
"*I will calculate our overall noise level on site. I think there is much focus on work accidents, but after what we have talked about today, I want to focus more on occupational diseases*."

Table 2-Toolbox-training: Extent of new knowledge after training course.



Moreover, the foremen utilized the given training materials in their daily work, for example, training templates were posted in the on-site hut or got used for joint reviews of work tasks together with the work crew. Participants used their communication skills just as much with their own leaders, colleagues and clients, as they did with their work crew. One foreman reported back as follows:

"*After the Toolbox training I have become much more conscious about using open-ended questions and to ensure participation. Especially with conflict management – escalation and resolution* [one of the training tools] *has been good. It has been particularly useful, since I had to use it for negotiations with management about piecework contracts. But I also use it in everyday situations. For example, we have challenges with our foreign subcontractor, who is responsible for demolition, and in other cases we have issues with residents - in both cases I made sure to involve construction site management in solving the problem*."

Foremen reported that they had a better understanding of their role as foremen, they felt more responsible to communicate and mediate information between management and crew members, and that they understood their position as role models to implement changes. Participants were also highly motivated to facilitate change, e.g. one foreman delivered an action plan on how to motivate and involve his work crew more frequently by giving his work crew more responsibility in making decisions. His crew members formed an internal working group to plan social activities (*psychosocial working environment*), and they chose a *contact-person* in addition to the crew boss to reduce the work load on the foreman's shoulders.
In the beginning, foremen experienced that asking open-ended questions was awkward, but recognized the change in their work crews' reactions and the positive consequence of a reduced work load. After completing an assignment on site one foreman reported the following:

"Instead of delegating the work, I asked who would take care of it. There was a pause and that was somewhat awkward. I said this is up to you today. There was a person who volunteered… that it would be ok. One may take too much responsibility. If you can't do that [let employees take initiative and responsibility] *you will hang on the phone all day, it's great when they* [work crew] *can* [take responsibility]*. It must also be good to take responsibility."*

The selected work crew members reported back that they felt involved in decisions when the foreman asked them open-ended questions without giving answers beforehand, and when using the planning system tool together with the whole work crew. However, work crew members were not always included in the planning process, and not all foremen liked to ask work crew members for their input and opinions. One foreman used the planning system tool, but did not involve his work crew in the planning process. He did not feel that employee involvement was necessary based on his understanding of a foreman as in-control organizer, who do not ask questions but give instructions. The participant's individual attitude and opinion towards the training and need for change were contextual barriers, which hinder the implementation of the *Toolbox-training*. Another barrier was the high turnover among work crew members, as one foreman reported back that he borrows manpower from other foremen.

"*It is easier to use that* [training tools] *with people who are your own. It is a waste of time to use a personality type tool* [HBDI training tool] *or questioning techniques with them as they disappear again*."

Selected work crew members experienced no evident change in foreman's OSH communication and behavior, due to turnover among this work crew. The crew members did not know the foreman before he had participated in the training course, and were unable to comment on change in their foreman's approach. Work crew members reported that other hindering factors which affected OSH dialogue and knowledge sharing negatively were lack of interest among their colleagues, tight time schedules, busy foremen talking on the phone and not being able to get their foreman's attention.

3.3. Discussion

This project provided preliminary evidence that *Toolbox training* can be adapted to the Danish construction safety culture to successfully improve OSH dialogue among Danish foremen and other parties.

The *Toolbox training* program was well-received among foremen and there are some indicators of improvements in safety communication among foremen and their crew members. Similar studies found that *Toolbox meetings* improved knowledge and behavior among employees (7, 11, 12). *Toolbox meetings* with focus on fall prevention suggested that safety communication training had an effect not only on participating foremen, but also on young apprentices' security practices and worksites that the foremen directed (12). *Kines* (*2010*) showed that construction site safety improves when foremen increased verbal safety dialogue (13). Foremen play a central role, when it comes to engaging work crew members actively in dialogue and problem-solving discussion on site. They can help to optimize safety in an otherwise dynamic industry where people and processes change constantly. Given that feedback from foremen and recognition are amongst the most powerful incentives influencing job performance (17), construction foremen should be trained how to teach their crewmembers and provide feedback to affect their safety behaviours (12).

A strength of this study is that we were able to address several construction trades and that we developed a manual for the *Toolbox-training* program *(training the trainer),* and therefore it can easily be delivered in various construction groups. In the present study we used different trainers with recent construction experience. Trainers with experience and relations within the construction industry increased the relevance of the *Toolbox training*.
However, there were challenges within this study. We often trained very experienced foremen, who had been on several training courses and who had already a high degree of OSH knowledge. The preliminary results showed that 60% of the participants (Table 2) gained new knowledge about safety and work-related accidents to a small and very small extent. The foremen sample was drawn from eight different construction companies noted for their active safety engagement. Thus, the foremen's responses may not be representative of construction foremen in general. For the purpose of optimizing the program, the selected target group was well chosen and gave valuable feedback. All foremen reported a high degree of knowledge transfer within the group of participants due to their different occupational background (e.g. different construction companies and various construction trades). In the future, we recommend recruiting more unexperienced and younger foremen, who are new to their role as leaders. We assume that the training course will have a higher impact on their safety knowledge and communication.

A successful implementation is a prerequisite for testing the effect of *Toolbox training* as a next step, as intermediate outcomes and final effects cannot be expected if the implementation fails. If successful, the training program could be integrated into existing vocational and educational training structures, and thereby help to improve vocational training for construction foremen in

Denmark. This study will continue to investigate which barriers and facilitators hamper and trigger the implementation of *Toolbox training*, and the program will be optimized accordingly.

4. CONCLUSIONS

This study identified training needs and opportunities for construction foremen and their work crews. *Toolbox training* was well-received among foremen, and their degree of OSH knowledge and safety communication skills increased. Safety communication between foremen and their work crews improved as selected work crew members' participation in OSH dialogue increased, which made them feel more involved in decisions regarding work tasks. The present study suggests that work crews' participation in safety communication and active employee involvement has a positive impact on planning and safety procedures. However, foremen did not utilize all learned training tools and skills after the training course and work crew members experienced no evident change in foreman's OSH communication and behavior. Most common factors, which hindered the foremen to apply new knowledge, were tight production schedules, turnover and lack of interest among work crew members and individual attitudes towards the training. Communication barriers with foreign subcontractors were also experienced as a challenge and based on the present study we recommend to optimize the *Toolbox training* program addressing these language challenges in the future.

5. REFERENCES

Arbejdstilsynet (2012). Anmeldte Arbejdsulykker - 2006-2011. Årsopgørelse 2011.

Andersen, L. L., & Zebis, M. K. (2014). Process Evaluation of Workplace Interventions with Physical Exercise to Reduce Musculoskeletal Disorders. *International Journal of Rheumatology 2014*; 2014: 761363.

Aust, B., & Ducki, A. (2004). Comprehensive health promotion interventions at the workplace: experiences with health circles in Germany. *J Occup Health Psychol.*, 9(3):258–70.

Aust, B., Helverskov, T., Nielsen, M.B., Bjorner, J.B., Rugulies, R., Nielsen, K., Sørensen, O.H., et al. (2013). The Danish national return-to-work program-aims, content, and design of the process and effect evaluation. *Scand J Work Environ Health.,* 38(2):120-33.

Baker, R., Stock, L., Szudy, B. (1992). Hardware to hard hats: training workers for action (from offices to construction sites). *American Journal of Industrial Medicine*, 22(5):691-701.

Baranowski, T., & Stables, G. (2000). Process evaluations of the 5-a-Day projects. *Health Educ Behav* 27: 157–166.

Dedobbeleer, N. & German, P. (1987). Safety practices in construction industry. *Journal of Occupational Medicine*, 29(11), 863-8.

Dyreborg, J., Andersen, L.P., Carstensen, O., Cleal, B., Grytnes, R., Grøn, S., Gubba, Kines, P., Mikkelsen, K.L., Nielsen, K., Nielsen, T.W., Rasmussen, K., Shibuya, H. & Spangenberg, S. (2008). Forebyggelse af Alvorlige Arbejdsulykker gennem Intervention i Sikkerhed og Sikkerhedskultur. Afsluttende projektrapport (AMFF-projekt nr. 2-2004-03).

Esmaeili B., & Hallowell, M.R. (2012). Diffusion of Safety Innovations in the Construction Industry. *Journal of Construction Engineering and Management-Asce 2012*; 138(8):955-63.

Harrington, D., Materna, B., Vannoy, J., Scholz, P. (2009). Conducting effective tailgate trainings. *Health Promotion Practice*, 10(3):359-69.

Hinze, J. (2003). Safety training practices for U.S. construction workers. Construction Safety Education and Training – A Global Perspective, 1-10.

Kaskutas, V., Dale, A. M., Lipscomb, H., Evanoff, B. (2013). Fall prevention and safety communication training for foremen: Report of a pilot project designed to improve residential construction safety. *Journal of Safety Research*, 44, 111-118.

Kines, P., Andersen, L.P., Spangenberg, S. Mikkelsen, K.L., Dyreborg, J., Zohar, D. (2010). Improving construction site safety through leader-based safety communication. *J Safety Research*, 41(5), 399-406.

Lehtola, M.M., van der Molen, H.F., Lappalainen, J., Hoonakker, P.L.T., Hsiao, H., Haslam, R.A., Hale, A.R., Verbeek, J.H. (2008). The Effectiveness of Interventions for Preventing Injuries in the Construction Industry: A Systematic Review. *American Journal of Preventive Medicine* 35:77-85.

Saunders, R.P., Evans, M.H., Joshi, P. (2005). Developing a process-evaluation plan for assessing health promotion program implementation: a how-to guide. *Health Promot Pract.* 2005; 6:134–147.

Spangenberg, S. (2010). Large construction projects and injury prevention. Doktor afhandling. Aalborg Universitet og Det Nationale Forskningscenter for Arbejdsmiljø.

Stajkovic, D. A., & Luthans, F. (2003). Behavioral management and task performance in organizations: Conceptual background, meta-analysis and test of alternative models. *Personnel Psychology*, 56(1), 155–194.

Steckler, A., & Linnan, L. (2002). *Process Evaluation for Public Health Interventions and Research*. San Francisco, CA: Jossey-Bass.

Stephenson, J., Imrie, J., Bonell, C., Wight, D., Obasi, A. (2002). Unpacking the "black box": the importance of process data to explain outcomes. In Stephenson, J., Imrie, J., Bonell, C., eds. Effective sexual health interventions: issues in experimental evaluation. *Oxford: Oxford University Press,* 2002: 151–66.

Wierenga, D., Engbers, L.H., van Empelen, P., Hildebrandt, V.H., van Mechelen, W. (2012). The design of a real-time formative evaluation of the implementation process of lifestyle interventions at two worksites using a 7-step strategy (BRAVO@Work). *BMC Public Health.* 2012; 12:619.

Wierenga, D., Engbers, L.H., van Empelen, P., Duijts, S., Hildebrandt, V.H., van Mechelen, W. (2013). What is actually measured in process evaluations for worksite health promotion programs: a systematic review. *BMC Public Health,* 13:1190.

Integration of Safety in Management tasks in onshore transport SME´s

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Abstract
In EU, the transport sector has an incident rate of accidents at work of 40 per 1000 employees. The transport sector is characterized by many small enterprises of which 97% of the enterprises in Denmark have less than 50 employees and 89% have less than 10 employees. The safety problems for the employees are the activities carried out when loading, unloading or work with transport equipment carried out at many different work places. The main safety problems are falls, heavy lifting, poor ergonomic working conditions, hits or collisions with goods, falling objects, the traffic risk situations, work with animals and the risk of violence and robbery.
To create a high level of safety in an enterprise is a difficult task that demands a great degree of management engagement. It is not only a question of having the right equipment, procedures and organization etc.; it is also necessary for everyone in the enterprise to have an understanding of safety and feel obligated to take responsibility for safety in all work at all times.
Accident research shows that safety must be integrated in the whole enterprise and function on all levels of management, while it must also involve all employees in their daily work. It is important to emphasize training in safety, good communication, good order and a stable staff of employees.
Pro-active accident prevention also involves process, communication and organization, where management plays a significant role, which includes its ability to involve both middle-level management and employees in creating a high level of safety. These findings are mostly derived, however, from large enterprises.
The research question is: “How can experiences from large enterprises regarding how to achieve good safety be adapted and applied to small enterprises in a branch such as the transport sector.
The aim is to present tools and barriers for SME´s on how to integrate safety activities in the daily work fulfilled with other duties and few resources.
An action based study for the prevention of accidents has been carried out in six SME transport enterprises over a three- year period. The study has been organized together with the employers to follow their plan for integrating safety into their basic work. The methods has been an action oriented research model, where together the researcher and the enterprises have developed and made experiences with the use of different tools for accident prevention.
The result is a realistic strategy for integration safety, quality and environmental factors in an SME and procedures for how to go from strategy to action. Different tools were developed to fulfil the strategy ranging from risk identification, involvement of the employee and motivational activities. These tools are designed to simplify the safety management methods, but they were adjusted to a new focus and awareness for managers of small enterprises including documentation of the SME´s own internal costs of compensation for all damages and injuries. However, several factors create barriers for the SMEs’ efforts, even when there is a visible economical advantage to be gained.

Keywords: Integration of Safety, Management in SME´s, The transport sector

INTRODUCTION

To create a high level of safety in an enterprise is a difficult task that demands a great degree of management engagement and its constant focus. It is not only a question of having the right equipment, procedures, organization, etc.; it is also necessary for everyone in the enterprise to have an understanding of safety and feel obligated to take responsibility for safety in all work at all times.
Accident research shows that safety must be integrated in the whole enterprise and function on all levels of management, while it must also involve all employees in their daily work. It is important to emphasize training in safety, good communication, good order and a stable staff of employees (Cohen, A.; Smith, M.; Cohen, H., 1975; Smith, M.; Cohen, H.; Cohen, A., 1978; Glendon, A.I.; Clarke, S.G.; McKenna, E.F., 2007; Kjellén, U., 2000).

Pro-active accident prevention also involves process, communication and organization, where management plays a significant role, which includes its ability to involve both middle-level management and employees in creating a high level of safety. These findings are mostly derived, however, from large enterprises. (Hale A., 2005) (Hale A.;Guldenmund F., 2004) (Jørgensen, K., 2015)

The transport sector is characterized by many small enterprises especially involved in the transport of goods on shore and has a high accident rate. The safety problems here are typically linked to the activities when loading and unloading, as well as work with transport equipment at many different workplaces. (The European Foundation for Improvment of Working and Living Condition, 2004) (Jørgensen, K., 2011)

The transport sector is also characterized by the fact that managers have to lead from a distance. The drivers are on their own and very often alone in the lorry. The drivers' working conditions are very often out of the managers' hands, because they are determined by the conditions at the place where the goods are picked up from the suppliers and where they are delivered to the customer.

The research question is: "How can experiences from large enterprises regarding how to achieve good safety be adapted and applied to small enterprises in a branch such as the transport sector.

METHODOLOGY

The methodology has been a combination of a theoretical view on how to integrate safety in the management of a company and an action-driven study of six small and medium-sized enterprises within the haulage contractor industry. The goal was first to create an understanding of how safety can be integrated in the management of a company and secondly try to see what could work in a transport company in practice. The questions asked were 1. What can motivate an employer in a small enterprise to participate and prioritize safety? 2. Is it possible to create a strategy and plan of action together with the employer that can be integrated with their wishes for their enterprises and the daily routine? 3. Is it possible to find and develop tools for safety activities that can identify risk, inform and motivate the employee, create training and awareness about safety, and reward good and safe behaviour?

The action-driven study was carried out in close cooperation and dialogue between the researcher and the enterprises' employers in 6 transport enterprises and run over 4 years.

The enterprises participating in the project are haulage contractor businesses employing between 20 and 50 drivers. The administrative part of the business comprises of two to ten persons. The medium-sized enterprises have transport managers, who are intermediate managers between the employer and the drivers. The items that are transported are packages and goods, earth, gravel and building materials, waste and waste disposal, and live animals.

The normal working day involves procuring jobs for the company and ensuring that they are carried out. When the drivers meet, they are told that they are to transport items from A to B; then, they are kept busy throughout the day with new instructions delivered over the phone. Most drivers have their "own" vehicles, i.e. they have a permanent vehicle for which they are responsible for with regard to maintenance and cleaning, but they must lend it to colleagues when they are off work. It is essential that the vehicles are out driving every day in order to generate revenue.

An analysis of the details regarding accidents shows that the causes of the injuries are falls to lower levels and falls on the same level, contact/collision with moving or stationary objects, and being struck by falling or moving objects, as well as physical strain during manual operations (lifting/carrying) and inappropriate movements and working positions (Jørgensen, K., 2011).

The transport industry's working conditions are generally poorer than the average for all industries, as risks are found in the surroundings with noise, dust, and dangers associated with hazardous goods and road traffic, vibrations, high and low temperatures, poor ergonomic conditions when loading and unloading and with the sedentary work as a driver, work outside normal working hours and long working days. Also, a number of organisational risks are observed, such as high job demands combined with a low level of self-inspection of the work and little potential for experience development on the job (The European Foundation for Improvment of Working and Living Condition, 2004).

THE THEORETICAL VIEW

To find a way of integrating safety in management we must look for what is needed for a company to survive and to grow; to see if we can integrate efforts for reducing injuries and losses in what else may be needed in a company. We could also look at what is of important for the employee´s, what they could be proud of to be.

Others have seen the needs for integration of safety in production. Rasmussen showed us in 2000 that the managers' wishes to obtain the most effectiveness organization and the employees' wishes to ease the workload are two very strong drivers for the drift to danger. Dangers that can be invisible until the trigger appears for the accident to happen (Rasmussen, J.; Svedung, I., 2000)

We must ask our self how we ensure that effectiveness includes safety and quality, and how we ensure that the easy way to perform the job also is the safe and qualified way.

In 2004, Gillen wrote that a major obstacle to implementing safety initiatives is that it is not put into context with production and productivity. To operate safely should be an equally important part of an organization's mission as being a financial success (Gillen, M.; Kools, S.; McCall, C.; Sum, J.; Moulden, K.;, 2004).

Research has found that the financial loss from accidents and errors in production can be tremendous for a company, but also that a high level of safety and quality assurance are related to high performance in production in the long run. Financial success is not only when you earn more money, but also when you minimize your losses (European Agency for Safety and Health at Work, 2010).

In 2005, Hopkins wrote that an organizational culture can be detrimental to safety, not because management has chosen to sacrifice safety in relation to productivity, but because they have not focused on safety at all - if management has their attention on both productivity and safety, then the organization as the leader can exhibit a culture that has the potential to host both (Hopkins, A., 2005).

Integration of safety and quality into all elements of an organization seems to be important. Let us try to see what that could look like:

A business plan must describe the key services the company can offer their customers. Included are key activities, key resources, and values of the services, customer relations, financial structure and profit stream. Knowing that occupational accidents are expensive for society, the companies and the victims; we must ask the question of whether the business plan could include elements like:

- That key activities can be completed without any mistakes or harm to people, goods, services, technology, customer's property, etc.
- That key resources makes it possible to ensure the provision of key activities.
- What you can offer the customer is something the customer can trust they will receive, on time and at the right price and without defects or damage.
- That customer relations are of mutual trust and understanding of the value provided and paid for.
- That the cost structure reflects the value of minimizing losses in production.
- That profit will be increased not only by higher sales, but also by minimizing costs.

We can look at an organization through the star-model of Galbraiht who looks at the organization's strategy, structure, processes, reward system and human resources, and the connection between these elements (Kates, A.; Galbraith, J.R. ;, 2007).

Strategy

A strategy determines which direction the company is to develop in. It is here that one sets out the strategic goals and vision for the company, which will operate the business model and what are the company's strategic objectives in relation to customers and employees.

This of course applies to the service, product, etc., that you would like to deliver, but it could also apply to production having a high standard of safety and quality as a responsible, reliable and resilient organization. In many companies injuries and accidents are considered as something that relates only to insurance issues and compliance with legislation or possibly a desire for a healthy work environment in terms of employees. However, why not make it clear that it is a business strategy of providing service to customers who are professionalized that is done safely and qualitatively correctly at the time agreed upon and at the right price. This also implies that employees are not sick or absent due to injury. Such a strategy requires considering what "safe and qualitatively correct" means in the company. For example, that there is no damage to services, products, customer's property, etc., but also that there is no damage to the technology or injuries to the employees, because these damages and injuries are losses that result in delays and costs that can only be determined on the price.

Structure

The structure of the company determines the power and dynamics of the work and tasks to be implemented with. They define the decision-making and collaboration. It includes the usual way to control how tasks come into the business, how they are being put in place for implementation, how they are implemented and how the task will be handed over to the customer.

It is important that this structure supports the objectives of the company's strategy and vision, including the possibility that tasks can be completed safely and qualitatively correct. This applies to the acceptance of tasks that are said yes to and their qualifications to be implemented, it is in order to give the framework and conditions for performing the tasks and ensuring that tasks can and will be resolved on the basis of this framework and objectives. Time, resources, technology, etc., are included as conditions for these tasks to be solved, while structures must ensure that procedures. This also includes the need to carry out tasks safely and qualitatively. This would not be any good if a seller accepts a job that there is no time or resources to perform it in a responsible manner. It is also about how the company is organized with middle managers to manage tasks, plans, finance, sales and customer relations etc. In this context, it is important that you consider how visions, strategies and plans will propagate down through the organization. Middle managers are very important to carry out plans and strategies in their daily work. They must therefore understand what their role is in relation to integrating quality and safety, partly through their own management and in relation to other managers' functions. In this way a line management task cannot disclaim the responsibility for safety and quality to other people in the organization.

Processes

Processes include information flow and work processes, but can also include collaborative processes and processes to follow up on that objectives and strategies are being implemented, i.e. some kind of monitoring processes. Getting adjusted information and work processes requires that you have a feel for what is happening right at the front end of the performance chain. This can only be done by involving employees' knowledge and ongoing experience, both at management level as well as at executive level. No one else knows better what can go wrong and what actually goes wrong.

It is also in control processes that you have the ability to pool knowledge and information that is useful for the assessment of the achievement of objectives and the impacts on the economy when things go wrong with safety and quality. Documentation is necessary to adjust and correct the state of affairs. It is also in the processes that managers can create motivation, learning, etc., through the involvement of all levels and through a mutual respect between and within all parts.

Rewards

Reward is about how to motivate employees to do the work, as expressed in the objectives and vision of the company's business.

Some would say that employees receive their salary in order to do a proper job, but dedication and commitment is often what can push a business forward. Here comes the importance of what the company perceives as the right thing, what it means to be professional and good to work for and ultimately rewarded with a salary, possibly a bonus, with possible promotion, more responsibility, praise, blame, etc. Below it is important again that the company's goals and strategy set clear accents in this view. A goal of "safe and qualitatively correct," should be a value that is known in the employees' professional understanding of their own efforts and level. This happens only if it is clearly making itself known in the management value understanding of who they consider to be "the good and professional staff."

Human resources

It is crucial for a business platform that you have the right staff to ensure the execution of tasks, both those that govern the organization, as well as performing core tasks. Here it is about the employees having the right skills and the right understanding of the company's goals and vision. Competence and understanding of what good quality and good safety are have a significant impact on all employees. Make sure that employees have the necessary knowledge of the work required to perform it safely and qualitatively correct, they have the ability to do the job with the time and technology that is available and that they have the motivation to do the work within the goals and strategy that the company wants. Correlation between knowledge, abilities and motivation across all activities people perform, where skills, resources and motivation determines how well the tasks are performed.

Connections between the 5 elements

Examples of connections between these 5 elements concerning safety are pointed out from other safety researchers. Rasmussen argued that the effective coupling of professional players to their work depends on their professional competences and also mentions how working culture depends on factors such as cognitive style and management style. Furthermore, he showed us how the individual adaption of the actual action-response characteristics of the work environment poses a problem for risk management since adaption guided by short-term process criteria such as work load or time spent will very likely override long-term risk criteria such as functional redundancy. This has to be avoided in a professional organization (Rasmussen, J.; Svedung, I., 2000).

Zohar has also touched upon the problems of being in an organization where organizational leaders trade-of production- related policies and they are in direct conflict with safety which provides the message to employees what is most important. If productivity is favoured over safety across a variety of situations it implies a higher priority and employees will align their behaviour accordingly to the detriment of safety. From an employee standpoint it is the overall pattern and signals sent by the complex web of rules and policies across competing domains that ultimately must be sorted out in order to discern what role behaviour is expected, rewarded and supported (Zohar, D., 2010).

As a matter of fact all our knowledge from a safety management system or high reliable organizations like Weicks 5 principles; to be preoccupied with failure, to be reluctant to simplify, to be sensitive to operations, to be committed to resilience and to have deference to expertise has to be taken into consideration for any organization, but it has to be integrated in the strategies, the structures, the processes, the reward system and the human resources (Weick, K.E., Sutcliffe, K.M., 2007)..

In the end it is about being professional towards finances, production, customers, qualities and safety. Back in 2000, Rasmussen said that where he referred to a fine definition of professionalism from the French Colas 1994.

Professionalism aims to make actions more reliable by implementing appropriate work methods. Theses more thorough methods refer to intellectual analysis, diagnostics, choice of appropriate response, etc, and to culture perception and values accorded to safety and production and consequently to the willingness to act in a certain way which in turn flows from a state mind, attitudes and behaviour (Colas, A., 1994) (Rasmussen, J., 1995).

They also listed the following dimensions for professionalism not only for the manager, but also for the employee (Colas, A., 1994) (Rasmussen, J.; Svedung, I., 2000). Principles for implementing professionalism application to management:

1. Permanently ensure that there is an appropriate balance between the capabilities of personal, the resources assigned to an activity and the requirements of this activity.
2. Draw up a contract for the performance of activities and define specifications for their execution.
3. Ensure that the coordination and synchronization of actions between different players is well organized.
4. Ensure that checks, verifications and validations are provided for and carried out.
5. Motivate and encourage reviews of work and enhance fundamental experience.
6. Establish and maintain a motivating work environment by setting an example, displaying quality in human relations and recognition.

Principles for implementing professionalism application:

1. A professional knows and respects their sphere of autonomy

2. A professional always plans and prepare actions thoroughly and thus has a clear vision of what is to be done before taking any action.
3. A professional manages the conditions governing the environmental and context in which they operate.
4. A professional ensures reliability by cross-checking and varying dab sources and having every action verified.
5. A professional gives priority to safety
6. A professional improves their skills, enriches their experience and that of others; they act in a transparent manner.
7. A professional pays attention to detecting and correction of non-quality
8. As a human being, a professional is aware of their capabilities and limits and knows how to take the necessary safeguards when in a vulnerable situation.

We may need to find new words and a new approach for minimizing the probability of occupational accidents. We have to make safety a part of the professionalism without making safety a separate issue, but as an integrated part of how the good and correct way to do things are.

Safety in SME

The challenge lies in finding out how to use the best from the approaches developed for large enterprises and adapting them to the day-to-day operations of small enterprises. Doing this creates more challenges, which makes it even more difficult to implement a safety practice.

The small enterprise seldom experiences an accident among its own employees. If an accident occurs, it is often seen as an accident process outside the responsibility of the employer. By far the majority of accidents are so-called ‘trivial accidents’, such as falls, bumping into something, or muscle sprains during heavy lifting. The triviality lies first in the fact that the course of events is simple and subsequently easy to explain, and secondly in the fact that such accidents are strongly connected with people's behaviour and actions, while the conditions causing the accidents are perceived as everyday occurrences and not anything particularly dangerous. This implies that there is a lack of competence in the small enterprise to investigate and analyse accidents (Walters, D.;, 2001). All in all, the awareness of hazards, their possible consequences, and potential preventive measures, is generally low.

It is well known that the managerial resources in small enterprises are limited. There is no need for large formal systems when things can just as well be discussed in the day-to-day situation. Therefore, informal and often ad hoc processes also characterize the organisation of work (Hasle, P.; Kines, P.; Andersen, L.P., 2009; Walters, D.; Lamn, F., 2003; Eakin, J.M.; MacEachen, E., 1998).

Moreover, many small enterprises are characterized by tasks that are performed elsewhere than where the employer is located. This applies in such sectors as building and construction, commerce, agriculture, cleaning and transport. Therefore, the challenge is to make the employer aware of potential safety costs in relation to risks rather than actual accidents, so that the value of safety can be evaluated. Since the small business owner's resources are limited with respect to finances and time, low priority is given to activities considered to be peripheral in relation to deriving income (Brooks, B.;, 2008; Walters, D.; Lamn, F., 2003). In addition, the small business owner and employer possesses primarily professional knowledge with regard to the core activity of the business, not specific knowledge regarding safety and the working environment, nor are these the first topics such an employer tackles. Priority is given to such areas as finance and accounting, legal requirements, sales and customer contact (Hasle, P.; Kines, P.; Andersen, L.P., 2009)

Knowledge about safety is not what is first on the list when hiring employees either. It is more important to have a few staff members to perform the tasks for which there are customers. Therefore, there can be resistance in small enterprises to investing in equipment and tools (Vickers, I.; Baldock, R.; Smallbone, D.; James, P.; Ekanem, I., 2003). Taking time to become acquainted with a new professional area, which is not product relevant, such as the working environment and safety, is not generally something the small employer has time and money for (Walters, D.; Lamn, F., 2003). Therefore, he needs to receive a plan and method developed by others with the necessary knowledge to fulfil his criteria: low cost, easy to use and maintain, and adapted to his tasks and the industry-related requirements (Vassie, L.; Cox, S., 1998).

The conclusion is that the SME needs a good reason and motivation for making safety a high priority in its daily work. It is also necessary to create procedures and tools that are not demanding of time and resources, and the manager needs to feel convinced that such tools are useful for him to implement, because they fulfil several goals in a simple way. Furthermore, the manager must find tools to motivate and train employees to take safety more seriously.

RESULTS

The results present the tools and procedures for meeting the four goals presented in the method section.

To find a motivating reason for the employer to participate and prioritize safety

The most obvious motivational factor to focus on was the economic. Therefore, the very first step in the enterprise was to go through all the bills from the last year and calculate the total cost of all injuries and damages. These calculations focused solely on enterprises' own costs, which included:

- Co-insurance, based on settlements according to the insurance claim list
- Absence, based on the number of days of absence due to illness and the driver's average salary
- Replacement or substitute of damaged goods
- Repairs for damages not covered by insurance, especially minor damages
- Repairs to damaged vehicles and compensation to customers and third parties for damages to property
- Administration costs, based on number of working hours and the hourly price for the administrative employees. This calculation for the 6 enterprises showed that the costs for damages were from DKK 250,000 (EUR 35,000) and up to over DKK 700,000 (EUR 100,000), which corresponded to between 20% and 100% of the different enterprise profits.

After this new realization, the employer's interest in participating in the project shifted from a general interest to a much more active attitude, which made the next step possible.

To create a strategy and plan of action together with the employer

The information about costs provided the basis and awakened interest for a dialogue regarding how to create a positive development in the business with fewer accident claims. The second step was thus a dialogue carried out regarding what each employer actually desired or their vision concerning precisely what their business could be known for. This had not previously been written down, but all the employers had thoughts about it.
The question was put to the employer as a challenge for them to formulate in words what they most wished for their enterprise. On this basis, visions were formulated for the enterprises with the help of the researcher.

To create understanding of how to transform a vision to a policy plan and a strategy

The third step was to agree to stepwise action plans with the primary purpose of integrating the necessary initiatives into the entire enterprise's objectives and mind-sets. The idea was to show that it was also a good idea for a SME to go through the following management steps:

vision – policy plan and strategy – operational activities

Through an intense dialogue with the employers, a number of general issues emerged as very important for the company to focus on. All employers were able to recognize these issues (figure 1).

Working environment, Safety, smoking, breaks, clothing, alcohol, health **Technology/vehicles** – responsibility/maintenance **Quality** of work in relation to customers, behaviour **Environment,** economy when driving and passive driving **Colleagues,** be a good colleague, respect, support, speed and attention **The road** as a place of work

Figure 1. Issues for the haulage contractor company policies

These issues were subsequently transformed into the following holistic approach for the company policies:

- The work environment must ensure that employees are not injured in their work or have contracted an occupational disease. The work will also help to develop employees in their work and creating greater job satisfaction, including being a good colleague.

- Technology / vehicles must be maintained in a safe and qualitative condition, and kept clean. It is a goal that all drivers need to understand the responsibility they have for the vehicle, both its maintenance and upkeep, but also that the vehicles are not damaged or to damage the property of others.
- The quality of work must be such that customers can be sure that they get the product they have purchased, that it is delivered on time, at the right place and without the product being damaged. In addition, you can add the service to the customer, who must follow a supply of goods.
- Environmental considerations must be related to the consumption of fuel, i.e. a goal of undertaking passive driving and to adjust the speed of traffic to minimize fuel consumption. This will also mean better road safety.
- The traffic work places special demands on drivers' abilities and willingness to drive safely and take account of other road users. High demands must be placed on employees' driving skills and motivation to do so. It should be such that there can be full confidence that employees understand the responsibility they have, that they have the necessary skills and that they are motivated to perform safe driving.

From strategy to operational activities.

The fourth step was to establish a process of implementation of the strategy, so that the policies gave meaning in the practical life of the company and could be communicated to the employees.

The employer was asked to formulate what they considered the five most important rules for the employees to follow in their daily work. One example is shown in figure 2.

Working environment, safety, smoking, breaks, clothing, alcohol

1. Be sure to wear reflective work clothes and safety shoes and a hard hat.
2. Be sure to have the necessary knowledge/training for the work you are doing.
3. Be sure that your lifting equipment and vehicle are approved and in a good maintained condition.
4. Be sure to think safety into your daily tasks (10 seconds).
5. Give yourself time in traffic and for your tasks – do not press yourself and follow driving time rules.

Technology/Vehicles – responsibility, maintenance

1. Check the oil and water of the vehicle every morning.
2. Check that the vehicle’s lights, lamps and mirrors are in order and clean every morning.
3. Check that the tyres are in order every morning and make sure that the vehicle is generally well maintained.
4. Check every morning that the especially sensitive parts of the vehicle are in order.
5. Never drive with an overweight load.

Quality of work in relation to customers, behaviour

1. The customer is in the centre in relation to all jobs.
2. It is your responsibility that the job is carried out in a professional manner.
3. If the agreed time cannot be met, contact and inform the customer.
4. Never discuss with the customer, but call the office if problems arise.
5. Be calm, positive and accommodating.

Environment, driving economy. Speed and passive driving.

1. Drive evenly and calmly, max. 80 km/h – you will surely get there.
2. Do not overtake; it disturbs other drivers.
3. Respect driving in cities that demand particle filters and adhere to traffic regulations.
4. Minimize driving in densely populated areas when possible.
5. Be considerate of other drivers even if they are not considerate of you.

Colleagues

1. When you drive another vehicle, find out before what you should be aware of.
2. Be sure to return a borrowed vehicle in the same condition as when you received it.
3. Maintain good discipline when using a trailer and return it in a clean condition.
4. If you have knowledge about special risks at a workplace where colleagues also come, inform them.
5. Support your colleagues when you can, and they will also support you.

The road as a workplace

1. Always be sure to wear reflective work clothes when you work on the road.

2. Be sure that there are good and clear signals of where you are working on the road in relation to other drivers.
3. Be very aware of where you move and stand in relation to other drivers.
4. Never expect other drivers to be considerate of you; there will always be some that won't.
5. Be sure you have had sufficient sleep when working on the road, especially when working at night.

Figure 2. Example of 5 key points for each of the items in the strategy

Mapping the problems/risk identification

One of the first activities includes mapping the working environment problems at the company through the use of a simplified workplace assessment scheme. Also the conditions for the vehicles and the technologies should be evaluated, as well as how satisfied the customer is and also an evaluation of the drivers' ability and competences for being a good driver should be examined. On the basis of the strategy and knowledge of the actual risks, the employer has made their baseline for a new change.

The process

A number of activities were initiated during the first half of the research period, some of which did not target the working environment. However, together with activities that were targeted the working environment they provide an overall picture that employers and drivers could identify with. Since many of the activities involve the drivers, they began to participate in the companies' initiatives. Precisely this involvement is a part of the strategy to create co- ownership, involvement and communication between drivers and management.
Figure 3 shows the range of activities initiated for the six haulage contractor businesses. All the activities aim to provide knowledge about safety through communication and information, guarantee the ability to behave safely through involvement and training, and motivate the employees to actually behave safely through rewards and dialogue.

Structure
Involvement of the middle manager, involvement of the drivers, Dialog and communication, planning of tasks, Time schedules, Resource allocation, availability of technology, training facilities, requirements for the clients
Processer
Information flows, Workflows, Collaboration, Processes control, Meetings, employee interviews, workplace assessments, newsletters, driver handbooks, ten seconds awareness
Awards
This year's driver, Bonus schemes, Praise and criticism through appraisal interviews, Gained skills and advantages, Elite status
Human resources
Employee's knowledge, competences and motivation, the wish to be seen as a professional and to be respected and also to respect others.

Figure 3. List of activities and the model showing the purpose of the activities

Developing the newsletter/information

A newsletter aims to ensure that all important information is disseminated through one channel to all relevant persons. Information may still be put up on a notice board, but not without it also being included in the newsletter, so that everyone knows where they can obtain a total overview of what is happening and what they need to know, including information about specific safety and health conditions at work. The newsletter should be developed according to needs, with new ideas and involvement of employees with regard to the newsletter's content, structure and frequency.

Meetings and involvement of employees

A meeting was organized with all the employees to inform and involve them regarding the vision and its practical implications, emphasizing that they would be asked to take part in formulating how to carry out the vision and to achieve the strategic goals.
Not everything can be communicated through a newsletter; there is always a need for management and employees to meet in dialogue. Space must therefore be created for holding regular, brief meetings – for example, once a month – with involvement of the

employees who participate. It might not be necessary to make the meetings obligatory, but they should be used to carry on a dialogue regarding work, working conditions, and safety conditions, where employees have the opportunity to influence their own situation, and where management also has the opportunity to explain what behaviour they expect of the employees. It should not be that the only way to have influence is to participate in such meetings, but it should be a pleasant and positive experience, and maybe include something to eat and drink.

Following up on costs for injuries and unexpected events
There is a need to systematize and ensure full knowledge regarding the injuries and damages that occur and their causes and consequences. This applies to both injuries to persons, vehicle damage, and damage to the property of others. This information should be collected electronically in such a way that evaluations can be made of: 1) how much the damages and injuries cost the company; 2) which types of damages and injuries occur, where they occur and who is involved; and 3) which initiatives are taken to avoid similar damages and injuries, i.e. a follow-up of the calculations of costs mentioned earlier in this section.

Employer-staff conversations/dialogue
Indirect knowledge exists about the individual employee's competences and capacity. A way is needed, however, to communicate personally with regard to what is good and bad, also in relation to safety behaviour. Personnel meetings between management and staff based on a regular procedure could form a sound basis for developing confidence in relation to the decisions made and communicating what is expected, also regarding safety behaviour. At the same time, individual needs could be clarified and satisfied. In this way, everyone can receive the praise and criticism that is necessary, and if any problem exists, it could be possible to clarify it and find a solution. Decisions should always be written down and accepted by both parties.

Training by elite employees
Different training demands are made in order to perform a job, but the job's special character can only be learned through practical experience. Some are better at their job than others, with regard to quality, safety and stability. Workers who are really good can be titled elite employees and awarded the task of teaching those who are not on the same level, as well as new employees. This can be followed up by a form of continual training of the other employees, so that everyone is lifted to a higher level.

Developed safety measures
Safety meetings should be held once every quarter with an agenda and minutes. Solutions to significant risks should be discussed and initiatives taken, but some of these initiatives depend on producers/customers carrying them out. There are great differences in the conditions that producers/customers offer the companies' employees, both in relation to the work at the customers' places of business and transport to and from them. Greater focus is necessary in this respect, eventually with audits at the premises of the producers/customers. Efforts should also be made to create good relations with producers/customers, but in such a way that they understand that it is their responsibility that collecting and transporting their goods is carried out in a proper way. This includes, for example, clearing snow and ice in the winter and providing space for large vehicles to come in and out, proper transport space in front of buildings so that lifts, etc., can come in and out, good outside lighting, etc.

Driver of the year awards
A set of values should be drawn up for work as a driver, based on the vision, which can be realized in a series of measures that management can continually observe, register and make public, so that everyone knows where they stand. Such measures could have the following themes:

- The ability to honour the demands for quality and safety in relation to customers
- The ability to honour demands for safe behaviour
- The ability to clean and maintain vehicles and drive without damage
- The ability to cooperate and create good collegial relations

The purpose of the driver of the year award is to make the good way of working visible, but also to reward the worker/workers who are stable, solid and contribute to fulfilling the company's goals. Finally, it should also be a motivating factor for everyone to be the driver of the year, i.e. continually try to achieve the agreed goals.

In this connection, it is important that the employees themselves are involved in defining the criteria for becoming driver of the year, as well as the way in which these criteria are measured and registered. The conditions must be known, and the justice of the system acknowledged.

Collective rewards/consequences
Some behaviour is not acceptable, but cannot be observed, because the employees are on the road on their own. Most drivers know who among them behave badly, but no one does anything about it, and the company incurs costs for damages caused by such bad behaviour. Sometimes this can be managed through dialogue, but collective responsibility, where employees influence one another, can also be a positive resource for regulating behaviour.

Ten-seconds of consideration before the task is carried out – awareness
There will always be a certain risk involved in work, especially when working on foreign ground using machines and driving on the roads. This is reinforced when the work is done at odd hours and through the night. It is therefore important that everyone involved is conscious of the risks and behaves in such a way that accidents do not occur.
In this connection, the drivers can be introduced to the value of taking a breath before acting or doing a job just to think safety, with regard to their vehicle, themselves, and others – for example, by using ten seconds to think:

- Is it a safety problem just for myself I should have under control?
- Is it a safety problem for the vehicle?
- Is it a safety problem for other people nearby?
- Is it a safety problem in relation to the customer's or others' property?

This requires this message being given to every driver and that the manager or owner them self continually reminds the drivers that they should think about safety for just ten seconds. However, it also demands that they know the risks involved. This knowledge can be gained from the above proposals for damage registration, as well as from elite employees. Finally, it is important that risks of various damage and injuries constitute a point on meeting agendas and are discussed in the newsletter.

DISCUSSION
All the employers knew about legal requirements. They had elected safety representatives, but kept formal safety meetings to an absolute minimum. They also adhered to rules regarding driving-rest time and traffic safety rules.
It was a real motivational eye-opener for the employers to realize the costs of damage and injuries. We found that none of the enterprises had an overview of these costs beforehand, as it was not included in their financial accounts.
None of the enterprises had any thoughts whatsoever regarding strategies or policies on safety or anything else. It was new for them to think in this more systematic way. Writing down the employers' thoughts and wishes and helping to formulate and compile them in a professional way was a very positive experience for all parties, but they would never have done it without help.
The same applies to the implementation of the various tools. It was possible to inform about them, but it became clear that they would not be used without help. The enterprises that participated most successfully in the process either found help from external partners or appointed one of their own employees to do the job.
The extent to which it was necessary to discuss employee leadership with the employers was surprising, as well as the need to present arguments for why it is necessary to talk with their employees and involve them in decision making. There was clearly a lack of managerial latitude and competence.
The employers have an overall need to understand the management task in relation to employees. The haulage contractor spends all their time getting work for the business and making agreements with customers, but exercising leadership toward employees and ensuring that they actually carry out the work as they are supposed to, also in a safe and qualified manner, does not lie within the haulage contractor's field of competency. It was

therefore necessary to help them understand this part of their responsibility as an employer and illustrate how they could gain positive value from the effort.
Many of the proposed initiatives were carried out in the enterprises, but acknowledging that it is a difficult task to create new forms of behaviour and basic conditions in a small enterprise has proven to be hard to maintain for the small employer, but in fact, it is not because they do not wish to change.
The experience from this project is that the SME employers, at least in the transport sector, need management training and help to formulate their visions and transform this vision into a plan for how to achieve it, and they need support to turn the plan into action. This kind of training and help does not need to be costly or too time consuming, but it needs to be done by professionals. Most of the employers would never go for it themselves, but the authorities, the insurance companies, and the employer's organisations could do a lot.

CONCLUSION

The research project has shown that it is possible to simplify and adapt management tools and methods to SMEs and thus create easily accessible activities that can set focus on safety. It can be difficult to maintain the companies' attention in the long run, and there are periods when their resources cannot handle more than getting work in for the business.
At least three issues have to go hand-in-hand:

- The first is to get the employer interested and to prioritize safety together with quality. This is actually rather easy to do by calculating all the costs that are incurred when things go wrong.
- The second is to help the employer understand what they can accomplish through small activities that involve the employees and are easy to implement.
- The third and most difficult is to ensure that the employer gives constant priority to the activities that are initiated.
- The employer can be interested and understand the problem and the solutions, but if their economic situation is critical, if they do not have the right technological resources, and if they do not have the proper staff and the right competences, then it is nearly impossible to begin to think of making changes in the social and cultural capital. Nevertheless, this is what they have to do.

The advantage is that if this surplus is in place, then it is not far from understanding to decision making and implementation. Something actually results from a clear effort. The main conclusion is that there is a need to help small business employers understand what the management task involves and how they can develop themselves and their businesses in a simple way without any grand system. However, our results also show that safety efforts first become accepted when they are integrated into other efforts to form a visible whole in relation to the company's overall goals.

REFERENCES

European Agency for Safety and Health at Work. (2010). *Economic Incentives to Improve Occupational Safety and Health: a review from the European perspective.* European Agency for Safety and health at Work.

Hale A.;Guldenmund F. (2004). *Aramis Audit Manual.* Delft: Delft University of Technology.

Brooks, B.;. (2008). The natural selection of organizational and safety culture within a small to medium sized enterprice(SME). *Journal of Safety Research, 39*, 73-85.

Cohen, A.; Smith, M.; Cohen, H. (1975). *Safety Programs Practices in High vs Low Accident Rate companies - An interim Report.* US Department of Health , Education and Welfare Publication.

Colas, A. (1994). *A New Stage in Improveing the Operating Safety and Performance of Edf´s Nuclear Power Plants by Enhancing Professionalisme and Developing the Safety Quality Culture.* EDF Nuclear Power Plant Organisation-Human Factor Group.

Eakin, J.M.; MacEachen, E. (1998). Health and the social relations of work: a study of the health-related experience of employees in small workplaces. *Sociology of Health and Illness, 20*(6), 896-914.

Gillen, M.; Kools, S.; McCall, C.; Sum, J.; Moulden, K.;. (2004). Construction managers perception of construction safety practices in small and large firms: A qualitative investigation. *Work 23, IOS Press*, 233-243.

Glendon, A.I.; Clarke, S.G.; McKenna, E.F. (2007). *Human Safety and Risk Management* (2 ed.). Taylor&Francis.

Hale A. (2005). Safety management, what do we know, what do we believe we know, and what do we overlook? *Tijdschrift voor toegepaste Arbowetenschap, 3*, 58-66.

Hasle, P.; Kines, P.; Andersen, L.P. (2009). Small Enterprise owners accident causation attribution and prevention. *Safety Science, 47*, 9-19.

Hopkins, A. (2005). *Safety Culture and Risk.*

Jørgensen, K. (2011). *Arbejdsulykker i Transportbranchen (Accidents in the Transport Sector).* DTU management Engineering.

Jørgensen, K. (2015). Prevention of "simpel accidents at work" with major consequences. *Safety Science*.

Kates, A.; Galbraith, J.R. ;. (2007). *Designing Your Organization - Using the Star Model to Solve 5 Critical Design Challenges.* Jossey-Brass.

Kjellén, U. (2000). *Prevention of Accidents Through Experience Feedback.* London: Taylor & Francis.
Rasmussen, J. (1995). *On Competence : A Note for Discuaaion - Contribution to project at Risk Centrum.* Not published.
Rasmussen, J.; Svedung, I. (2000). *Proactive Risk Management in a Dynamic Society.* Sweden: Räddningsverket.
Smith, M.; Cohen, H.; Cohen, A. (1978). Characteristics of Successful safety program. *Journal of Safety Research*, 5-15.
The European Foundation for Improvment of Working and Living Condition, .. (2004). *EU road freight transport sector: Work and employment conditions.* Dublin: Eurofond.
Vassie, L.; Cox, S. (1998). Small and Medium Size Enterprises (SME) interest in voluntary certification schemes for health and safety management:Preliminary results. *Safety Science, 29*, 67-73.
Vickers, I.; Baldock, R.; Smallbone, D.; James, P.; Ekanem, I. (2003). *Cultural Influences on health and safety attitudes and behaviour in small business.* HSE Books UK.
Walters, D.;. (2001). *Health and Safety in Small Enterprises, European Strategies for ;amaging improvement.* Saltsa.
Walters, D.; Lamn, F. (2003). *OHS in Small Organisations: Some Challenges and Ways Forward.* The Australian National University.
Weick, K.E., Sutcliffe, K.M. (2007). *Managing the Unexpected - Resilient Performance in an Age of Uncertainty.* WILEY.
Zohar, D. (2010). Thirty Years of Safety Climate research: reflections and future directions. *Accident Analysis and Prevention, 42*, 1517-1522.

The importance of managers' participation including interpersonal and group communication in the prevention of near miss accidents in safety management systems

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Abstract

More and more enterprises are struggling with a relatively small amount of reported near-miss accidents which are the base of Heinrich's pyramid and the source of knowledge of accidents causes. In order to prevent unwanted occurrences this knowledge is essential. The research, when conducted, focuses on managers' activation in terms of safety culture and the reasons of employees‘ reporting negligence. ***Objectives.*** The aim of the study is to build the awareness concerning the importance of reporting any inconveniences/disturbances at workplace and, consequently, the implementation of prepared tools based on the research. ***Material and methods.*** The study was conducted on the corporate factory's premises and involved around 120 workers. The methods used included: questionnaires, interviews, work observations as well as literature analyses. ***Results and Discussion.*** The study confirms that managers' activity has a huge impact on the engagement of their subordinates in the accident prevention. ***Conclusion***. Permanent effects of developing system of health and safety management can be achieved if apart from improving techniques and organization of the workplaces, the organizations will care about building safety awareness among its employees. Safety culture depends on the extent of trust as well as effective communication in companies.

Keywords: communication; awareness; safety culture; preventive measures

1. INTRODUCTION

Within the past few years there has been an increasing number of talks on safety conscience at numerous companies. Since there is not enough knowledge concerning all the real causes of accidents, different companies find it difficult to develop a safe workplace. Among the publications on building safety culture, we may find a wide range of publications on the influence of managers' on building safety culture. Without any precise information on the source of problems, it is impossible to solve its factors, which is the indirect cause, initiating serious consequences of accidents. The main factories' resources are blue-collar workers, who have a direct contact with work factors, which is equal to having knowledge about threats at workplace. The Main Statistical Office in Poland (GUS) summarized the quantity of accidents in industry manufacturing. The numbers are as follows: in 2012 there were 85 fatal accidents, 262 injury accidents and 33431 minor accidents. The year later the numbers were respectively: 60, 240, 29943 (GUS,2013,2012). Among the factors affecting the accident rate most often, one can distinguish:

- no motivational system for the employees' to use personal protection measures (Tint P, Paas O, Reinhold K., 2010);
- no continuous system of employee training (Tint P, Paas O, Reinhold K., 2010);
- too little awareness among the employees of the importance of health and safety rules (Chaib R., Verzea I., Benidir M., Taleb M., 2012);
- human errors (Ali H., Abdullah N.A.C, Subramaniam C., 2009; Goetsch D.L.,2002);
- improper management practices in terms of safety at work (Ali H., Abdullah N.A.C, Subramaniam C., 2009);
- insufficient level of operating machines and tools (Ali H., Abdullah N.A.C, Subramaniam C., 2009; Vredenburgh A.G., 2002);
- technological system failures (Ali H., Abdullah N.A.C, Subramaniam C., 2009; Vredenburgh A.G., 2002);
- safety culture in the enterprise (Ali H., Abdullah N.A.C, Subramaniam C., 2009; Beckmerhagen I.A., Berg H.P, Karapetrovic S.V, Willborn W.O., 2003).

There is no obligation in the Polish law to record so called near miss accidents, which could lead to injury if some circumstances appeared. However, more and more companies are trying to report those kinds of incidents according to the proverb, 'prevention is better than cure'. That is why the managers should be aware that 'the lowest standards, which a boss tolerates become the highest standards of your employees' (Marchel M., 2014, p.69). Due to the restructuring of companies, which is widespread in a market economy, there have been created system solutions that support the company's management (Dahlhe G, 2013, p.13). However, it requires to be constantly improved according to the PDCA cycle. In order to create an effective prevention system, the analysis of collected literature and the three-months-research were conducted. The aim of the research was to analyse and evaluate the actions taken in the area of accident prevention, taking into account near miss cases (NMC) as well as unsafe acts/conditions (UA/UC) and to develop the concept of interpersonal and group communication, which activates employees to join the scheme in preventing potential accidents. The overall objective of Health and Safety Management system is to determine methods of collecting and transferring information about working conditions in order to avoid the costs (remuneration for the time not worked due to employee absences, production downtime, damage of machinery, equipment and products and the cost of health care and recovery (Dahlke G., 2013, p.13).

2. MATERIALS AND METHOD

There has been put forward a hypothesis that top managers have a huge impact on the engagement of their subordinates in accident prevention. The research sample accounts for 106 factory workers. While designing the system, there was gathered an accidents analysis in a corporate factory within four years. It concerned: the most common ways of reporting NMC and UA/UC as well as the reasons of accidents. Then, the presented juxtaposition (Table 1) shows significant differences between the analysis of traditional accidents causes, shown by OSHA (Occupational Safety&Health Administration), which was also used in the factory, and the MORT method (Management Oversight Risk Tree) which focuses not only on blue-collar workers mistakes but also on the negligence of management personnel (Karczewski J., Karczewska K., 2000).

Table 1 – The comparision of OSHA and the MORT accident causes analysis.

OSHA METHOD	MORT METHOD
Dangerous workers behaviour 85%	Top managers failure 12.8%
	Safety inspectors failure 15.6%
	Technical services failure 18.4%
Unsafe working conditions 15%	Supervisor failure 24.7%
	Dangerous workers behaviours 14.8%
	Unsafe working conditions 13.7%

Source: based on: Karczewski J., Karczewska K., Systemy zarządzania bezpieczeństwem pracy, 2000

The project is based on the MORT accident analysis method in which a simple division of accidents' causes were divided into the above mentioned elements. The number of dangerous behaviours decreased from 85% to 14.8% and also there is a small drop in the unsafe working conditions cause – from 15% to 13.7%. Furthermore, also the current situation was examined. Using a questionnaire containing 4 questions, 102 employees had an opportunity to anonymously express whether they understand 'the near miss accidents' statement, if they report them and if not, what the reasons are and what disturbs them in safe working. This tool recognized whether the terminology and rules of the procedure for reporting such incidents as NMC/UA/UC are familiar to the workers or not. The next method was the Method for Industrial Safety and Health Activity Assessment (MISHA). Both part B1 and B2 were selected to check the co-participation and communication in the factory from different organizational levels perspective. The tool assumes that the audits must be conducted by the staff at various levels of the organization: CEO, top management, middle management supervisors as well as blue-collar workers (Kussito A., 2000, p.138). The last method used during the research was interviews defined as a form of casual exchange of opinions between an interviewer and respondents. The problem of fear report NMC/UA/UC was raised as well. Since the interviews were led by an external specialist, the received feedback is assumed to be highly relevant and sincere.

3. RESULTS

Despite the fact that a number of reports concerning disturbances at workplace has aroused, it is still an undesirable quantity of records. For the company, it is important to expand knowledge about causes of those kinds of accidents in order to constantly develop the system and prevent the effects of accidents. The table below presents quantity of different kinds of accident within 5 years.

Table 2 – The summary of accidents reports. Source: Company research.

	2009	2010	2011	2012	2013
Accidents	19	14	10	12	20
Near mis	3	7	2	8	24
Unsafe behavior/ conditions	1002	801	3051	1374	1634

Till this moment all employees have had an opportunity to inform about aroused occurrences as shown in the table below.

Table 3 – The ways of reporting. Source: Company research.

Means of reporting	Year					TOTAL
	2009	2010	2011	2012	2013	
Mailbox	80	38	16	1	4889	5024
Phone call	4	4	6	4	2	18
Personal contact	39	38	51	26	20	174
E-mail	11	8	11	13	6	49
TOTAL	134	88	84	44	4917	5267

The significant growth of records in 2013 was due to the campaign which engaged all employees to report NMC, UA/UC. In the remaining years the number of records is unsatisfactory.

The chart presented below recognizes the reasons of accidents according to the general method (Figure 1).

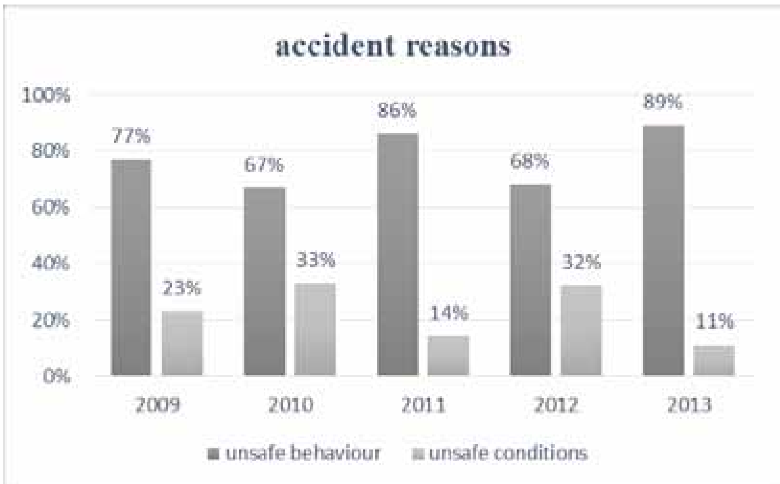

Figure 1 – General reasons of accidents. Source: Own research.

The research proved that, according to the general method, the major reasons for accidents result from unsafe behaviours of employees. As it was written in the previous part, it does not take into consideration indirect causes which, when accumulated, lead to injuries while working. Then, obviously the worker is the one who fails. For this reason the system is based on the MORT method (Table 1). The results from another analysis – questionnaire are depicted in Figure 2.

1. What do you understand by 'near miss accident'?
2. Do you know how 'near miss accidents' are marked in your factory?
3. Do you report it? If not, please write why.
4. What disturbs you in safe working?

Figure 2 – The questionnaire results – safety awareness in the factory. Source: Own research.

1. Approximately 12% of the respondents do not know what the "near miss accident" is.
2. Most of the workers are not informed how "near miss accidents" are marked on information boards on the factory premises.
3. Most of the workers do not report NMC.
4. Most of the workers complain about working conditions and inconveniences.

Following a more thorough analysis of the problem, more detailed results of point 3 and 4 are presented below.

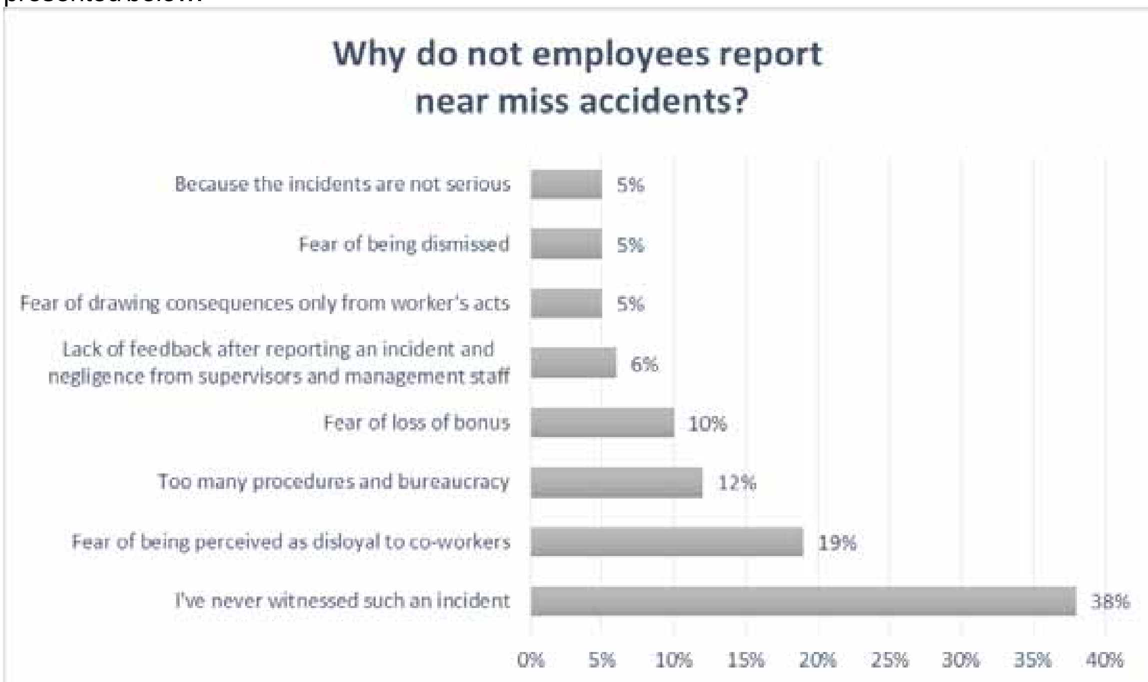

Figure 3 – Reasons of reporting negligence. Source: Own research.

The fact that most workers declared that they had never witnessed near miss accidents circumstances can indicate a slightly dismissive attitude towards safety. The other essential reasons are: anxiety about being an unfriendly snitch –the opinion of co-workers values, too much bureaucracy connected with reporting as well as fear of loss of bonuses. These reasons are result from misinformed employees on how their feedback will be used. Not only do they not receive any responds from their supervisors after reporting, but also they are worried about drawing the consequences solely on their behavioural basis – fear of being made the only person responsible for near miss accidents without considering intermediate causes. The added value of the questionnaire is the feedback from point 4 which covers disturbing aspects during work (Figure 4).

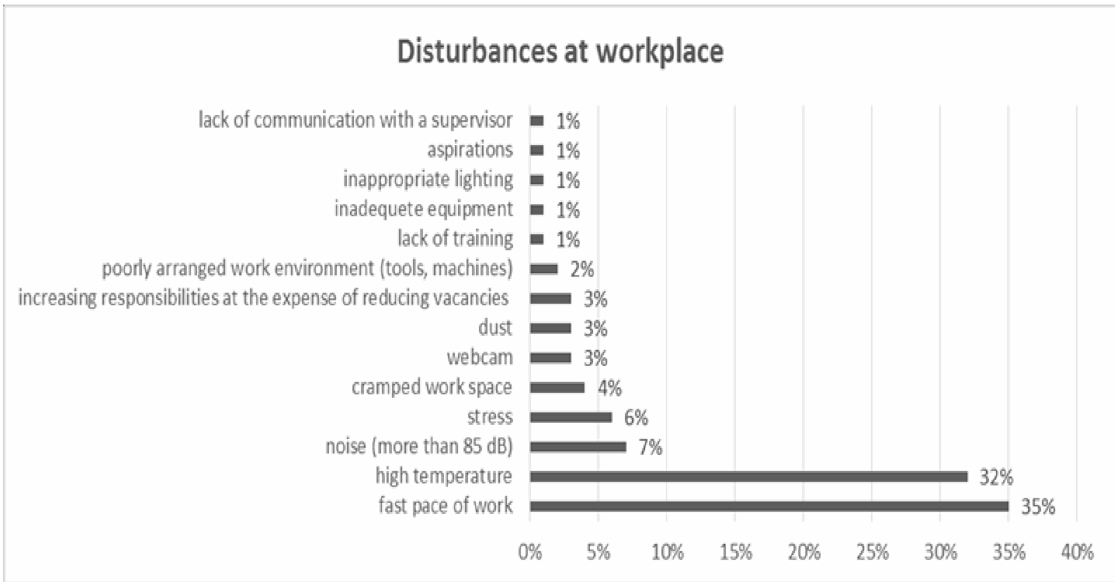

Figure 4 – Factors causing disturbances at workplace. Source: Own research.

The fast pace of work which is connected with deadlines of contracts, high temperature and noise as well as stress are at the top when it comes to the disturbances during work. These aspects can contribute to near miss or injury accidents.
The subsequent tool analysis – the MISHA, in which the Manager of Health and Safety Department, the Manager of Production Line as well as blue-collar workers answered the following questions concerning: communication between worker-supervisor, development in teamwork, main communication procedures, information about shifts, suggestions for the development of actions and safety campaigns. The results reveal that the perception of the collaboration and communication between workers from different organizational levels vary considerably.

Table 4 – MISHA results. Source: Own research.

	Health and Safety Department Manager	Production Line Manager	Blue-collar workers
Evaluation	69%	52%	67%

In Table 4 the evaluation of the effectiveness of participation and communication in the enterprise was calculated by the formula given in the MISHA method. It is worth mentioning that, for the purpose of the project, only a part of the MISHA questionnaire was examined (part B1 and B2). The other parts are not closely related to the subject of the study. The results show that unlike to the Health and Safety Manager, The Production Line Manager feels communication relations between other workers to the least extent. Among the respondents only H&S Manager does not see a need to improve the way of immediate response to proposals for improvement which come from workers. It indicates that Health&Safety Department can be unaware of their lack of feedback to workers who previously reported appeared disturbances.
Last but not least there come the interviews. The interviewees often admitted that they do not report NMC, UA/UC because they do not receive any feedback. They feel neglected and tired of the reporting procedure which requires signatures which later can be used against them. The answers cover the questionnaire results.

4. DISCUSSION ABOUT THE CONCEPT

Shaping the workers behaviour in potentially accidental events, prevention area can be defined as building approach in the organization towards Health and Life of the employees. This approach to Health&Life and the environment can be understood as: ‘A collection of psychological, social and organizational factors and other triggers which support measures to protect the health of both life and work, as well as activities aside from profession’ defined as safety culture (Studenski R., 2000, p.1). It is a part of the organizational culture, defined as :’any system of values and norms of behaviour, which are the part of every organization. Organizational culture shows the way of thinking and proceeding of educated and approved employees’ (Wyrwicka M., Stasiuk A., Drzewiecka M., Masadyński M.,2011, p.176).

The presented above research facilitated the development of a concept of communication system which can activate workers to prevent from unwished events. There are several ways of shaping it. The system is based on following concepts: ‘4A’ and ‘7P’(Karczewski T.,W., pp.358-268).

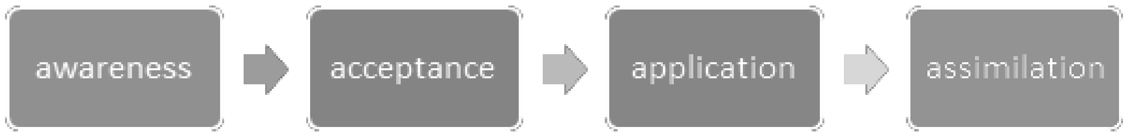

Figure 5 – ‘4A’ concept. Source: based on Karczewski T.,W.,2012, pp.358-268

Every stage of the system must be well prepared by the company. Concept ‘4A’ distinguishes the most important elements affecting the success of the implementation (Figure 5). Since the effectiveness of the measures will depend on the employees, it is necessary to build their acceptance in order to awake the sense of procedures in them. Firstly, we need to refer to the knowledge which is the base of *Awareness.* The next step is kind of a struggle to convince workers that reporting NMC is profitable. There are two common reasons: one is profits for workers concerning their health and life protection, and the other are profits for the factory, such as avoiding the cost of post-accident issues, for instance, compensation, repairs of machines, production standstills. The third ‘A’ stands for *Application.* The workers slowly start to report but they need the encouragement. At this stage of the system workers tend to forget about the importance of reporting NMC, so the involvement of top managers is essential. They should support, encourage and be role models for their subordinates. The last step is *Assimilation*. Since good habits do not immediately become a permanent part of the system, we need to ‘take care of them’ and constantly develop the prevention system. It is comparable to a flower that withers without watering (Karczewski T.,W., pp.358-268). It is a long process, so the benefits and financial effects may occur after some time.

The process of building safety awareness should be discussed in four dimensions (Berkowska A., Drzewiecka M., Mrugalska B., 2014, p. 23):

- self-knowledge on health and safety conditions. It should be shaped, for example, by trainings,
- the obedience of safety at work regulations – it is crucial to persuade workers that the responsibility for safe working environment belongs not only to the employer or Health&Safety inspectors but also to themselves. Pursuant to the regulations, it is the employer who bears the responsibility for safety at work, however, all the people working in a given organization should be alert and obey safety rules at work,
- the perception of how health and safety at work regulations are interpreted- whether both employers and employees are aware of technical and organizational aspects and their impact on health and safety at work,
- attention – understood as due to diligence, taking special care of healthy and safe working conditions. The concept of building the awareness of health and safety at work is presented in Figure 6.

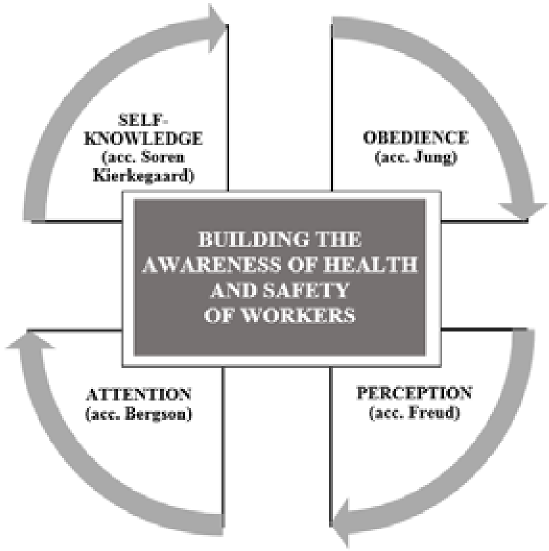

Figure 6 - The concept of building the awareness of health and safety at work. Source: Own work based on Berkowska A., Drzewiecka M., Mrugalska B., 2014, p. 24; Gajdzik B., 2009

A similar approach can be seen in the concept ‘7P’ (Table ' 7P '). The development of desired safety habits requires time. Firstly, it is extremely important to build the sense of safety awareness among the workers. Only then it is possible to gain the approval of the project and its accomplishment. ‘7P’ concept covers (Karczewski T.,W.,2012,p.235):

Table 5 – ‘7P’ concept. Source: based on Karczewski T.,W., 2012, p. 235

No.	Explanation
1.	The workers conviction of safety awareness (promotion campaign)
2.	A simple form + reporting procedure
3.	A positive first reaction of the supervisors
4.	Thanks and feedback
5.	Professional analysis of the causes of unwished occurrence
6.	Appropriate implementation of effective preventive and corrective measures
7.	Positive reinforcement – visualization of success and achievement of the system

This concept is based on the development of collecting and transforming the information about NMC.

As a result, a trainee program was prepared, for so called, ‘Safety Minutes’ which are practiced in most of corporation factories. Those are single issue meetings between production leaders and their subordinates. Each of the meeting aims to develop safety concerns in the workplace and build up safety awareness by discussing safety management best- practices (the ways how to perform in order to reduce the probability of unwished occurrences by maintaining the principles of quality and ergonomics). According to the feedback from workers (Figure 2) the employees do not know what the differences between injury accident and ‘near misses’ or unsafe conditions/acts are. So, in order to familiarize them with the topic, all workers were trained. The leaders are the ones liable for leading ‘Safety Moments’ and enhancing the consciousness of blue-collar workers. However, it should be doubtless that the person leading the training thoroughly understands the subject under discussion. For that reason, firstly the training material should be presented to the leaders and top-level managers by the external couch or Health&Safety inspector. An independent tutor often is more respected and listened to than a full-time employee, who is working close to the shop floor on a daily basis. Once, the leaders understand all issues they are able to train their subordinates. The training material consists of two parts: theoretical and practical. The theoretical part incorporates the analysis of accidents in accordance with the Heinrich’s pyramid, then ‘Safety Minutes’ participants analyse together three examples: the accident, the NMC and the UA/UC. The practical part is based on a team work. It is conducted in form of a test. Therefore employees work together on solving task which is not supposed to be a form of test – a stressful factor. Working in groups encourages brainstorming, integration and help to remember issues under discussion. After 15 minutes of teamwork, there is an open discussion and clarification of any doubts. Understanding those terms enable them to notice incidents while working and report them afterwards. Moreover, the health and safety aspects cannot be a taboo. Safety topics should resonate through the factory's premises by posters, campaigns etc. The workers need to be accustomed with safety culture.

The next step of the project is reporting unwished events by specially prepared cards. In blank spaces the workers can mark: date, time, place, brief description and presumable reasons of an occurrence. There is also some space for signature which is not obligatory at the beginning of the system since the workers need to be convinced by the company that only the information about an occurrence, not to whom it happened, is essential. People, who show evident courage by signing the card will be praised by their supervisor. Thanks to that, workers are appreciated and feel satisfaction.

After that, the project focuses on noticing admirable behaviour and rewarding workers. Appreciation is one of the most important motivation factor. People tend to see whenever something is done badly in order to: notice and perpetuate favourable actions. Any actions taken by the supervisors, which consists of praising their subordinates for a safe way of working helps creating safety work culture. It can involve: a constant safety way of working without admonishment, preventive actions like: reproving co-workers for unsafe actions, reporting any inconveniences and others.

Finally, after each record of NMC, UA/UC the feedback given to the workers ought to be created since communication is not a one-sided process. Each record requires an analysis by a Health&Safety Inspector, Line Manager and others to whom the matter concerns. The presentation of the records' results on a notice board indicates that the company cares about the workers and the development of a safe work environment. When the employees are informed about their records and see consequently that preventive and corrective measures are implemented, they become aware of the importance of their actions.

Last but not least - the impact of words on behaviour should be discussed. The communication process can be considered effective if the recipient can interpret a message as intended by the sender. Not only do environmental conditions, or, means of delivering messages influence an effective interpretation of the message but also the way how the words are uttered. The same sentence can be pronounced in different ways and can create numerous different attitudes and behaviour. The table below presents some positive and negative impacts of communication (Urban H.).

Table 6 – Positive and negative organizational communication.

No.	Ways of communication	
	+	-
1.	Expressing gratitude and rewarding for safe working	Treating workers contemptuously
2.	Asking about suggestions, prospects, opinion	Ignoring
3.	Specifying managers' expectations towards workers	Permanent complaining about the work, behavior of subordinates
4.	Showing interest, offering help	Speaking with higher tone of voice
5.	Calling by the first name	Using obscene, rude language
6.	Encouraging, trusting	Gossiping and threats
7.	Short, constructive criticism in private	Sharp criticism among workmates.

Source: Based on Urban H., Słowa mają moc, pp.171-172

Irrespective of the position held, the workers have the same needs; to be respected and experience gratitude. The way managers communicate with their subordinates affects working atmosphere.

The company which has already implemented the project also has changed the name of 'near miss accident' as the word 'accident' has a negative connotation (search of the guilty, after accident investigations, questioning). It suggests that something unwished will happen. The word does not reflect the essence of the problem which is searching for causes, not the guilty. The investigation needs to be focused on human mistakes which are natural – not workers' fault. Commonly known organizations changed the name from 'near miss accident' to 'incident', 'safety defect', 'improve proposal' and others.

5. CONCLUSIONS

There are many factors which determine a company's ability to work with safety culture and thus implement an effective strategy. It is a multistage process which requires time as attitude of the workers concerning inclination to any preventive activities has been shaped by their past experience as well as previous and current work environment. Therefore, presented study and tools should be considered while creating safety management concept. It contributes to ultimately sustainable working atmosphere in the long term. However, it should be stressed that the key to success is the awareness. More emphasis should be placed on safety training methods and internal communication. A gradual increase of engaged workers may also convince other workmates to preventive participation. Good habits do not immediately become a permanent part of the system. The top-managers play an important role. Their passive attitude leads to preservation of bad habits as lack of reaction is equal to perpetuation of hazardous behaviour. The reinforcement of the system requires approval of performing safe work, and in case of risky behaviour, constructive but unpretentious dialogue between leaders and their subordinates should be carried out. The system also focuses on changing the attitude of workers. They should have a positive attitude to safety issues, not treat them as chores.

6. ACKNOWLEDGMENTS

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7. REFERENCES

Ali, H., Abdullah, N.A.C, Subramaniam, C. (2009), *Management practice in safety culture and its influence on workplace injury: An industrial study in Malaysia.* "Disaster Prevention and Management", Volume 18, Issue 5; pp. 470-477. Beckmerhagen, I.A., Berg, H.P, Karapetrovic, S.V, Willborn, W.O. (2003), *Integration of management systems: focus on safety in the nuclear industry.* "International Journal of Quality & Reliability Management", Volume 20; pp. 210-228.

Berkowska, A., Drzewiecka, M., Mrugalska, B. (2014), *Świadomość pracodawców o istocie bezpieczeństwa pracy a poziom wypadków przy pracy w małych i średnich przedsiębiorstwach*, [in:] Zeszyty Naukowe Politechniki Śląskiej, Seria: Organizacja i Zarządzanie, nr 71/2014, pp. 21-31.

Chaib, R., Verzea, I., Benidir, M., Taleb, M. (2012), *Promoting a culture of health and safety at work: Safety - A permanent priority,* [in:] WIT Transactions on Information and Communication Technologies, Volume 44; 2012, pp. 405-413

Dahlke, G. (2013), *Zarządzanie bezpieczeństwem pracy i higieną pracy*, Politechnika Poznańska.

Gajdzik, B. (2009), *Kształtowanie świadomości pracowników w systemach zarządzania bezpieczeństwem i higieną pracy na przykładzie przedsiębiorstwa hutniczego,* [in:] Zarządzanie Przedsiębiorstwem, PTZP, Nr 1, pp. 13 – 20.

Goetsch, D.L. (2002), *Occupational Safety and Health for Technologist.* "Engineers and Managers", 4th ed. Prentice- Hall, Upper Saddle River, NJ.

Karczewski, J., Karczewska, K., *System zarządzania bezpieczeństwem pracy*, Wydawnictwo Ośrodka Doradztwa i Doskonalenia Kadr, Gdańsk, 2000.

Kennedy, R., Kirwan, B., *Development of a Hazard and Operability-Based Method for Indentification Safety Management Vulnerabilities in High Risk Systems*, Safety Science, no 30, s. 249-274.

Kussito, A. (2000), *Safety management systems. Audit tools and reliability of auditing*, Technical Resarch Centre of Finland, ESPOO.

Malinowska, A. (2004), *Rola kultury i jej znaczenie w środowisku pracowniczym*, in: *Kultura organizacyjna w teorii i praktyce*, Materiały na Ogólnopolską Sesję Studenckich Kół NAukowych, Leszno, pp. 55-65.

Marcinkowski, J.S. (2011), *Podstawy Bezpieczeństwa Pracy*, Wyd. Politechniki Poznańskiej, Poznań.

Marchel, M. (2014), *Komunikacja w systemach bezpieczeństwa*, [in:], Promotor BHP 4/14, Wyd. Elamed, Katowice. Nogalski, B. (1998), *Kultura organizacyjna, Duch organizacji*, TNOiK, Bydgoszcz.

OHSAS 18001:2007 *Occupational health and safety management systems – Requirements.*

PN-N-18001:2004 *Systemy zarządzania bezpieczeństwem i higieną pracy. Wymagania*. Rocznik statystyczny przemysłu 2013. GUS.

Stasiuk-Piekarska, A., Drzewiecka, M., Dahlke, G. (2014), *Influence of Macroergonomic Factors on Production Systems Organizing in Automotive Industry*, [in:] Advances in Social and Organizational Factors, Vink P. (eds.), Published by AHFE Conference © 2014, pp. 194-205.

Stasiuk-Piekarska, A., Drzewiecka, M., Dahlke, G. (2014), *Metoda sieciowa w analizie bezpieczeństwa technicznego*, [in:] Logistyka 5/2014, pp. 1445-1458.

Studenski, R. (2000), *Kultura bezpieczeństwa i higieny pracy i jej kształtowanie w procesie zarządzania*, [in:] Materiały II Krajowej konferencji: Zarządzanie bezpieczeństwem i higieną pracy w przedsiębiorstwie, Wyd. CIOP, Kielce, 3- 4 listopad,1999, pp. 43-61; Kultura bezpieczeństwa pracy w przedsiębiorstwie, Bezpieczeństwo pracy, 2000, 9, pp.43-59).

Tint, P., Paas, O., Reinhold, K. (2010), *Cost-effectiveness of safety measures in enterprises*, [in:] Engineering Economics. Volume 21, Issue 5, pp. 485-492.

Urban, H. (2007), *Moc pozytywnych słów*, Studio EMKA, Warszawa.

Wiernek, B., (2000), *Kultura organizacyjna przedsiębiorstwa*, Oficyna Wydawnicza TEXT, Kraków

Wyrwicka, M., Stasiuk, A., Drzewiecka, M., Masadyńsk,i M., (2011), *Organizational culture diagnosis as an element of supporting organizational change management*, [in:] Knowledge management and organizational culture of global organization, Grzybowska K., Wyrwicka M.K.(eds.), Publishing House of Poznan University of Technology, Poznań, pp. 175-192.

The current experience and training of Romanian Occupational Health and Safety (OHS) professionals

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Abstract
The study it`s a research about history of health and safety legislation in Romania, about European tools, empowerment procedures, organisations and association in the field.
It`s an overview about European tools to allow people free movements all around European Union (EU). The study presents tools which identifies the fundamental skills, the most important abilities and knowledge that people would need to be recognised, in order to allow free movements all around European employment market. The study is about possibilities to be voluntary recognised as a health and safety professionals across EU and why not, around the world. It`s a brief list of ways of transfer and recognition of learning experiences in Europe, including vocational education and training, for a better understanding of qualifications from different EU countries.
The research presents ENSHPO (The European Network of Safety & Health Professional Organisations) and EUSAFE (European project) voluntary certification procedures for occupational health and safety professionals (OHS) and where the Romanian practitioners are placed, if their qualifications could be recognised through Europe.
The research presents the necessary characteristics for a well developed profession, as mentioned by Ferguson and Ramsay (2010) and also presents IOSH, the most valuable health and safety professional association and the necessary steps for Romanian OHS practitioners to build such a strong association. IOSH it`s the model of a profession and Romanian practitioners could learn to become Charted Members.
The European Union single market - as well as the increasing number of companies operating across Europe that are applying a consistent set of safety and health standards to their work sites - has created a great need for safety and health managers with credentials that are recognised at a Pan-European level. The absence of a harmonised, agreed system for the mutual recognition of safety & health qualifications at a European level creates uncertainty about professional competence across countries within Europe and may create problems for multinational companies in the effective use of their safety and health expertise. It also forms a barrier for safety and health professionals wishing to offer their services across the EU.
Knowing the level of training is necessary to determine the training needs of OHS practitioners, now that Romania has joined the EU in order to allow free movement of the work force. Knowing where to start and what needs to be improved, will allow the Romanian practitioners to be just as good and compete with their European colleagues. The study will show which of the Romanian empowerment procedures was better, with or without examinations, and whether practitioners were more prepared than these days.
The research is part of a study that aims to thoroughly analyze the transformation in the Occupational Health and Safety (OHS) field in Romania following the major political, economic, social and cultural transformations that are necessary in the context of Romania`s accession to the European Union. The research evaluates the current experience and training needs of Romanian OHS professionals. A review of the changes in the legislation and qualification requirements in Romania will be presented and placed into the context of European legislation and standards.

Keywords: health and safety; OHS practitioners, qualifications, OHS competence, training.

1. INTRODUCTION
In the past 25 years, Romania has gone through major political, economic, social and cultural transformations, all necessary in the context of Romania`s accession to the European Union (2007). The admittance in the EU, the alignment of national legislation and OHS standardization across Europe, forces the profession to reach faster the European requirements for quality and competence; the question that arises and the project want to find out is: are the Romanian OHS professionals prepared?
This research it`s a small part from a bigger study whose aims is to thoroughly analyze the transformation in health and safety field and present the current experience and training needs of Romanian OHS professionals, to help professionals to obtain answers about their daily

practices, that are best answered through systematic investigation, or the research process` (DePoy and Gitlin,1994). The purpose of the research is to understand the meanings, experiences of Romanian professionals through a naturalistic design, where the scope is exploration, understanding and description (DePoy and Gitlin,1994). The study is being undertaken by an insider, herself a practitioner, and therefore gains insights from experience but may be influenced by personal perception.

OHS professional is a relatively new profession in Romania, dating from 1998 and having many changes since then. Ferguson and Ramsay (2010) reviewed the characteristics of a well developed profession and this research will evaluate training and career development, will discuss future steps that may be necessary.

The objectives of the study include:

1.To review the ways of becoming an OHS professional, through literature highlighting the legislative requirements and competences with the EUSAFE Project (2010-2012).

2.To evaluate the perception of Romanian OHS practitioners about the quality of their training and preference for delivering of future training (survey)

3.To estimate the demand for development of a professional code of ethics for Romanian OHS professionals and to identify potential barriers (survey)

4.To evaluate colleagues` professional experience and training level, in order to establish the current training needs of the Romanian OHS professionals.

The project could be interesting for the OHS professionals from Romania, as the world is changing and practitioners must prepare themselves for the new challenges. The opening of labour market towards Europe could bring European OHS professionals to the country and this might create great competition for our experienced safety officers. The research will be interesting, also, for European OHS professionals, as they could find out who they are competing against in Romania and what the level of local competition is.

2.1. MATERIALS

In the Romanian literature, there are no studies regarding the OHS professionals, their preparation level or the ways of becoming one; this is why the researcher used the legislative provisions and the mandatory steps needed to become an OHS professional as literature review. The researcher learnt from Robson (2011) and proved that a research project could have three possible purposes traditionally recognized: to explore the background of how someone could become an OHS services provider, to describe the necessary steps and to explain one`s development as a professional in the field. Due to lack of scientific evidence about this topic, the researcher could only hope that this project will be important for the development of OHS practitioners, considering that all research is concerned with contributing to knowledge (Robson, 2011).

2.1.1.History of health and safety legislation in Romania

The first evidence of activity related to labour protection in Romania can be considered to be the 1864 enactment of the Civil Code (inspired by Napoleon`s Code) which established the legal basis of the individual labour contract. Chronology of labour protection activities as presented on the website of the Ministry of Labour is:

1890 - Servants Act
1894 - Regulation of unsanitary industries
1902 - Trades Act
1905 - Law on Child and Women Labour
1907 - Trade Unions Act
1912 - The first law of insurance in case of illness, accidents
1920 - Establishment of the Ministry of Labour
1927 - Setting up of Labour Inspection
1932 - Establishment of work and pension contributions
1945 - Trade Unions Act
1946 - Law setting up the work day and work departments in court premises
1949 - Law on Disease pension
1954 - Introduction of the work groups
1965 - Labour Protection Act No.5 in force until 1996
1972 - Labour Code, Law No. 10 in force until 2003
1989 The Romanian Revolution
1996 - Law no.90 of labour protection (in force until 2006)

1998 - Order no.236 empowerment process of OSH specialists
2002 - Law no. 346 of insurance in case of accidents at work and occupational diseases
2002 - Order no. 251 changing the conditions regarding the empowerment of OHS specialists
2003 - Law no. 53 Labour Code (in force)
2004 - Order 167 changing the conditions regarding the empowerment of OHS specialists
2006 - Law no. 319 Occupational Health and Safety Act (in force) modified in 2010.
2007 - Romania joined the European Union

2.1.2. Steps for empowerment of OHS provider in Romania, a history of legislative requirements

The economic development of Romania has increased the attention given to work and everything related to the process. The history of health and safety is tightly connected to the qualification necessary to workers for facing the novelties brought over by the work technologies. The induction and training of employees was accompanied by the concern to provide decent work conditions and to enforce some measures to protect the components of the work system.

Order no.236/12.05.1998 established, for the first time, the OHS external services` provider empowerment and the requirements for OHS consultant. The mandatory conditions for the authorization to provide services in the field of OHS, are:

- (art. no 4) 5 years of experience in the field for those with university degrees, or 15 years for those with pre university qualifications; for the members of Labour of Ministry or local inspectorate, 4 years of experience are enough;
- (art. no.6 point d) Technical university degrees and post university degrees with a duration of at least 6 weeks in the work protection field;

The subscription folder should contain (according to art.no.6): the mandatory request form, Curriculum Vitae, diplomas and certificates from the work protection courses, the proof for the years of experience in the work protection field and also in the economical domain of activity, for the empowerment authorization request (art.no.16 point d).

The authorization procedure (art.no.9) included presenting a file with all the documents, passing a written exam and interview with representatives of the Labour Ministry. The validity of the certificate so obtained, was of 3 years (art.no.11); for renewing the certificate, a new examination was done after 3 years, with the specification that continuous professional development courses (CPD) had to be attended in the meantime.

Order no. 251/01.07.2002 followed; it reduced the years of experience from 15 to 10 (art.no.14), for those with pre university qualifications and increased post university courses (art.no.4) from 6 to 8 weeks.

Order no. 167/16.04.2004 added new conditions, such as a recommendation from the Local Labour Inspectorate (art.no.24 point b), with mandatory examination by members of Labour Ministry or local Inspectorates (art.no.24 point b).

Law no.319/26.07.2006 and the Government Decision no.1425/30.10.2006, changed matters in the field. The procedure was changed, the authorization (art.no.36) being made only after the analysis of a candidate`s file by a board of professionals from the local Inspectorate. Other changes were made: the name was modified from work protection, to external services for occupational health and safety (art.no.28) and also the minimum requirements for the employees and the leader of this external services (art.no.32 (1) and (2)). The empowerment was made now for a minimum of 5 years' experience, without the mandatory requirement of having experience in any economical field of activity (art.no.37 point e); also, a declaration of confidentiality became mandatory (art.no.37 point i). Art.no.45 also stipulated a year for re authorization of all those empowered by the former legislation (Law no.90/1996), following to be done by a board of professionals from the local Inspectorate, named by Order no.754/16.10.2006. The validity of the certificate so obtained was of 3 years (art.no.41) – followed by a new examination of submitted files by the local inspectorate (art.no.36); also, health and safety courses needed to be attended (art.no.42) in those 3 years.

Two levels of training were introduced (art.51):

- OHS technician (art.no.48) – with technical high school degree and health and safety courses of at least 80 hours;
- OHS expert (art.no.50)– with an engineering degree, health and safety courses of at least 80 hours and also post graduate courses of 180 hours;

The modifications brought by Government`s Decision no.955/2010 had the purpose of harmonizing the Romanian Legislation with the European Directive 2005/36/EC, in order to

allow the free movement of OHS professionals within the European Union, Romania being a member since 2007. These modifications (art no.45 (1), 45 (2), 45(3), said that any OHS professionals authorized in a similar way in any of the EU member states could practise in Romania, just by notifying the Empowerment Commission.
For empowerment, there was no longer the requirement to prove experience in some economical area of activity (art.no.37point.g), but 5 years' experience in the field of health and safety, to become the leader of the external service; the conditions referring to mandatory CPD (art.no.42) courses and the limited validity of the certificates (art.no.41) were dropped. All these changes brought a large number of new OHS practitioners on the market.
For those OHS professionals authorized in a similar way in their own countries, there is a possibility of them practicing in Romania, if they were authorized in the same conditions as the local practitioners (art no 45(2)). These empowerment conditions require the submission of a file with the evidence papers to The Empowerment Commission from the local Labour Inspectorate (named by Order no. 455/14.06.2010), without any examination.
The research is also a history of health and safety legislation in Romania, about European tools, empowerment procedures, organisations and association in the field. It`s an overview about European tools to allow people free movements all around European Union (EU). The study presents tools which identifies the fundamental skills, the most important abilities and knowledge that people would need to be recognised, in order to allow free movements all around European employment market. The study is about possibilities to be voluntary recognised as a health and safety professionals across EU and why not, around the world. It`s a brief list of ways of transfer and recognition of learning experiences in Europe, including vocational education and training, for a better understanding of qualifications from different EU countries.
The research presents ENSHPO and EUSAFE voluntary certification procedures for occupational health and safety professionals (OHS) and where the Romanian practitioners are placed, if their qualifications could be recognised through Europe.
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2.2. METHODS

Questionnaires have been chosen for the research since it is important to be objective, while reflecting the values, perceptions and interests of the respondent (Gray, 2004). Questionnaires, by their very nature, can start to impose a structure on the answers and shape the nature of responses in a way that reflects the researcher`s thinking, rather than the respondent`s (Denscombe,2003); in order to avoid this limitation, the researcher used open questions for giving her colleagues enough freedom to express themselves. It is quite difficult to develop questionnaires that are valid, reliable and objective. Validity means that an instrument must measure what was intended to measure (Gray, 2004:219), in this research, the current experience and training needs of Romanian OHS practitioners. The research has to be very precise if the study wants to prove its external validity – the extent to which findings from a study can be generalised, as Gray (2004) suggests.
A number of key attributes of a good questionnaire (Denscombe,2003) were incorporated into the design in order to ensure that:
•Privacy was assured in this case the respondents` names are known only by the researcher; every questionnaire is identified by a number.
•The respondent will have some knowledge on the topic - the respondents are participants because they have an active role – they are OHS professionals.
•The proposed style of questions is suited to the target group – the target group consisted of OHS practitioners, members of ARSSM (Romanian Health and Safety Association).
The participants have to answer 18 questions about their age, gender, years of experience in OHS domain, education and training, the year of their authorization by Labour Ministry as OHS practitioners, training needs, voluntary empowerment procedures, their opinion about code of ethics, ways of granting CPD. Ethical dilemmas around access, who and how are accessed, the fact that researcher must continually reflect around the data collected (Miller and Bell, 2002) and about their representativeness for OHS professionals, was resolved by working with and for a professional association. ARSSM`s voluntary members understood the necessity of the study

and they freely agreed to participate by signing the consent form and filling in the questionnaires.
Other reasons for choosing questionnaires in this study, because they are economical, low cost in terms of materials, money and time; they supply standardized answers, all respondents are asked exactly the same questions; they have a wide coverage; they contain pre-coded data and they eliminate the effect of personal interaction with the researcher (Denscombe, 2003). For this particular research, it was relatively easy to contact and arrange the participation of the respondents, because the questionnaires were filled in during the general meeting of ARSSM and the researcher had the opportunity to explain to the participants why the study was of high importance and all the steps for being part of the survey.
Some disadvantages of using the questionnaires were anticipated at the designing stage. The questions were limited in length to four or six pages, to avoid the return rate being adversely affected or respondents give flippant, inaccurate or misleading answers (Gray, 2004). Another important potential limitation is the fact that attention is focused on topic that the researcher considers meaningful or important. The respondent has no freedom to negotiate the relevance of the attribution with the researcher (Cassel and Symon, 2004). Incorporation of open questions gave them the opportunity to express their own ideas about the topics.

3. RESULTS AND DISCUSSION

The results of the research depict an image of Romanian OHS practitioners with their education and experience, wishes for improving the personal skills, outlining the portrait of a profession. The participant practitioners represent just a small part of all the OHS practitioners in the country out of a total of three thousands (Inspectia Muncii, HSE, 2014) but they are representative for Romania, being members of a nationwide professional association, ARSSM. Being member of a professional body, represents one of the steps for becoming a true professional (Ferguson and Ramsay, 2010) as this experience brings together voluntary members from all important cities of the country for learning from each other and sharing knowledge. This is an achievement as they are likely to be more reflective and evaluative about their profession. On the other hand this may introduce some achievements in place, as discussed above.
The image of the Romanian OHS professionals can be seen in the results from the first nine questions. The age of the participants shows that the ones more interested in this research are of more than 50 years old (question no.1), a few of which are women (question no.2), with about 20 years of experience in health and safety (question no.3), many of them have a university degree (question no.4) and plenty of OHS courses (question no.5), a third of them are in this field before 1996 prior to Law no.90/1996 (question no.7), a third of them are full time OHS practitioners and more than a half have their own consultancy company (question no.6). Statistically 55,7% from Romanian population (Ziarul Gandul, The Thought Paper, 2013) are mature person (25-64 years) and this demographic result can be seen here as a sample of mature person having a profession. The high percentage is more than 50 years old category in this research, maybe as a result of empowerment conditions and necessary years of experience or maybe because of the lack of interest of young professionals about being member of a professional association like this.
Statistically in Romania there are 51,4% women, but as OHS participants in the research are 80% men, maybe OHS is seen as a male profession and is no likely to reflect the true gender balance of the wider population.
There are 12 people with 10-20 years of experience in the field and this experience could reflect their age group, around 30-50 years old (q. no.1b), 1c)) and 7 people with more than 20 years experience among that one with more than 50 years age (q.no.1d)).
Years worked in a regulatory body it`s a particular way of becoming OHS practitioners and reflect the situation of members of Local Inspectorates who didn`t have to have health and safety courses to became OHS practitioners; the legislation allowed the labour inspectors to be empowered as safety practitioners, without any exam, just through the submission of a file. There are 7 members of local inspectorates with more than 10 years experience in health and safety; one of them could be of the five empowered as OHS professionals before 1998, if we look at question no.7.
About participants education`s, there are 25 people university graduate because having one was mandatory for doing post university studies (courses) with a length of 180 hours in health and safety. Former members of local inspectorate were mandatory of having university studies for being an inspector, so all HSE practitioners have a high level of training.

All of the participants have lots of health and safety courses but which one was more useful for their training will be seen in the answers from questions no.10 and 11. Having such an experience in doing OHS courses will help the researcher to rate which ones are more useful for their training needs.
There are 8 participants with HSE master degree and one doctor. If extrapolated to the wider population of OHS practitioners, we can state that maybe, a third of them are highly educated. There are 25 from a total of 29 people university graduate because having one was mandatory for doing post university studies (courses) with a length of 180 hours in health and safety. Former members of local inspectorate were mandatory of having university studies for being an inspector, so all HSE practitioners have a high level of training. Seven of them graduate a second university and this is a good reason for stating they are educated.
The Romanian OHS professional is also interested in continual professional development (CPD) and question no.13 proved this interest. If we are looking ways of granting credits and utility of selected ways for CPD we can check question no.14. These results could be the starting point for organizing CPD for OHS professionals in a different way than just doing another course.
All the 27 participants who answered question no.14 agreed the granting credits system by participating to conferences and workshops, as a way of accumulating knowledge and credits simultaneously. We could allege that the wider population of OHS practitioners is interested and very happy about CPD, about learning from others through workshops and conferences.
It was a time when attending courses was mandatory for CPD, but these days practitioners proved they have other wishes for improving their skills, knowledge and expertise.
This represents a good way for ARSSM and other similar organisations for developing and growing the number of members or finding other people interested of becoming member of a professional association by organizing conferences, workshops and OHS meeting each others. There are a few comments who illustrate their position about this subject: `It's Romania's obligation as a EU member"; "They (EU) required so we can meet those special requirements of foreign employers", "Very useful because they permanently refresh the know-how with new methods in the area of activity".
The answers to question no.14 (figure no.1) looks at the various ways of training that could be delivered and asks participants to indicate the types of subject that they would like to attend. CPD could be achieved through inclusion in one or more of the options below and they indicated most important subject to study. These results shows that Romanian OHS practitioners are interested in CPD and have clear ideas about what would be needed for developing their knowledge and agreed granting credits for participation in conferences and workshops. There were given 14 tips of granting CPD and the participants are very clear about their wishes, the most voted (24 answers with 8 would attend and 15 certainly attend) was interactive workshops on a theme previously released before the meeting and discussed over several hours 14b). Some of them have even propositions about theme, like alternative method of risk assessment, organisation and ways of working of H&S internal services, collective protection for workplaces, quality of H&S providers. The participants are very interested about analysis of work accidents with (14i) human casualties and deceased (5 people would attend and 17 certainly attend), even if MOK trials are almost unknown in Romania. They consider this analysis a good opportunity in motivating staff to increase attention given to health and safety at work and they wish to learn new methods of determining the causes and consequences of work accidents. We can put here together the answers given to 14h) meetings with prosecutors or judges to present the steps of a process in criminal and/or civil practice related to work accidents (7 people would attend and 14 certainly attend) for proving their interest about the circuits of documents between involved organisations, tracking and social implications of a serious work accident. This result is a strong proof that people wants MOK trials even a few of them known that powerful organisations like IOSH (IOSH, 2014), organise such.
Meetings with experts to answer questions regarding law enforcement (9 people would attend and 12 certainly attend), the impact of legal regulations on health and safety, meetings with members of Executive Health and Safety all over the country have 23 answers.
Case studies to analyze legal requirements neglected 14e) is another new way of learning in Romania, but the participants shows their interest about with 8 "would attend" and 10 "certainly attend" and they have interest about employers liability in health and safety.

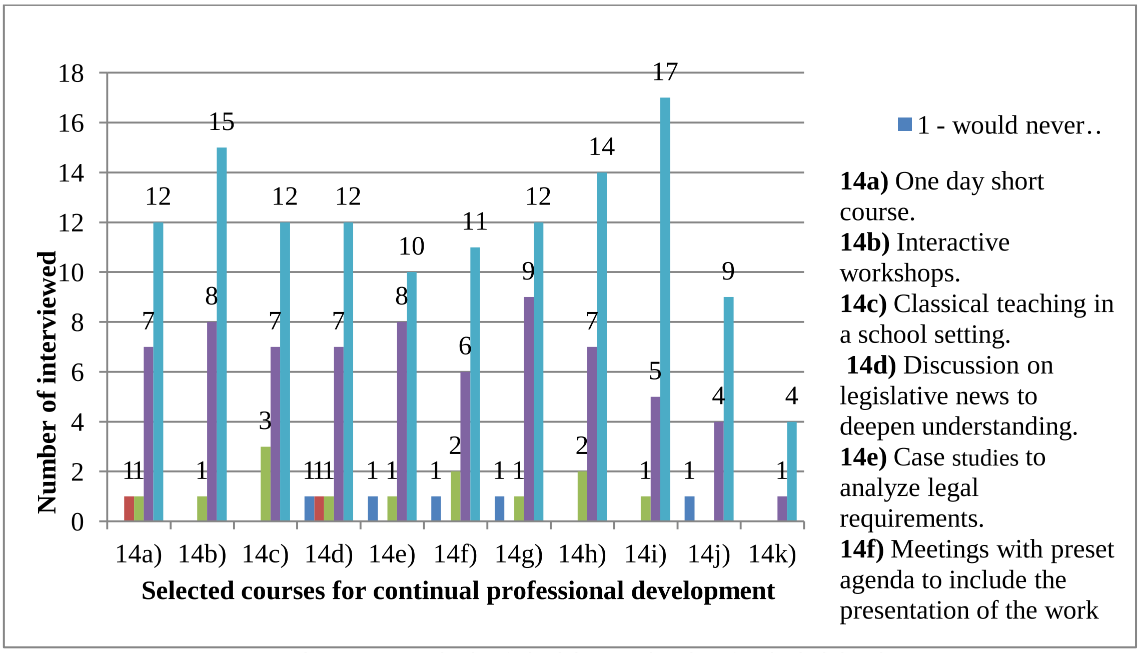

Figure no.1 Methods of obtaining continual professionbal development, CPD

4. CONCLUSIONS

The OHS profession was born in 1998, so it is a relatively new in Romania, therefore, so far, no studies have been made about the professional`s level of knowledge and their needs. As outlined above in the study if we discuss haw to become real professional practitioners, ready to fight with our competing peers from the EU, we need a lot of studies about what the current preparation level is, what their training needs are, if any certification is needed.

The participants are very interested in certification by an international organization like ENSHPO - knowing that ARSSM is an ENSHPO member and they agree with Ferguson and Ramsay (2010:28) that certification is viewed as credible evidence of skill and knowledge within a field of professional practice.

ENSHPO believes there is a need for a voluntary standard for Occupational Safety and Health Managers (EurOSHM), which is accepted throughout the European Union. The EurOSHM standard meets that requirement. Furthermore ENSHPO has developed a second standard to reflect the level of competence required for those with a health and safety role either reporting to managers or working in lower risk industries as Occupational Safety and Health Technicians (EurOSHT). ENSHPO decided to introduce these voluntary standards for EurOSHM and EurOSHT, together with a process for assessing and recognising both national certification systems for these two levels of qualification and national schemes to assess individuals against these ENSHPO criteria” (ENSHPO, 2013).

Minimum requirements and criteria for eligibility of individuals for EurOSHM are:

- a university degree at least at Bachelor level
- occupational safety and health training courses at a professional level, at least 250 study hours with a balanced coverage of the topics and with 150 hours examined
- professional work experience for at least two years full-time since the completion of the occupational safety and health training
- continuous professional development (CPD)

The candidate shall be a full member of an ENSHPO national professional organisation or association. Renewal of the certification at three yearly intervals. The ENSHPO Certification Standard is voluntary. The candidate, by submitting the application form agrees to ENSHPO Certification Standard provisions and unconditionally accepts its rules and procedures, the ENSHPO Code of Conduct and the resulting duties and obligations.

Among the necessary characteristics for a well developed profession, as mentioned by (Ferguson and Ramsay, (2010), should be:

- A valuable service to society and Code of Ethics, the study shows their work is about learning others working safely and the second one is now missing. The Romanian OHS practitioners are aware about the necessity of a voluntary code of ethics and they express very clearly their support for developing and implementing of such a code.

- a specialized body of skills and knowledge, the Romanian law requests health and safety courses, minimum years of experience, as seen in the empowerment procedure and all these can be the proof for their skills.
They also should have:
- Academic qualifications, the study shows that many of them have one or two university degrees not at least Bachelor degrees.
- CPD could be a challenge because it`s not mandatory at the moment and isn`t officially recognised as a way of learning. But all interviewed practitioners supported as a way of learning and agreed that is extremely useful.
I can`t yet declare the OHS practitioners` profession as being a well developed one in Romania, looking (only) at the results of this research. The future necessary steps are known, as it has been suggested by Ferguson and Ramsay (2010:6):
- The existence of an accrediting organization – could be ARSSM using ENSHPO or EUSAFE empowerment procedures. OHS practitioners were very interested about ENSHPO system of certification, they supported the idea of being recognised by an international organisation and many of them are fulfilling the requirements. The study shows that it is the proper time for this certification procedure, the practitioners desire such an empowerment procedure they have opportunity and evidence for being recognised as European OHS practitioners.
- Establishes conditions for access (establishing a metric(s) that can discern the qualified from the unqualified) – steps for becoming an ARSSM member used these days (ARSSM, 2013), should be carefully revised, qualifications exists but are not mandatory. Future development might grow towards chartered status, where membership of a chartered organisation is required in order to practice. This system already exists in Romania for doctors, accountants, engineers and if we are looking for European models, we can fallow IOSH system of chartered safety and health practitioners (IOSH, 2014).
- Establishes the professional associations with their roles: socialization/ collegiality; offering CPD training courses; lobbying for specific policy and legislation that affect the practice of the profession. Knowing, as an insider, the way of working of an association like ARSSM, the researcher thinks that there is a lot more work to do in order to grow and achieve the expectations of a mature, well-established association;
- Establishes and enforces a professional code of ethics as a common characteristic of a profession. A proper and suitable way needs to be found, as the questioned members express their wish for having a code of ethics and they showed very clear that the proper time is now.
To the 7th International Conference Workingonsafety.net (IOSH, 2014) 30 September – 03 October 2014 Scotland, UK which I attended, it was a technical session,TS10, Competence Workshop, chaired by Jane White – IOSH, UK. In this session the speakers, Andrew Hale former chairman of Certification Committee of ENSHPO, Pam Pryor - Registrar of Australian OHS Education Accreditation Board, Australia and Luise Vassie, Executive Director- Policy, IOSH, UK have had some presentations about developing a global framework for the training and certification needs across the world. Speakers and participants have underlined the necessity of an international harmonisation of qualifications for the occupational health and safety practitioners and their presentations are the proof that OHS professionals from all around the world are interested to be international recognized. The common empowerment procedure should be acknowledged and encouraged by all OHS professionals and now days ENSHPO and INSHPO (International Network of Safety and Health Practitioners Organisations) (INSHPO, 2014) are working together to a common framework.
Future licensing of OHS professionals may rely on ENSHPO or EUSAFE or INSHPO competency schemes; one question arises: which is the best way to equate the years of professional experience with theoretical education (diplomas, certificates). Transforming professionals experience gained with or without studies, diplomas, recognized skills in the vocational training system and the ways to do so, represent a point of interest for the Romanian OHS practitioners and the research will present their opinions.
The researcher is very positive about these results provide a great deal of useful evidence for future decision making on professionalisation of OHS, even if a generalization of the OHS practitioners can`t be done only by a single study; bearing this in mind, the researcher found out that practitioners are aware of their personal training needs, of CPD and the necessity of a voluntary code of ethics.
Romania as a EU member should use the European tools:

- EQAVET and EQF are ways of recognizing the vocational learning all over the EU and could be used by Romanian OHS practitioners with the support of Labour Ministry, Education Ministry and professional associations;
- ECVET a system to help the transfer and recognition of learning experiences including vocational education and training (VET) for those wishing to use this instrument in EU.
- ECTS credit points; for example now, a university diploma has 240 credits. The system is simple and easy to understand. There are 1500 -1800 hours of work for an academic year and 1 credit shows 25-30 hours of work, so this means 240 credits x 30 hours of work = 7200 h : 4 years of study= 1800 hours/year of study.

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6. REFERENCES

Cassell, C., and Symon, G., (2004) Essential Guide to Qualitative Methods in Organizational Research, London, Sage Publications Ltd.

DePoy, E., and Gitlin, L., (1994), *Introduction to Research. Multiple Strategies for Health and Human Services*,. Printed: United States of America, Mosby-Year Book, Inc.

Denscombe, M., (2003) *The Good Research Guide*, 2nd edn., Berkshire, England, Open University Press.

Ferguson, L.H., and Ramsay, J.D., (2010) Development of a profession, The Role of Education & Certification in Occupational Safety Becoming a Profession, In *Professional Safety. Journal of the American Society of safety engineers.* October 20, 2010, 24-30, Retrieved September 15, 2013 from: http://www.asse.org/professionalsafety/indexes/2010.php,.

Gray, D., (2004) *Doing research in the real world,* Sage Publications Ltd., London.

Miller, T., and Bell, L., (2002) *Consenting to what? Issues of access, gate-keeping and 'informed' consent*, London, Sage Publications Ltd.

Gandul Paper (The Thought Paper) (2013, November, 11) Recensamant (Census). *Gandul Paper*. Retrieved from http://www.gandul.info/financiar/recensamant-date-finale-cati-romani-mai-sunt-in-romania-hartapdf

EUSAFE.(2013). www.eusafe.org, (September 9, 2013). Retrieved from http://www.eusafe.org/index.php/en/theprj-eng.html.pdf

Inspectia Muncii.(2014).*Lista servicii externe*.(September 19, 2014). Retrieved from http://www.inspectmun.ro/site/Servicii%20externe/Actualizare%20Lista%20servicii%20externe%20abilitate_13_08/Lista_serv_2012.

IOSH. (2013).*Memebreship*. Retrieved from http://www.iosh.co.uk/Membership/About-membership/Professional-development/About-CPD.aspxpdf.

EUSAFE. (2014). *EUSAFE Project*. (October 12, 2014). Retrieved from http://www.eusafe.org/index.php/en/theprj-eng.html

INSHPO. (2014). Workingonsafety. November 12, 2014). Retrieved from http://inshpo.org/about.php

IOSH (Institute of Occupational Safety and Health), (2014) \`Technical sessions 10.Competence workshop\`, Learning from the past to shape a safer future. Scotland, UK, 30 September-03 October, Leicester UK, IOSH, pp.88-93.

Romanian Parliament \`Law regarding Health and Safety\`, no.319, published in the Official Monitor, Part I, no.646 from 26.07.2006.

Romanian Parliament \`Law on the protection of individuals regarding the processing of personal data and free movement of such data\`, no.677, published in the Official Monitor, Part I, no. 790 from 12.12.2001.

Romanian Government Decision \`Amending and supplementing the Norms for applying Law of health and safety no.319/2006 approved by Government Decision no. 1.425/2006\`, no. 955, published in the Official Monitor, Part I, no.661 from 27.09.2010.

Romanian Labour Ministry Order \`Regarding the approval of empowering individuals and businesses to provide services in the field of labour protection\`, no.236, published in the Official Monitor, Part I, no.194 from 26.05.1998, replaced by Order no.251, published in the Official Monitor, Part I, no.291 from 05.07.2002, replaced by Order no.167, \`Regarding the approval of empowering individuals and businesses to provide services in the field of labour protection\`, no. 167, published in the Official Monitor, Part I, no.409 from 07.05.2004.

Measuring improvement of communication attitude toward railway safety through training in a Japanese train operation control center

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Abstract
Accurate and smooth communication is necessary for train dispatchers to ensure railway safety. Railway companies are trying to introduce communication training for train dispatchers. However, it is not clear whether or not communication training actually improves the communication. It is important to verify the benefits of such training in order to keep introducing and implementing the training. Thus, we developed self-rating 45 communication attitude items to examine whether or not communication training improved communication attitude toward safety in a Japanese train operation control center. Thirty train dispatchers took part in our communication training for study. They rated the degree of the importance of these items using a seven-point scale (1. Not important at all - 7. Extremely important) immediately before and after the communication training. In addition, we asked both the dispatchers who took part in the communication training and those who didn't (total 106 dispatchers) to rate the degree of practice of the 45 communication items in their everyday work approximately one or two month after the training. The results of ratings of the degree of the importance before and after the training showed that the average rating values of 12 items after the training were statistically significantly higher than those before the training. Moreover, the results of the rating of the degree of practice one or two months after the training showed that the dispatchers who took part in the training rated 18 items statistically significantly higher than dispatchers who didn't take part in. These results suggested that the communication training actually improved the communication attitude toward safety and it affected dispatchers' everyday communication practice even one or two months after the training. Although we neither studied the longer effect of the training nor observed the behavioural changes of communication, we confirmed that the communication training helps to improve communication for safety. The self-rating attitude measurement is one of the effective and easy tools to check the unobservable inner effects of communication training.

Keywords: attitude survey; communication attitude; measurement of training effectiveness

1. INTRODUCTION

1.1. Train Dispatchers and Communication for Safety
Accurate and smooth communication is necessary for train dispatchers to ensure railway safety. When a train accident happens, they have to gather information accurately from the train crew and the station staff, give proper instructions to them and share information smoothly with other dispatchers in order to make proper decisions. Train dispatchers traditionally make efforts to prevent commutation mistakes through repeating back what they receive and using standardized words.
Moreover, in recent years, the Japanese railway field has been introducing trainings for activating communication of train dispatchers to improve response capability of abnormal events (e.g., Oshikoshi, 2003; Moriya,.Kishino, Wada, Abe, Ishibashi, 2011).
However, effects of communication training have not been verified sufficiently yet in railway field. It is important to verify the benefits of such training from various aspects in order to provide training effectively. If benefits of the training are not verified, it is difficult to keep introducing and implementing the training.

Thus, this study examines whether or not communication training actually improves communication for safety in a Japanese train operation control center by using a self-rating attitude measurement.

1.2. Communication Training for Safety

Effective communication requires good communication elements such as “explicitness”, “timing”, “assertiveness”, and “active listening” (Flin, O’Connor, & Crichton., 2008). To improve train dispatchers’ communication skill in their works, a communication training which encourages such communication elements in practical conditions is desirable.

We can refer to CRM training in the aviation field for such communication training. CRM is the idea that crew members manage all the resources available including other crew-members, procedures, machine interface, and themselves to ensure safety and best performance (CAA, 2014). Especially, Line Oriented Flight Training (LOFT), which is a core of CRM training, intended to simulate actual problem situations that require CRM skills including communication skill and let trainees discuss their operations using video recording of their operations in debriefing (Butler, 1993).

In the railway field, training like LOFT seems also useful to encourage good communication elements in practical conditions. Thus, this study employs a simulation of abnormal events and discussion using video recording of their operations as a communication training to examine training effects for train dispatchers.

1.3 Evaluation Measurement of Communication Training

Evaluation techniques of CRM training are categorized in terms of reactions, learning, attitudes, behavior and organization effects (O’Connor, Flin, & Fletcher, 2002). Among these techniques, this study especially focuses on measurement of attitude. Though behavioural rating is also useful to detect effects of communication training, checking detailed behaviour during the training session or before and after trainings becomes a burden for training instructors. In addition, internal attitude is hard to capture by behavioural rating though forming internal attitude of putting high value on communicating accurately and smoothly for safety must be important for appropriate communication. Thus, we try to measure effects of our communication training by using self-rating communication attitude items instead of behavioural rating from training instructors.

Previous studies about CRM training in other domains such as the aviation (Gregorich, Helmerich, & Wilhelm, 1990) and the medical field (Awad, Fagan, Bellows, Albo, Green-Rashad, Garza, & Berger, 2005) already have proved that CRM trainings improve communication attitude. Hence, attitude measurement is considered appropriate for measuring effects of communication training also in the railway domain.

In this study, first, we develop self-rating communication attitude measurement items for train dispatchers. Then, we measure communication attitude toward safety immediately before and after training by using the communication attitude items. Furthermore, we measure communication practice in everyday work one or two months after the training to check practical effects and persistent effects of the communication training by using the similar self-rating items.

2. MATERIALS AND METHOD

2.1. Developing Communication Attitude Measurement Items

We developed communication attitude measurement items in the following procedure.

First, we extracted communication errors of dispatcher from a previous study of dispatchers’ errors (Hayama & Miyachi, 2012) and classified the communication errors into three error patterns (i.e., “improper timing”, “not accurate information”, “not received or misunderstood.”)

Second, we collected communication points to keep in mind about communication for safety from the various previous studies. Subjects of these previous studies include Japanese CRM skills behavioral markers in aviation (Iijima, Noda, Sudo, Muraoka, & Funabiki, 2003), non-technical skills in British railway (Bonsall, 2012), Japanese Railway CMR training (Moriya et al., 2011), Japanese fire-brigade (Shindo, Hosoya, Takai, Ymaguchi, Kobori, & Chiba, 2012), safety skills for workers in Japan (Cross-industrial safety research network, 2011) and general non-technical skills guide (Flin et al., 2008). We organized these extracted communication points into three perspectives, that is, “proper timing”, “accurate information”, “appropriate response”, with the aim to prevent the three communication error patterns of train dispatchers.

Then, we discussed the communication points with dispatcher instructors and modified communication points so as to be suitable for train dispatchers. Finally, we developed 45 communication attitude items as shown in Table 1.

Table 1 – Communication attitude items.

Perspective	Num	Item
Proper timing	1	In a state of emergency, tell the most important thing first.
	2	Give instructions in a working sequence, not in a haphazard way.
	3	When you can predict disruption to train services, coordinate with related staffs before disruption actually occurs.
	4	Instruct one by one as much as possible.
	5	In a state of emergency, use strong voice.
	6	Correct your mistake as soon as possible when you notice it.
	7	Ask for help when you can't manage it.
	8	When you find hard-pressed dispatchers, offer your help.
Accurate information	9	Don't indicate an object only by using pronoun such as "that" or "this", even when you think the indicated object is obvious.
	10	Convey all information correctly even in a state of emergency.
	11	Don't use abbreviated and slangy words assuming that everyone may not know them.
	12	Speak with an appropriate loudness of voice and check that others can hear your voice.
	13	When you refer to numbers, clarify the unit of measurement.
	14	Talk face to face as much as possible.
	15	Distinguish between asking and instructing.
	16	Convey your intention clearly, even it seems obvious.
	17	Ask a clear question.
	18	Instruct what and by when operators should do.
	19	Don't convey your intention only through gestures.
	20	In case sudden change happens, arrangement instruction should be conveyed carefully in details.
	21	Rephrase confusing words which have similar sounds.
	22	Tell clearly from the other person's perspective.
	23	Ask to repeat back after you instruct.
	24	Ask to confirm if there are dubious points.
	25	Tell important information repeatedly.
	26	Pronounce each important word clearly.
	27	Call a receiver's name and clarify who is responsible for.
	28	Give advice rather than blaming.
	29	Don't rush others with an angry and loud voice.
	30	Tell your feeling of wrongness, even if you don't have confidence of it.
	31	When you deny others' opinion, add the reason why the opinion is wrong.
	32	When you don't have enough time to answer questions, tell that you will do it later.
	33	Even if you receive an easy question, don't make fun of the questioner.
Appropriate response	34	Repeat back certainly when you receive directions or reports.
	35	Respond to a question certainly.
	36	When you feel something wrong about directions or reports, confirm the intention through paraphrasing.
	37	Listen again if you can't understand what others said.
	38	Listen again if you feel something wrong about directions or reports.
	39	When you are too busy to cope with a direction, tell when you can follow it.
	40	Listen to directions or reports until the end.
	41	When you find a lack of information, confirm the information without estimation even if it is trivial.
	42	Giving a reply when your name is called.
	43	Don't deny any opinions without consideration.
	44	When there is a question about an instruction, ask the reasons of it.
	45	Listen to others in a calm way even when your opinion is denied.

Additionally, we requested ten dispatcher instructors preliminarily to rate the degree of the importance of these communication attitude items using a seven-point scale (1. "Not important

at all", 2. "Low importance", 3. "Slightly important", 4. "Slightly important", 5. "Moderately important", 6. "Very important", 7. "Extremely important").
Their rating results of 44 items (1 item was excluded due to missing data) showed moderate interclass correlation coefficient (ICC = 0.73). This meant that rating of each item was almost consistent among the dispatcher instructors. The average values of 42 out of 45 items were higher than 5 point (moderately important). This result showed that attitudes of these items were actually important for railway safety. Although average rating values of three items (i.e., "Instruct one by one as much as possible.", "Tell your feeling of wrongness, even if you don't have confidence of it.", "Talk face to face as much as possible.") are less than 5 point, we didn't cut the three items and used all 45 items to measure the effect of communication training in view of the fact that about half of dispatcher instructors rated these three items higher than or equal to 5 points. We treated this attitude measurement like a checklist to check each attitude item rather than measurement of abstract constructive concepts or latent factors of communication attitudes.

2.2. Measurement of Attitude Before and After the Communication Training

We examined the effect of communication training by using developed communication measurement items. Thirty dispatchers took part in our communication training for study. The communication training was conducted ten times in July and September, 2014. Our communication training required three different dispatchers at one time, namely a crew and vehicle dispatcher, a traffic controller, and a vice-chief traffic controller. They dealt with an abnormal events scenario (e.g., railway vehicle trouble) in mutual cooperation. A facilitator and a responder handled this training. A facilitator assigned events and controlled the progress of the training; a responder played the roles of a driver, conductor and station staff and responded to dispatchers during training session. The scenario training session took about an hour. After dispatchers finished the training session, they discussed the way by which they communicated watching their video-recorded operations in training (Hatakeyama, Okada, Hayama, Kaburagi, & Miyachi, 2015).
Dispatchers rated the degree of the importance of 45 communication attitude items using a seven-point scale as shown in Table 2 immediately before and after the training.
We used two-version of communication attitude item lists for each of which the item order was different. The dispatcher rated each of the different item order lists before and after training. Besides, the rating order of the two lists before and after the training was counter balanced across training sessions.

2.3. Measurement of Attitude One or Two Months After the Communication Training

In addition, we studied the effect of the training on communication attitude in everyday work. We asked the dispatchers to rate the degree of practice of the 45 communication items in their everyday work approximately one or two month after the training. We modified the expression of the communication attitude items slightly to measure everyday practice.
Both the dispatchers who took part in the communication training and those who didn't (total 106 dispatchers) rated the degree of practice of the 45 items in their everyday work using a seven-point scale (1. "Very untrue of me", 2. "Untrue of me", 3. "Somewhat untrue of me", 4. "Neutral", 5. "Somewhat true of me", 6. "True of me", 7. "Very true of me").

3. RESULTS AND DISCUSSION

3.1. Communication Attitude before and after Communication Training

We compared the rating values of importance of the items before and after communication training. Figure 1 shows average rating values of all 45 items before and after training.
Paired *t*-tests indicated that the average rating values of 12 items after the training were statistically significantly higher than those before the training (*ps* < 0.05). Typical examples of higher rated items were "In a state of emergency, tell the most important thing first.", "Don't use abbreviated and slangy words assuming that everyone may not know the words.", and "Tell clearly from the other person's perspective." As shown Figure 1, these 12 items were relatively lowly rated before training. This suggests that the communication training improves the awareness of importance of communication attitudes items which are difficult for dispatchers to recognize as important in everyday work.
On the other hand, items whose average rating values were not increased after training were highly rated even before training. This may have caused a ceiling effect which prevented training effects from being detected for high rated items especially over 6 points.

There were no items whose average rating values after training became statistically significantly lower than those before training.

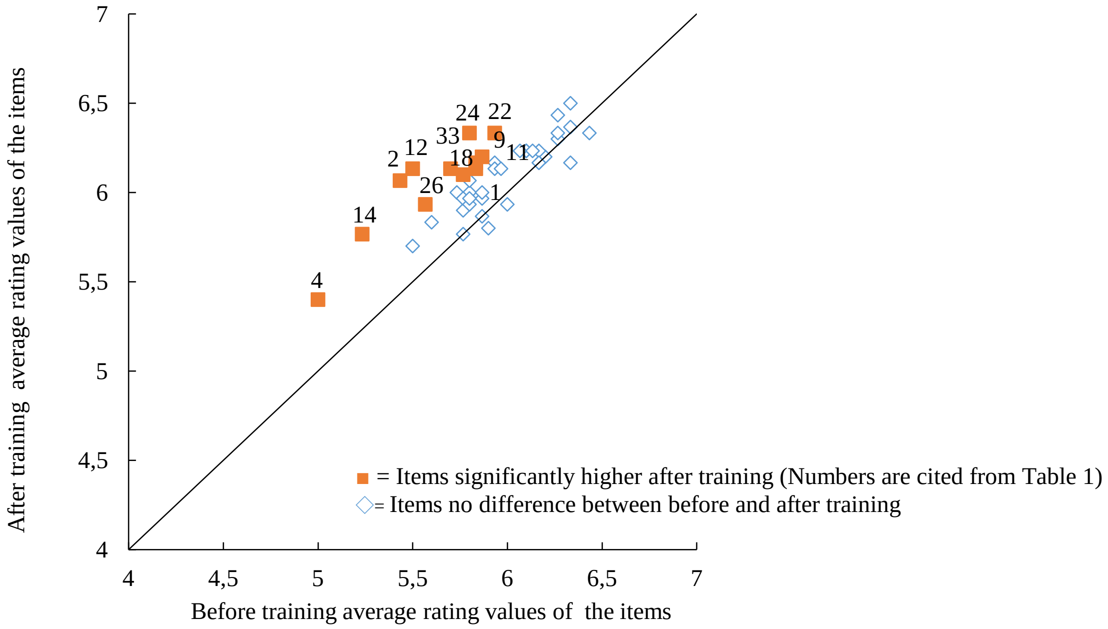

Figure 1 – Plots of average rating values of degree of importance of the communication items before and after training.

3.2. Communication Attitude One or Two Months after the Communication Training

In addition, we compared the ratings of the degree of practice of the items one or two months after the training between trained and non-trained dispatchers. Figure 2 shows average rating values of all 45 items rating of trained and non-trained dispatchers.

T-tests indicated that dispatchers who took part in the training rated 18 items statistically significantly higher than dispatchers who didn't take part in ($ps < 0.05$).

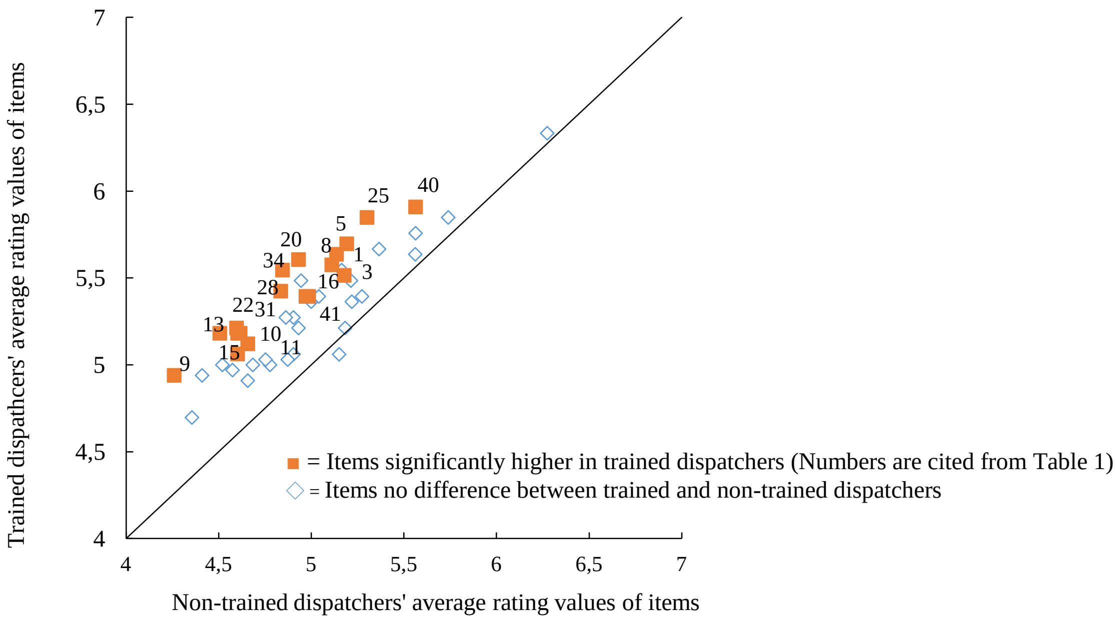

Figure 2 – Plots of average rating values of degree of practice of the communication items of trained and non-trained dispatchers.

This result revealed that the communication training affected dispatchers' everyday communication practice even one or two months after the training.

Besides, this result seemingly shows that the training effects were detected for more items one or two months after the training (18 items) than for those immediately after training (12 items), contrary to a general trend that CRM training effects are declining over time (O'Connor et al., 2002). This may be because we measured not pure communication attitude but communication practice one or two months after training. This may have led to inhibiting a ceiling effect of the attitude measurement and enabling to detect wider effects of the training on everyday communication.

However, only four attitude items detected the training effects commonly in both the cases: before and after training and between trained and non-trained dispatchers one or two months after the trainings. This may also stem from the difference between attitude measurement and practice measurement. The four items are "In a state of emergency, tell the most important thing first.", "Don't indicate an object only using pronoun such as "that" or "this", even when you think the indicate object is obvious.", "Don't use abbreviated and slangy words assuming that everyone may not know the words.", "Tell clearly from the other person's perspective." These all four items represent the idea that dispatchers should take perspectives of information receivers in terms of timing or explicitness. This suggests that the communication training is especially effective for developing the attitude of taking others' perspectives which is useful for smooth and accurate communication for safety.

4. CONCLUSIONS

These results described above suggested that the communication training actually improved the communication attitudes toward safety, especially an attitude of taking others' perspectives, and it affected dispatchers' everyday communication practice even one or two months after the training. Although we neither studied the longer effect of the training nor observed the behavioural changes of communication, we confirmed that the communication training helps to improve communication for safety. The self-rating attitude measurement is one of the effective and easy tools to check the unobservable effects of communication training.

5. REFERENCES

Awad, S. S., Fagan, S. P., Bellows, C., Albo, D., Green-Rashad, B., De La Garza, M., & Berger, D. H. (2005). Bridging the communication gap in the operating room with medical team training. *The American Journal of Surgery*, 190, 770-774.

Bonsall, K. (2012). Non-technical skills for rail: A list of skills and behavioral markers for drivers, with guidance notes, *RSSB Report*, Rail Safety and Standards Board.

Butler, R.E. (1993). LOFT: Full-motion simulation as crew resource management training. In Weiner, E.L., Kanki, B.G., & Helmreich, R.L. (Eds.). Cockpit resource management (pp. 231-259). San Diego: Academic Press.

CAA. (2014). Flight-crew human factors handbook. CAP 737. West Sussex: Civil Aviation Authority.

Flin, R. H., O'Connor, P., & Crichton, M. (2008). *Safety at the sharp end: a guide to non-technical skills*. Ashgate Publishing. (Japanese Translated, Komatubara., A., Sogame, H., Nakanishi, M., (2012). Tokyo: Kaibundo Publishing.)

Gregorich, S. E., Helmreich, R. L. & Wilhelm, J. A. (1990). The structure of cockpit management attitudes. *Journal of Applied Psychology*, 75, 682-690.

Hayama, K., & Miyachi, Y. (2012). Method to support risk management of human error in the traffic dispatchers, *RTRI report*, 26, 15-20. (In Japanese with English abstract)

Hatakeyama, N., Okada, Y., Hayama, K., Kaburagi, T, & Miyachi, Y. (2015). The training method of communication skills for train dispatchers in abnormal situations, *RTRI report*, 29, 11-16. (In Japanese with English abstract)

Iijima, T.,Noda, F., Sudo, K., Muraoka, K., & Funabiki, K. (2003). Development of CRM skills behavioral markers, *National Aerospace Laboratory Report*, No.1465, 1-59 (In Japanese)

Moriya, Y., Kishino, M., Wada, K., Abe, K., & Ishibashi., A. (2011). Study of the support for railway organization members in the event of trouble –For developing Railway-CRM (R-CRM). *Proceedings of the 27th Annual Meeting of the Japanese Association of Industrial and Organizational Psychology*, (pp.183-186). (In Japanese)

Oshikoshi, R. (2003). Improving team strength of train dispatchers. *Proceedings of the 40th railway cybernetics symposium*, (pp.588-591). (In Japanese, translated by the author of this article)

O'Connor, P., Flin, R. H., & Fletcher, G. (2002). Techniques used to evaluate Crew Resource Management training: a literature review. *Human Factors and Aerospace Safety*, 2, 217-233.

Shindo, T., Hosoya, M., Takai, H., Ymaguchi, Y., Kobori, Y., & Chiba, H. (2012) Study on the formulation of CRM action guidelines for use in traffic accident prevention, *Report of Fire Science Laboratory* , 49, 77-84. (In Japanese with English abstract)

Cross-industrial safety research network. (2011). *Workplace skills to protect life - role of workers for safety and security-*, Tokyo: Kaibundo Publishing. (In Japanese, translated by the author of this article)

Occupational health and safety knowledge of students in secondary vocational schools in Croatia

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Abstract

Introduction: Vocational secondary education aims to ensure the acquisition of competencies required for the labor market. Young workers are in accordance with the Occupational Health and Safety Act particularly vulnerable group of employees. Because of their inexperience, lack of practical knowledge, lack of awareness about safety and health risks, the inadequate supervision by experienced workers, young workers get injured more often than others. For this reasons the employer shall be obliged to provide special occupational health and safety for this group for the purpose of preserving his unimpaired mental and physical development. For the purpose of minors' safety and health protection at work, the employer shall be obliged to adjust conditions and working time organization.

Objectives: Students, as future young workers to be, in the framework of educational program, learn about safety at work and gain their first practical experience in the practical workshops in school as well as in employer's workshops. Are they ready to work to work independently from the standpoint of OSH?! Have they developed safety awareness?

Methodology: Study was conducted in twenty eight secondary vocational schools in Croatia in which students study for professions: carpenter, chemical technician, agricultural technician, construction technician, graphic technician and forestry technician. The research was conducted through the questionnaire survey and included total of 896 students with the aim to exam awareness of students on OSH and application of OSH measures in selected schools.

Results: The results of the survey indicated the need for additional investment in the development of students' safety culture. As a result of the project Croatian Institute for Health Protection and Safety at Work developed the educational posters for the classrooms and school workshops and educational booklets for young workers entering the labor market.

Keywords: occupational safety and health protection, vocational schools, students, young workers, professional practice

1. INTRODUCTION

Young workers together with students belong to particularly vulnerable groups from the standpoint of regulations in the field of labour and safety at work. In support of the above going concern goes data on accidents at work that are part of both national (Croatian Institute for Health Protection and Safety at Work, Labour Inspectorate) and statistical reports of the European Union (Eurostat, ESAW). Graphic depiction 1 emphasizes the importance of the integration of occupational safety and health in the education system, especially when it comes to educational programs for high- risk occupations. Children and students need to develop a safety culture from their early age and make it a part of their pattern of behaviour when they became young workers and throughout their lifetime (EUOSHA, 2009.). Start of development of a safety culture cannot be timed to coincide with the beginning of work experience for young workers. Entering the world of work, young workers already must have awareness of the importance of safety and occupational health to protect themselves and others. The importance of integrating the content from this area in education was recognized in 2004. by the European Agency for Safety at Work (EU OSHA) through the project of integration of safety and health at work in education ('Mainstreaming occupational safety and health into education') The aim of the project was to emphasize that occupational safety must be part of lifelong education, from kindergarten to retirement. This implies that the fundamentals of occupational safety for children and pupils should be implanted through attitudes related to safety and health and need to generally develop a safety culture in schools and other educational institutions.

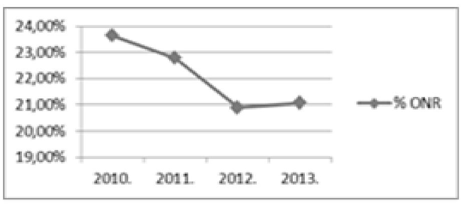

Figure 1 - Share of injuries at work for workers aged 18 to 30 in Croatia

2. METHODS

For the study purpose, questionnaire for students in secondary vocational schools, composing of 13 questions was used. Study was conducted in twenty eight secondary vocational schools in Croatia in which students study for professions: carpenter, chemical technician, agricultural technician, construction technician, graphic technician and forestry technician. Study included total of 896 students who were surveyed in order to examine their knowledge and experience on occupational health and safety issues. Research was conducted in the period of two years (2013-2015) by the Croatian Institute for Health Protection and Safety at Work (CIHPSW).

Data from the research of valid filled questionnaires were entered into a computer database and statistical analysis of data was performed using the tools of statistical analysis within Microsoft Excel.

3. RESULTS

Students, as future young workers, in the framework of their educational program, learn about safety at work and gain their first practical experience in the practical workshops in school as well as in employer's workshops. Most influence on the development of safety culture among students have their high schools teachers, practical training teachers and craftsmen where students perform professional practice. As part of the project, the presentations were held to the students in order to emphasize the importance of safety at work before they complete their education. Students were familiarized with the most often hazards, harmful events and consequences, general principles of prevention, basic and specific occupational health and safety rules, employer's obligations and employee's obligations and rights. Also, one of the results were posters created for each profession and flyers created for students containing information on their rights, employer's obligations, safety tips and useful contacts and web sites.

In accordance with the curricula, all schools tested in the same educational programs have theoretical part of occupational safety taught in the first grades of the prescribed number of hours, after which the students take an exam that is equal for all directions. Later in the higher grades students get acquainted with the dangers and hazards related to the particular technology of work which is emphasized through practical training. Practical classes are held in the schools and at employers (usually, craftsmen) but some of the schools that participated in the survey do not have this form of cooperation with craftsmen and a certain number of students with practical work meets only at school. None of the schools that participated in the survey has registered accidents at work during the training at the school as well as with employers or craftsmen. Despite this, in the questionnaires students report that there were cases of work-related injuries during the practical training.

3.1. Educational program for the profession carpenter

Students who are being educated for future carpenters were interviewed in 3 vocational schools. Interest in this profession is constantly falling as evidenced by the small number of students who are students of final grades. A total of 24 students were surveyed.

The survey showed that future young carpenters recognize general hazards and are able to identify efforts and harmfulness they may occur on their future work. The students say that they are familiar with the safety measures by teachers or leaders of practical training as well as by craftsmen where they go for practical training. In parallel, 60% of surveyed students consider personal protective equipment (PPE) to be the first measure of protection and only 4% as a measure that is applied only when the protection of workers at the workplace cannot be achieved with other measures. Even 24% of students consider that personal protective equipment is unnecessary. Availability and application of personal protective equipment in schools is positively evaluated according to 13 students and is considered to be inaccessible by 5 students. Teachers and practical educators deny injuries at work (practice) but 20% of students said that there were some injuries during practical work. More than half of the surveyed students said that they do not want to gain additional knowledge about the occupational safety and health.

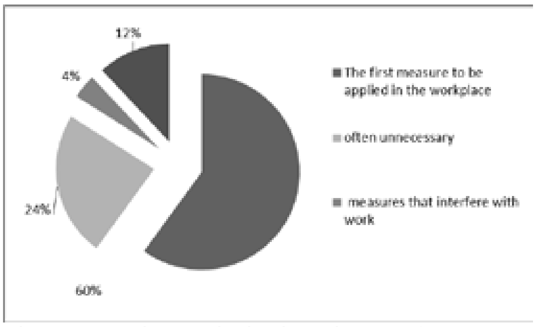

Figure 2 - Students attitude about the use of PPE

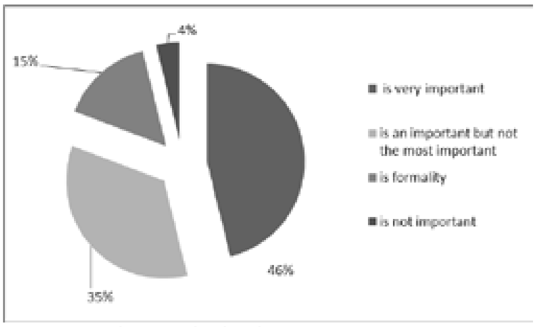

Figure 3 - Students attitude about OSH

3.2. Educational program for the occupation agricultural technician

Students who are trained for the profession of agricultural technicians were surveyed in 5 secondary vocational schools in Zagreb, Varazdin and Split. 147 students were surveyed from 10 classes learning for avocations: general agricultural technician, fitofarmaceut, agritourism and gardener.

Final year students who participated in the survey are able to list the hazards related to their future profession. Students consider occupational safety and health very important and are familiar with the area, primarily through lectures in schools (Figure 4 and 5). Most of the students said that they are well-informed about safety measures and danger of their future profession. At the same time, 79% of students' consider personal protective equipment to be the first measure to be applied in the workplace. The availability of personal protective equipment at the school was confirmed by 53% of students. 56% of students expressed their interest in finding out more about the safety measures and occupational health.

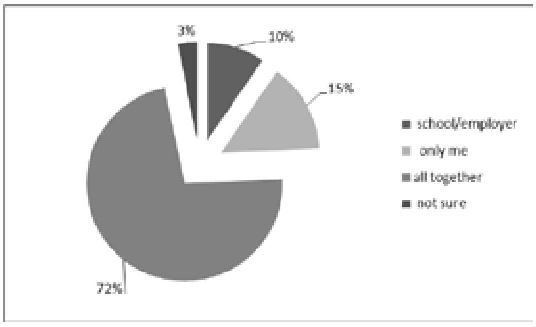

Figure 3 - Students attitude about the responsibility for OSH

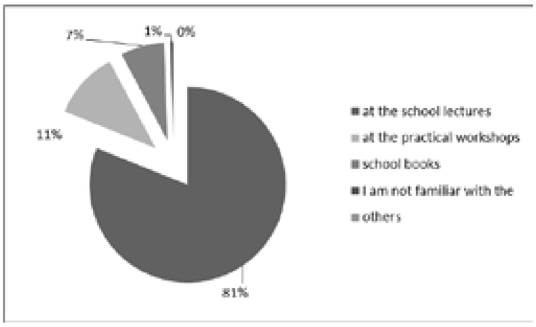

Figure 4 - Introduction to health and safety

3.3. Educational program for the occupation chemical technician

Study on awareness of students on occupational safety and health questions involved 80 students who are studying for the profession of chemical technicians in 4 secondary schools. Similar to the previous two educational programs, students get familiar with OSH through school program, and this area is considered to be very important.

Most of the students successfully recognize dangers, hazards and efforts specific to their profession. 80 % of surveyed students consider personal protective equipment to be the first safety measures and report that the same is provided and available in the school (31% of students) and in practice with the employer (18% of students).

An equal percentage of students (39%) denies and confirms injury to students during practical training, while half of the students expressed an interest in additional education about safety measures.

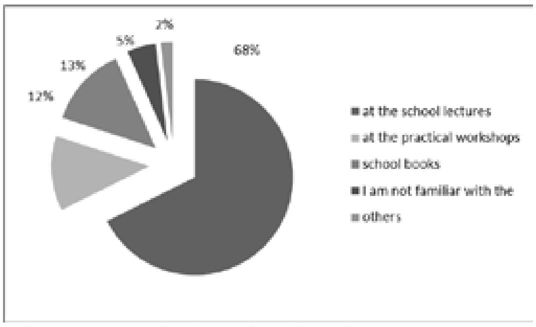

Figure 5 - Introduction to health and safety

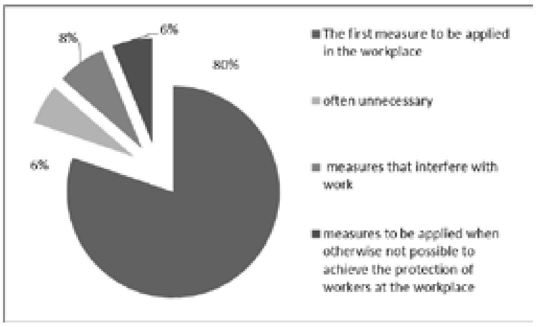

Figure 6 - Students attitude about the use of PPE

3.4. Educational program for the occupation construction technician

Students who are being educated for construction technician were interviewed in 6 vocational schools in Croatia. A total of 226 students were surveyed. The survey showed that students recognize general hazards and are able to identify efforts and harmfulness that may occur on their future work. The students say that they are familiar with the safety measures by teachers or leaders of practical training as well as by craftsmen where they go for practical training. 86 % of surveyed students consider personal protective equipment (PPE) to be the first measure of protection, and 12 % believe that this measure is often unnecessary. Most of the students agree (78 %) that responsibility for OSH should be divided between worker (student), employer and teacher. Teachers and practical educators deny injuries at work (practice) but 20% of students said that there were some injuries during practical work. More than half of the surveyed students (56 %) said that they do not want to gain additional knowledge about the occupational safety and health.

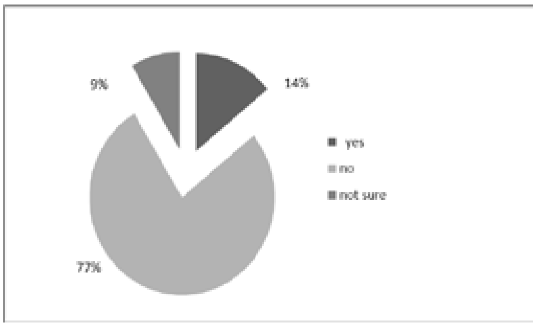

Figure 7- Injuries at work during practical work

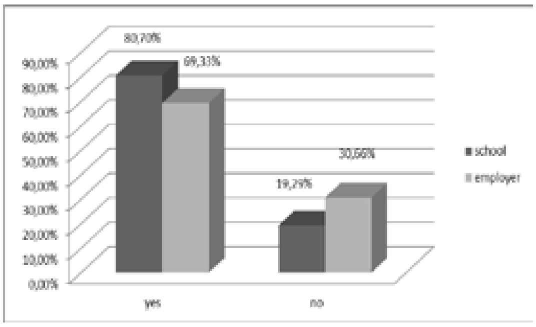

Figure 8- Availability of PPE

3.5. Educational program for the occupation graphic technician

Students who are trained for the profession of graphic technicians were surveyed in 3 secondary vocational schools. 66 students were surveyed. Final year students who participated in the survey were able to list the hazards related to their future profession. Students consider occupational safety and health very important and are familiar with the area, primarily through lectures in schools. Most of the students said that they are well-informed about safety measures and danger of their future profession. At the same time, 97 % of students' consider personal protective equipment to be the first measure to be applied in the workplace. The availability of personal protective equipment at the school was confirmed by 97% of students. 64 % of students expressed their interest in finding out more about the safety measures and occupational health.

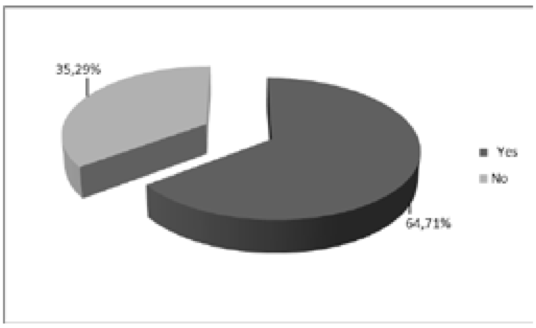

Figure 8 – Interest of students for OSH education

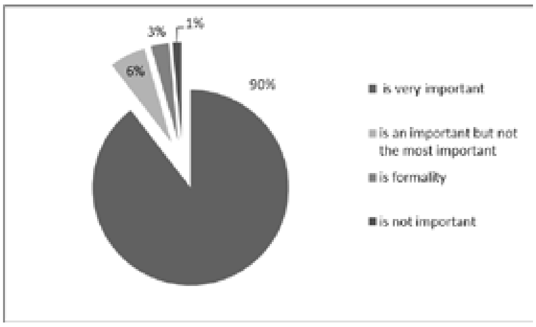

Figure 9 - Students attitude about OSH

3.6. Educational program for the occupation forestry technician

A total of 182 students were surveyed from 5 vocational schools in Croatia. The survey showed that future young workers in this field recognize general hazards and are able to identify efforts and harmfulness they may occur on their future work. The students say that they are familiar with the safety measures by teachers (80 %) or leaders of practical training as well as by craftsmen (8 %) where they go for practical training. 92% of surveyed students consider personal protective equipment (PPE) to be the first measure of protection, and none of them as a measure that is applied only when the protection of workers at the workplace cannot be achieved with other measures. Availability and application of personal protective equipment in schools is positively evaluated according to 92 % students and is considered to be inaccessible by 8 % students. Teachers and practical educators deny injuries at work (practice) but 10 % of students said that there were some injuries during practical work. 78% of the surveyed students said that they do not want to gain additional knowledge about the occupational safety and health.

4. CONCLUSION

The aim of this research was to gain insight into the awareness of occupational safety and health protection of *s*tudents in secondary vocational schools in Croatia and the application of measures in this area. The survey of students in the final grades in selected educational programs conducted in 28 high schools, showed similar trends. Final year students in the profession of carpenter, agricultural and chemical technician, construction technician, graphic technician and forestry technician gain theoretical knowledge on occupational safety and health protection in the first few grades. Afterwards they have to pass the theoretical exam and then they can take part in practical training. Although most of the students state that they are very familiar with the safety measures, the application of personal protective equipment was evaluated as the most important measure of protection, which actually shows that they have not adopted the basic OSH principles. In accordance with the rules of the profession, the risks to the safety and health of workers first should be removed or reduced by applying the basic safety rules that apply to the means of work, and in addition by special safety rules that apply to workers, manner of operation and operating procedures. Collected data on the availability of personal protective equipment in schools and employers were students have their practice, as well as allegations of occupational injuries, are very controversial, even when it comes to the same schools. The study noted that there is a difference in the attitudes and awareness of the importance of safety at work with the leaders of practical training with experience in the real sector and those who do not have any experience in real sector. The leaders of practical training expressed their desire and need for education in the field of safety and health at work. A bright spot is the perception of students that safety at work is very important and that the responsibility for the safety and health at work is divided between students, schools and employers.

Safety and prevention culture are the basis of maintaining and improving the quality of work. According to European statistics, the rate of injuries at work of young workers is 50% higher than in the case of other age groups (5). The reasons for this are in addition to the physical and mental immaturity, lack of practical experience and level of awareness of the OSH importance. The students, as future young workers, must be prepared through theoretical and practical training, they should develop a safety culture starting from school desks, rather than entering into a working relationship. In this process, there is a common need to engage teachers, practical training managers and employers were students carry out part of their practical training.

The aim of the vocational education is to gain the competencies needed for the labour market. Health and safety at work is a competence to learn, practice and develop, and without it, all other skills and competences could lose purpose and meaning**.**

5. REFERENCES

Berghaus, B.J. (2010) Research needed on behavior skills training to teach young workers safety skills, *Behaviorology Today,* 13, 2010. 1, pp. 10-14.

European Agency for Safety and Health at Work: *Mainstreaming occupational safety and health into education:good practice in school and vocational education.* EU OSHA*,* Belgium, 2004.

European Agency for Safety and Health at Work: *OSH in the school curriculum: Requirements and activities in the EU Member States,* EU OSHA, Belgium, 2009.

Koo, K.E., Nurulazam, A., Rohaida, S.: Examining the potential of safety knowledge as extension construct for theory of planned behavior: Explaining safety practices of young adults at engineering laboratories and workshops, *Social and behavioral sciences*, No. 116, 2014., pp. 1513-1518.

Rimmer, P., Copsey, S.: *Safe Start! A european campaign dedicated to young people and young workers to ensure a safe and healthy start to their working lives,.* Prevention today. January/June, 2006.

Reinhold, K., Siirak, V., Tint, P.: The Development of Higher Education In Occupational Health and Safety in Estonia and Selected EU Countries, Social and Behavioral Sciences 143 (2014) 52-56.

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Integrated management systems as complex adaptive systems

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Abstract

It is a difficult task to avoid the “smart systems” topic when discussing smart prevention and, similarly, it is a difficult task to address smart systems without focusing their ability to learn. Following the same line of thought, in the current reality, it seems a Herculean task (or an irreparable omission) to approach the topic of certified occupational health and safety management systems (OHSMS) without discussing the integrated management systems (IMSs). The available data suggest that seldom are the OHSMS operating as the single management system (MS) in a company so, any statement concerning OHSMS should mainly be interpreted from an integrated perspective. A major distinction between generic systems can be drawn between those that learn, *i.e.*, those systems that have “memory” and those that have not. These former systems are often depicted as adaptive since they take into account past events to deal with novel, similar and future events modifying their structure to enable success in its environment. Often, these systems, present a nonlinear behavior and a huge uncertainty related to the forecasting of some events. This paper seeks to portray, for the first time as we were able to find out, the IMSs as complex adaptive systems (CASs) by listing their properties and dissecting the features that enable them to evolve and self-organize in order to, holistically, fulfil the requirements from different stakeholders and thus thrive by assuring the successful sustainability of a company. Based on the revision of literature carried out, this is the first time that IMSs are pointed out as CASs which may develop fruitful synergies both for the MSs and for CASs communities. By performing a thorough revision of literature and based on some concepts embedded in the “DNA” of the subsystems implementation standards it is intended, specifically, to identify, determine and discuss the properties of a generic IMS that should be considered to classify it as a CAS.

Keywords: complex adaptive systems, integrated management systems, properties, emergence, agents.

1. INTRODUCTION

Winston Churchill once stated that ‘Out of intense complexities, intense simplicities emerge’. Although not a scientific novelty, the complexity construct has been recently increasingly addressed by a great deal of scholars due to, among others, the emergence of mathematical tools that deal with some and other way, seemingly impenetrable fields of research. Revolving around this construct one often finds concepts such as chaos, symmetry, entropy, modularity, hierarchy, nonlinearity, connectivity, synchronization, schemata, homeostasis (equilibrium), self-regulation and self-organization. Inherent to this discussion lays the duality organization *versus* disorganization, or more accurately in the present case, organized MSs *versus* entropic or disordered (chaotic) MSs. A proper descriptive approach concerning this latter concept considers that a system “grows” in organization when the amount of information needed to fully describe it decreases. This notion may be accurately understood if one recalls the concepts of crystallinity (lattices- organized system) and amorphous materials (disorganized system) that were addressed at the Chemistry sessions in the yearly years of academic studies. The self-organization construct considers the notion that organization is achieved through local interactions among the agents of a generic system that, on his own, do not have any awareness of their contribution to patterned emergent behavior developed by the whole system.

The systems approach (and the nine complexity levels suggested by the general systems theory) is a paradigm of the current science and considers a minimalistic perspective of a system consisting in a set of elements and a set of relations (Chen and Stroup, 1993). This concept evolved after the realization by the academic and industrial communities that the decomposition of a system under study into smaller subsystems, or components, provides relevant information but not explain all the original system behavior. This seems to concur with the notion that a system is more than the sum of its parts and, on this issue, one may quote Mainzer (1997) when he stresses that 'Linear thinking and the belief that the whole is only the sum of its parts are evidently obsolete'. Concerning organizational systems and organizations as living and dynamic systems, Wheatley (1993) pointed out the outdated nature of several approaches stating that 'Each of us lives and works in organizations designed from the 17th century images of the universe….We learned to manage by separating things into parts'. Several synergies could be developed when researching IMSs adopting a CASs approach. On one side, although the scientific context may differ from each identified CASs, they all share the same set of properties and, inherently, the methodologies to be adopted to deal with one of them may be valid to deal with all the others. In fact, the opportunity to extend the scope of the research of IMSs from the "claustrophobic" and classic management and systems engineering topics to a new "fresh" research field should not be wasted. On the other side, CAS academic community will certainly welcome the contribution from a new field with a remarkable diversity of agents often operating in turbulent environments and encompassing social, human and organizational nonlinear interactions. From our viewpoint, the following features characterize IMSs as CASs:

- Multiple agents: An IMS encompasses multiple agents (people, organizational structure, equipment, customers, society, shareholders and regulatory requirements, etc.) interacting each other.
- Learning: An IMS is an adaptive system, that is, past experiences condition present and future behaviour.
- Evolutionary or co-evolutionary perspectives: IMSs evolve from external and internal stimulus, which, if one consider an appropriate implementation should promote the co-evolution of the MSs that comprise the IMS.
- Emergence: The structures of an IMS emerge from patterns that have their source in the standards and experience. In addition, some common features (or patterns) may be detected not being dependent on the geographic location, company dimension, activity sector or organizational culture. This emergence results in a structured higher hierarchical order of organization. New properties not identifiable in the subsystems that comprise the IMS emerge after MSs integration.
- Modularity and redundancy which leads to resilience.
- Complexity (encompasses several parts) and nonlinear behaviour: the interrelationships developed among its elements originate nonlinear emergent behavior in which the complexity is higher than the sum of behaviors of its parts.
- Multi-dimensionality in the sense that many different elements interact on many different scales.
- Non deterministic behavior, that is, several responses (outputs) from the system are possible given any cause.

"Complex adaptive systems" is a research topic that encompasses the most different systems typologies either in dimension, degree of complexity, agents involved, physical or organic nature. One may state that there is not a peculiar research environment where this topic is studied and the contributions provided by the research into a distinct system typology may be valuable to other systems presenting different characteristics but encompassing the features that enable them to evolve as CASs. According to the literature, the term CAS has different meanings to different researchers and a consensual definition seems to be a difficult task among academic experts but it is possible to list the agreed properties that a CASs should present.

The revised literature pointed out the adoption of CASs related methodologies to study ecological and biological systems, social systems, organizational systems and MSs, supply chain networks and information systems, among others. Table 1 and Figure 3 list some of the scientific domains and the correspondent bibliographic references where CASs have been identified and studied.

Table 1: Topics crossover concerning CASs.

Topic	References
Social systems	Antonacopoulou and Chiva, (2005b) Eidelson, (1997)
Ecological systems	Anand *et al.* (2010) Hartvigsen *et al.*, (1998) Hulsman *et al.*, (2011) Rammel *et al.*, (2007)
Biological systems	Hegazi *et al.*, (2009)
Airline industry	Igbo, (2013)
Archaeology	Kohler (2012)
Healthcare	Cordon, (2013) Edgren and Barnard, (2012) Martin, (2011) Martínez-García and Hernández-Lemus, (2013) McDaniel Jr. *et al.*, (2009)
Organizational systems, management, innovation and planning	Akgün *et al.*, (2014) Amagoh, (2008) Arévalo, (2013) Bolton and Stolcis, (2008) Bovaird, (2008) Champlin *et al.*, (2013) Diment *et al.*, (2009) Fabac, (2010) Monostori and Csáji, (2008) Nan *et al.*, (2014) Øgland, (2008) Palmberg, (2009a,b) Prewitt *et al.*, (2012) Rogers *et al.*, (2005) Rowe and Hogarth, (2005) Schneider and Somers, (2006) Sutherland and van den Heuvel, (2002)
Supply chain	Choi *et al.*, (2001) Isik (2011) Kanta and Zechman, (2014) Marchi *et al.*, (2014) Pathak *et al.*, (2007) Wycisk *et al.*, (2008)
Information systems and technology	Kovács and Ueno, (2004) McCarthy, (2003) Montmain *et al.*, (2015) Niazi, (2014) Phister Jr, (2010)
Leadership	Lichtenstein *et al.*, (2006)
Language	Beckner *et al.*, (2009)
Product design development and management	Chiva-Gomez, (2004) McCarthy *et al.*, (2006)
Psychology	Barton, (1994)
Economics	Foster and Pyka, (2014) Harper, (2014)
Law	Kim and Mackey, (2014)

Other papers dealt with the abstractive features of the CASs concept (Cornish *et al.*, 2009; Holden, 2005; Kochugovindan and Vriend, 1998; Lansing, 2003), namely, listing the key elements (Ellis and Herbert, 2011), on how to control and efficiently manage them (Abbott, 2007; Laszlo and Krippner, 1998), on the development of methodologies to assess them and their complexity (Avram and Rizescu, 2014) and on the identification of their mechanisms (Akgün *et al.*, 2014). In addition, a significant number of papers focused CASs modeling such as the one authored by Berry *et al.* (2002), the transfer of the theoretical concepts to a real world environment (Goldstone and Sakamoto, 2003; Pohl, 1999), the proposal of representational tools and improved visualization (Hmelo-Silver *et al.*, 2015; Viste and Skartveit, 2004), the underlying mathematical theory to the concepts (Levin, 2002), how to engineer them (White, 2010) and providing some theory concerning the mechanisms of failure (Woods and Branlat, 2011).

This paper follows with a brief description of the research methodology adopted. The next section, “Results and Discussion”, lists the properties or characteristics that were mentioned and adopted by the authors in the consulted bibliography to classify the most various focused systems as CASs. These same properties and characteristics are then targeted and dissected from the view point of the IMSs which, we expect, make our point concerning the classification of the IMSs as CASs. The “Concluding Remarks” section sum up the main topics addressed in the paper and points to potential further work considering scientific synergies between the two concepts (IMSs and CASs).

2. MATERIALS AND METHODS

A thorough revision of literature was carried out in order to proceed with the identification of the main properties that are ascribed in the different published papers and studied systems in order to label them as CASs. Several queries were performed in the soundest data bases, such as the “Web of Science”, “Scielo” and “Scopus” and in the repositories of *e*-journals such as “Elsevier Sciendirect”, “IEEE Xplore”. “Springer” and “Taylor and Francis” containing academic bibliographic resources. The papers considered for analysis were the ones containing keywords such as “CAS”, “Complex adaptive systems” and “Complex systems” in the title. Furthermore, although the desirable contribution from several research domains, a theoretical sampling took place of the bibliographical resources considering the topics closely related to IMSs (Organizational systems, management, innovation and planning). In addition, a comprehensive analysis of the sections of the standards that assist in the implementation of the various subsystems commonly combined into an IMS (ISO 9001- Quality MSs, ISO 14001- Environmental MSs and OHSAS 18001- Occupational health and safety MSs) was developed.

3. RESULTS AND DISCUSSION

IMSs are systems of systems and, from a viewpoint of the CASs, are complex adaptive systems of systems (CASoS) a concept proposed and adopted by several authors and entities such as Brown *et al.* (2013) and Sandia (2015) that depict systems where the primordial components are themselves systems, CASs or not, with several agents interacting internally and some features interacting beyond the original boundaries with other features from other subsystem(s). Evolving from a single CAS to a CASoS demands a compulsory redefinition of the boundaries, the assessment of the newly interactions arisen, the identification of novel emergent features and of all the dynamics involved. IMSs encompass several agents such as people, entities and organizations among other (Domingues *et al.*, 2012; Sampaio *et al.*, 2012). Additionally, and as stressed by Almeida *et al.* (2014), IMSs are standardized and certifiable organizational systems implemented by companies that intend at the same time to fulfil several stakeholders’ requirements, usually, the customers’ requirements (according to the ISO 9001 standard), the environmental requirements (according to the ISO 14001 standard) and the employees safety requirements (according to the OHSAS 18001 standard). In addition to the implementation of these standards it is possible to find out IMSs that comprise other MSs seeking to fulfil several sector specific requirements such as the ISO/TS 16949, the ISO 50001, the ISO/IEC 27001, ISO 13485 and the ISO 22000 (Domingues *et al.*, 2011).

The properties identified and discussed in this section were pointed out in a sample of 58 papers collected as described in the “Methodology and Methods” section. Figures 1 to 3 present the sample characterization concerning the year of publication, the typology of bibliographical resource and the topic or context where the study took place.

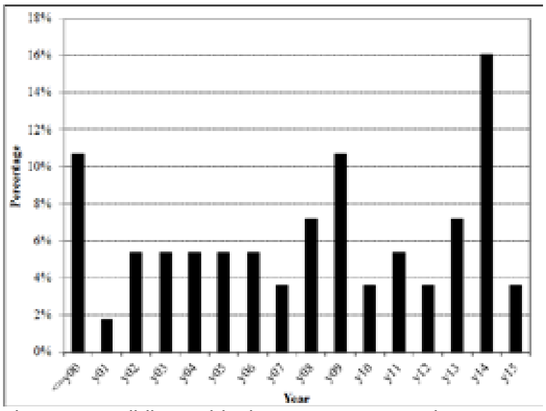

Figure 1: Bibliographical resources sample- Year of publication.

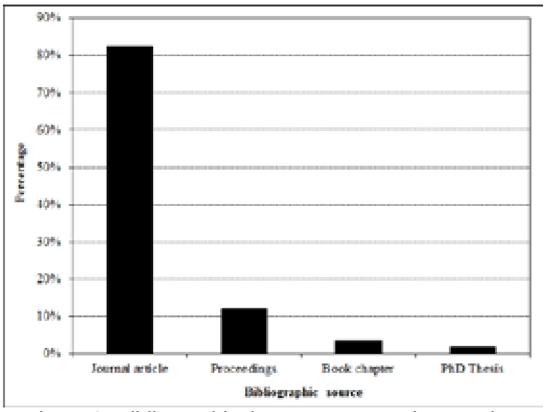

Figure 2: Bibliographical resources sample- Typology.

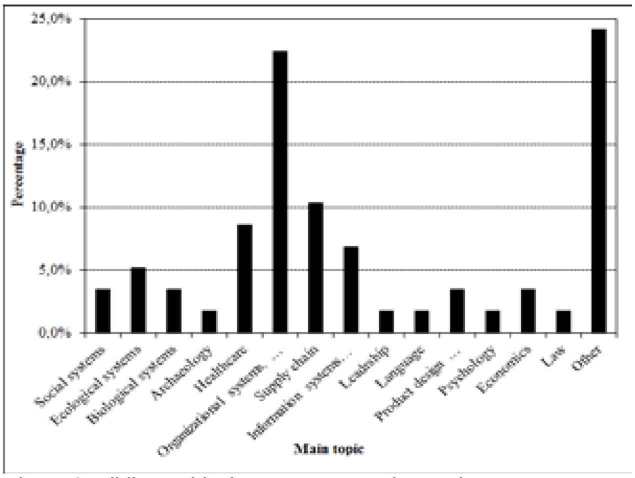

Figure 3: Bibliographical resources sample- Topic.

As one may observe, mainly journal articles (Figure 2) and publications from the last 5 years (Figure 1) were considered. Regarding the main topic addressed by the bibliographical resource (Figure 3) one should point out that the topic encompassing the organizational systems, management, innovation and planning concepts accounts for approximately a quarter of the sampled resources. From our viewpoint, the relevant and diverse contribution of the sampled articles (regarding the year of publication, typology and main subject) assures and improves both the reliability and internal validity of the findings.

3.1. IMSs as learning systems- How MSs learn?

A common feature from all the reported subsystems usually combined into an IMS is the continuous improvement methodology. This methodology, if properly implemented, triggers the stimulus for the learning process requiring that the system "learns" from mistakes and make progress through the identification of the improvement opportunities. Figures 1 and 2 display the continuous improvement construct ascribed to Deming and the Plan-Do-Check-Act (PDCA) cycle attributed to Shewart, both considered two Quality gurus. In fact, not pursuing a detected non-conformity or an improvement opportunity is itself a mistake that will be pointed out in the following internal or external audit. This is commonly and widely reported in CASs related bibliography as the feedback loops. This concept will be addressed later on in this paper.

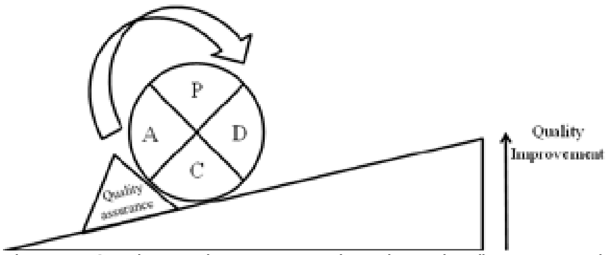

Figure 1: Continuous improvement (Deming Wheel).

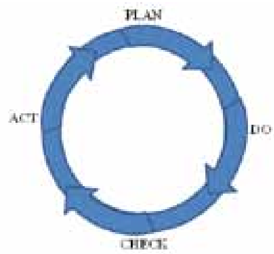

Figure 2: P-D-C-A Cycle (Shewart).

Although from a background that relates mainly to the quality MSs the continuous improvement methodology was later adopted by the other MSs as a proper and suitable tool to assure the learning process.

3.2. Agents that comprise the IMSs and their non-linear behavior- Which agents should be considered and which are the relationships between them?

In opposition to companies operating solely with a MS, a company operating simultaneously with multiple MSs (Figure 3) encompasses different and not always convergent goals seeking to attend several stakeholders' requirements. An IMS encompasses several agents and the relationships between them are not, at this moment, fully understood.

Figure 3: Domain of integrated management.

Among these agents, the individuals supersede the others. Beside the individuals, one may consider as agents, among others, the national bodies that manage environmental and OHS policies, the customers (other companies), the subcontractors, consultants and the company itself (its organizational culture that impacts on the employees, its strategic orientation, etc.). Several studies pointed out the lack of evidences concerning the relationships between the implementation methodologies adopted and the integration level attained (Bernardo *et al.*, 2011), the difficulties of integration and the integration level of MS human resources and the constructs of innovation and satisfaction (Simon *et al.*, 2014b) and event if MSs integration by SMEs was advantageous (Olaru *et al.*, 2014). In addition other papers stressed the lack of understanding of IMSs complexity, its integration levels and possibilities varies among companies (Mežinska *et al.*, 2013). These results illustrate the typology of relationships that one may find when researching into IMSs although it is not fully clear if the relationships are effectively absent or if the instrument that is being adopted to measure the phenomenon is adequate and, if adequate, is reliable.

3.3. Adaptive and (co)evolutionary perspective of the IMSs- How IMSs adapt to internal and external challenges?

One should take into account that the most popular MSs implemented by the companies are, in fact, standardized MSs so they are exposed to the successive external revisions developed in the standards. A closer look at the standards revision process, namely on the inputs collected for the process, disclose other concepts widely reported in CASs- the feedback loops and the notion of different scales of a peculiar phenomenon. The revision process from the most popular MSs, namely that of the ISO standards, is developed from the inputs provided by ISO members being these, usually, appointed by the national bodies that coordinate the quality system in each country. Hence, the revision process is in fact a feedback loop at a macro scale considering IMSs.

3.4. Emergent patterns and properties from the IMSs- What adds an IMS to an existing single MS?

Some properties, not previously discernible in the subsystems, arise and emerge from the integration of MSs. Each of these properties are characterized by a certain number of features that add increased complexity and demands for an analysis of the system through different levels, usually described as micro-, meso- and macro levels. One of these properties is what one may address for as the holistic property. IMSs are autonomous systems but are dependent on the environment (universe that surrounds the boundaries) concerning two critical factors to their evolution: resources and information exchanges, similarly, to the features pointed out by Oliveira *et al.* (2011) regarding horizontal inter-organizational networks.

3.5. Modularity and resilience

Several researchers pointed out that IMSs do have a modular nature or, at least, may be seen from a modular perspective. The main benefit to be collected from a system that has a modular nature is that although a module may be impaired regarding its performance that whole system is able to reconfigure in order to maintain its functionality, that is, the system has an improved performance when coping with change. Each MS that comprise the IMS has a structure that is common to the other MSs standards and some features that are specific. Concerning the environmental subsystems one can found the relevant feature of the identification and quantification of environmental impacts and regarding the OHSMSs one may found the systematic risk assessment concerning the menaces to the wellbeing of employees.

3.6. IMSs and self-organization- How IMSs manage to self-organize and which are the evidences of it?

Self-organization inherently arises from MSs integration if one consider, for instance, the audit function and the continuous improvement concept. When dealing with the follow up of a non-conformity or an improvement opportunity, in an integrated context, one should consider the requirements from all the stakeholders that should be attended. This constrains the set of possible solutions which, in an integrated context, decrease the degrees of freedom to a hypothetical upgrade proposed to deal with that distinctive non-conformity or improvement opportunity. Thus, in accordance with the definition previously pointed out in the "Introduction" section concerning the construct "Organization", the amount of information to describe the hypothetical solutions to deal with the non-conformity decreases, hence, the system self-organize. To sum up, it is not farfetched the statement that local interactions between the subsystems promotes the emergence of properties, characteristic of each IMS, that were previously (before the integration process) absent.

3.7. IMSs as complex systems

Comparing with other complex systems IMSs are hardly classifiable as fractal systems, *i.e.*, they are not self-similar at all scales. The different subsystems that comprise an IMS do have a common structure, known in the new 2015 revision of the standards as the high level structure (HLS), and this structure should be evidenced at the throughout all IMS levels but some low level elements that share intrinsically intimacy with the stakeholder to whom the standard addresses differ from standard to standard, hence, from subsystem to subsystem. The HLS acts as a command or control module and, due to this fact, the IMSs do not present the properties that are shared by other type of systems, on a related scientific domain, namely, the (hyper)networks (Johnson, 2010). Several strategies and methodologies have been adopted in the intent of "making sense" of the IMS phenomenon, namely, by "normalizing" them to enable comparison. Concerning this issue one may point out the development of maturity models by Domingues *et al.* (2014) and Idrogo *et al.* (2012) and several other models that sought to accommodate an increasingly number of stakeholders (Genaro and Loureiro, 2015; Rebelo *et al.*, 2014).

3.8. Multi-dimensional nature of the IMSs

IMSs are systems of systems with both horizontal and vertical (top-down and bottom-up dynamics), *i.e.*, taking into account an individual one may state that she (he) is affected and impacted by other individuals (horizontal dynamics) and affected by the group and organization where she (he) is inserted (e.g. organizational culture)- top-down dynamics. Nevertheless, it should be pointed out that both groups and organizations are developed based on individuals, on their beliefs, values, actions and aspirations (Johnson, 2010), *i.e.*, one should consider also bottom-up dynamics to accurately model and characterize the whole state of a company. Figure 4 displays the different levels of organization that one may find when researching into IMSs from a CASs perspective. It was adapted from a study concerning organizational learning but, from our viewpoint, suits accurately to the research field of IMSs and points out the notion that in the IMSs many different elements interact at many different scales. Although several other features that impact on the performance of the IMS (such as the culture adopted in the company and its mission) one of the most relevant, certainly, are the individuals that comprise it. These are in fact the 'butterfly wings' that may promote a "game changing" event.

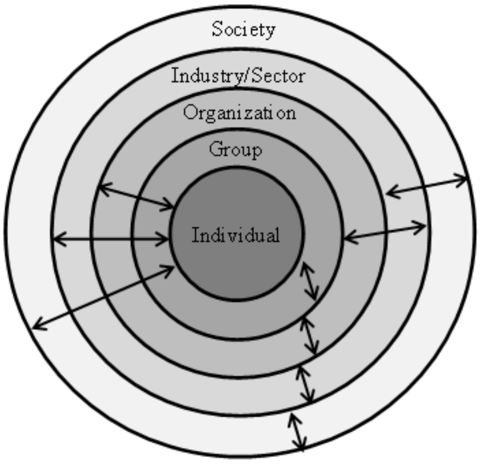

Figure 4: Levels of organizational learning (adapted from Antonacopoulou, 2005a)

3.9. Non-deterministic behaviour of IMSs

At the time, and although some published studies pointing out some critical success factors seems that some of the features that favours integrated management over non-integrated management are not totally accomplished even if, apparently, the implementation conditions are the same. Hence, it is appropriate to state that to distinctive features of the IMSs implementation are ascribed with a remarkable uncertainty. Among those features one may point out the integration level to be attained by the MSs, the expected benefits to be collected, the degree of articulation between the MSs that comprise the IMS, the inertia from the IMS concerning external inputs and its flexibility regarding the adaptation to the revisions from the implementation standards. This latter issue is particular relevant due to the major revisions expected in 2015 of both the ISO 9001 and ISO 14001 standards. Other relevant feature is the development of the audit function that apparently, considering the findings of the study from Simon *et al.* (2014a), differ according to its own nature- internal or external.

4. CONCLUDING REMARKS

This paper intended to point out some of the properties of the IMSs that match the properties of a peculiar type of systems known as CASs. To our knowledge, this is the first time that IMSs are depicted and dissected from the view point of learning, adaptive and dynamic systems which, hopeful, can be a fruitful contribution and may "open doors" concerning the development of further synergic studies involving the two concepts. By one side the scientific and academic community that address IMSs may collect relevant insights and a new and fresh perspective from the CASs community. On the other side, the CASs or CASoSs scientific communities, more focused on the concept itself than on the scientific domain, will certainly benefit from the reports of a particular system that is singular, often turbulent and that encompasses several agents. Specifically, the occupational health and safety researchers will be particularly fortunate if one consider that seldom are the OHSMS that operate as the single MS in a company (Domingues *et al.*, 2014). It is possible to conclude that IMSs are, in fact, CASoSs, *i.e.*, systems of systems with the capability of adaptation in order to prevail and attain success in its environment.

At the moment, there are several shortcomings that should be overcome so that they do not preclude the approach of IMSs from a CASs perspective. The major concerns are ascribed to the MSs integration phenomenon from an academic point of view, namely, the methodological issues to be adopted in the research design. The research approach concerning the integration of MSs should take into account that this is a contemporary and hardly controllable phenomenon, *i.e.*, in opposition to other systems approached through a CASs perspective the IMSs are not transferable to a laboratory environment. Although the collection of the data and the development of grounded theory may be achieved by qualitative research methods some underlying quantitative mathematical concepts seem to be critical to attain successful outcomes. Other methodological related limitation is the fact that when dealing with IMSs research one deal with a domain closely related to that of social sciences. To other scientific domains that embrace mainly quantitative research methods and that deal with "more easily" measurable variables the notion of a construct (widely adopted by qualitative researchers) is somehow alien

and may be looked with suspicion. In our view, the notion of construct and how to translate it to a mathematical language may be crucial to the development of a IMSs research field backed up by CASs related methodologies. This, we believe, will be the challenge for the next years and quoting once again Winston Churchill 'So, I have myself full confidence that if all do their duty, if nothing is neglected and if the best arrangements are made, as they are being made, we should prove ourselves once more able… to outlive the menace …' of ignorance regarding IMSs '…if necessary for years, if necessary alone.'.
To conclude, and it seems an appropriate metaphor due to the addressed topic, like the flapping wings of a seemingly unaware butterfly that output a hurricane on the other side of the world we humbly hope that this paper may impact similarly.

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6. REFERENCES

Abbott, R. (2007). Putting complex systems to work. *Complexity*, Vol. Nov/Dec, 10-11.

Akgün, A.E., Keskin, H., Byrne, J.C. & Ilhan, Ö.Ö. (2014). Complex adaptive systems mechanisms, adaptive management practices, and firm product innovativeness. *R & D Management*, 44(1), 18-41.

Almeida, J., Domingues, J.P.T. & Sampaio, P. (2014). Different perspectives on management systems integration. *Total Quality Management and Business Excellence*, 25(3-4), 338-351.

Amagoh, F. (2008). Perspectives on organizational change: Systems and complexity theories. *The Innovation Journal: The Public Sector Innovation Journal*, 13(3), 1-14.

Anand, M., Gonzalez, A., Guichard, F., Kolasa, J. & Parrott, L. (2010). Ecological systems as complex systems: Challenges for an emerging science. *Diversity*, 2, 395-410.

Antonacopoulou (2005a). The relationship between individual and organizational learning: New evidence from managerial learning practices. *Management Learning*, 37(4), 455-473.

Antonacopoulou, E. & Chiva, R. (2005b). Social complex evolving systems: Implications for organizational learning. *In proceedings of Organizational Learning, Knowledge and Capabilities (OLKC) Conference*, Boston, USA.

Arévalo, L.E.V. (2013). La organización empresarial como sistema adaptativo complejo. *Estudios Gerenciales*, 29, 258-265.

Avram, V. & Rizescu, D. (2014). Measuring external complexity of complex adaptive systems using Onicescu's informational energy. *Mediterranean Journal of Social Sciences*, 5(22), 407-417.

Barton, S. (1994). Chaos, self-organization, and psychology. *American Psychologist*, 49(1), 5-14.

Beckner, C., Ellis, N.C., Blythe, R., Holland, J., Bybee, J., Ke, J., Christiansen, M.H., Larsen-Freeman, D., Croft, W. & Shoenemann, T. (2009). Language is a complex adaptive system: Position paper. *Language Learning*, 59, Suppl. 1, 1-26.

Bernardo, M., Casadesús, M. and Karapetrovic, S. (2011). Are methods used to integrate standardized management systems a conditioning factor of the level of integration? An empirical study. *International Journal for Quality Research*, Vol. 5, No. 3, pp. 213-222.

Berry, B.J.L., Kiel, L.D. & Elliott, E. (2002). Adaptive agents, intelligence, and emergent human organization: Capturing complexity through agent-based modeling. *Proceedings of the National Academy of Sciences (PNAS)*, 99, Suppl. 3, 7187-7188.

Bolton, M.J. & Stolcis, G.B. (2008). Overcoming failure of imagination in crisis management: The complex adaptive system. *The Innovation Journal: The Public Sector Innovation Journal*, 13(3).

Bovaird, T. (2008). Emergent strategic management and planning mechanisms in complex adaptive systems. *Public Management Review*, 10(3), 319-340.

Brown, T.J., Conrad, S.H., Beyeler, W.E. & Glass, R.J. (2013). Complex adaptive systems and risk reduction. *Proceedings of the ICE- Engineering Sustainability*, 166(5), 293-300.

Champlin, C.J., Hartmann, T., Dewulf, G.P.M.R. & Flacke, J. (2013). Industrial revitalization and complex adaptive systems: A framework for exploring the context of collaborative planning. *In proceedings of the European Research Association (EURA) Conference*, Enschede, The Netherlands.

Chen, D. & Stroup, W. (1993). General system theory: Toward a conceptual framework for science and technology education for all. *Journal of Science Education and Technology*, 2(3), 447-459.

Chiva-Gomez, R. (2004). Repercussions of complex adaptive systems on product design management. *Technovation*, 24, 707-711.

Choi, T.Y., Dooley, K.J. & Rungtusanatham, M. (2001). Supply networks and complex adaptive systems: control versus emergence. *Journal of Operations Management*, 19, 351-366.

Cordon, C.P. (2013). System theories: An overview of various system theories and its application in healthcare. *American Journal of Systems Science*, 2(1), 13-22.

Cornish, H., Tamariz, M. & Kirby, S. (2009). Complex adaptive systems and the origins of adaptive structure: What experiments can tell us. *Language Learning*, 59, Suppl. 1, 187-205.

Diment, K., Yu, P. & Garrety, K. (2009). Complex adaptive systems as a model for evaluating organisational change caused by the introduction of health information systems. *In proceedings of the Health Informatics Society of Australia Conference*, 19-21 August, Canberra, Australia.

Domingues, J.P.T., Sampaio, P. and Arezes, P.M. (2011). Integrated management systems: the vision from the perspective of the OHS&MS. *In proceedings of SHO 2011*, 10^{th} - 11^{th} February, Guimarães, Portugal, pp. 240-245.

Domingues, J.P.T., Sampaio, P. & Arezes, P.M. (2012). New organisational issues and macroergonomics: integrating management systems. *International Journal of Human Factors and Ergonomics*, 1(4), 351-375.

Domingues, J.P.T, Sampaio, P. & Arezes, P.M. (2014). Analysis of integrated management systems from various perspectives. *Total Quality Management and Business Excellence*, in press, DOI: 10.1080/14783363.2014.931064.
Edgren, L. & Barnard, K. (2012). Complex adaptive systems for management of integrated care. *Leadership in Health Services*, 25(1), 39-51.
Eidelson, R.J. (1997). Complex adaptive systems in the behavioural and social sciences. *Review of General Psychology*, 1(1), 42-71.
Ellis, B. & Herbert, S.I. (2011). Complex adaptive systems (CAS): an overview of key elements, characteristics and application to management theory. *Informatics in Primary Care*, 19, 33-37.
Fabac, R. (2010). Complexity in organizations and environment- adaptive changes and adaptive decision-making. *Interdisciplinary Description of Complex Systems*, 8(1), 34-48.
Foster, J. & Pyka, A. (2014). Introduction: co-evolution and complex adaptive systems in evolutionary economics. *Journal of Evolutionary Economics*, 24(2), 205-207.
Genaro, A.F.S. & Loureiro, G. (2015). Stakeholder management as an approach to integrated management systems (IMS_{STK}). Advances in Transdisciplinary Systems, Vol. 2, in Curran, R., Wognum, N., Borsato, M., Stjepandić, J. and Verhagen, W.J.C. (editors), ISBN: 978-1-61499-543-2, IOS Press BV, 31-39.
Goldstone, R.L. & Sakamoto, Y. (2003). The transfer of abstract principles governing complex adaptive systems. *Cognitive Psychology*, 46, 414-466.
Harper, D.A. (2014). Property rights as a complex adaptive system: How entrepreneurship transforms intellectual property structures. *Journal of Evolutionary Economics*, 24(2), 335-355.
Hartvigsen, G., Kinzig, A. & Peterson, G. (1998). Use and analysis of complex adaptive systems in ecosystem science: overview of special edition. *Ecosystems*, 1, 427-430.
Hegazi, A.S., Hashish, A.H. & Ahmed, E. (2009). On managing complex adaptive systems motivated by biosystems application to infections*. Nonlinear Biomedical Physics*, 3(11).
Hmelo-Silver, C.E., Liu, L., Gray, S. & Jordan, R. (2015). Using representational tools to learn about complex systems: A tale of two classrooms. *Journal of Research in Science Teaching*, 52(1), 6-35.
Holden, L.M. (2005). Complex adaptive systems: concept analysis. *Journal of Advanced Nursing*, 52(6), 651-657.
Hulsman, K., Tularam, G.A. & Willett, G. (2011). The application of reductive methods to study complex- and complex-adaptive systems in ecology. *International Journal of Ecology and Environmental Sciences*, 37(3), 93-104.
Igbo, K.E. (2013). Managing disruptions in complex adaptive systems: A case for resilience in airline operations control. *In proceedings of the International Conference on Naturalistic Decision Making*, Marseille, France.
Isik, F. (2011). Complexity in supply chains: A new approach to quantitative measurement of the supply-chain-complexity. Dr. pengzhong Li (Ed.), ISBN: 978-953-307-184-8, InTech, Available from: http://www.intechopen.com/books/supply-chain-management/complexity-in-supply-chains-anew-approachto-quantitative-measurement-of-the-supply-chain-complexity.
Johnson, J. (2010). Hypernetworks for the science of complex systems. *Presentation at the Complex Systems Winter School*, Lisbon, 11th- 15th January.
Kanta, L. & Zechman, E. (2014). Complex adaptive systems framework to assess supply-side and demand-side management for urban water resources. *Journal of Water Resources Planning and Management*, 140(1), 75-85.
Kim, R.E. & Mackey, B. (2014). International environmental law as a complex adaptive system. *International Environmental Agreements- Politics Law and Economics*, 14, 5-24.
Kochugovindan, S. & Vriend, N. (1998). Is the study of complex adaptive systems going to solve the mystery of Adam Smith´s “invisible hand”?. *The Independent Review*, III(1), 53-66.
Kovács, A.I. & Ueno, H. (2004). Towards complex adaptive information systems. *In proceedings of the 2nd International Conference on Information Technology for Application*, Harbin, China.
Kohler, T.A. (2012). Complex systems and archaeology. In *Archaeological Theory Today*, 2nd edition, Ian Hodder (ed.), Polity Press, Cambridge, 93-123.
Lansing, J.S. (2003). Complex adaptive systems. *Annual Review of Anthropology,* 32, 183-204.
Laszlo, A. & Krippner, S. (1998). Systems theories: Their origins, foundations, and development. In J.S. Jordan (Eds), Systems Theories and A Priori Aspects of Perception. Amsterdam: Elsevier Science, chapter 3, 47-74.
Levin, S.A. (2002). Complex adaptive systems: Exploring the known, the unknown and the unknowable. *Bulletin of the American Mathematical Society*, 40(1), 3-19.
Lichtenstein, B., Uhl-Bien, M., Marion, R., Seers, A., Orton, J.D. & Schreiber, C. (2006). Complexity leadership theory: An interactive perspective on leading in complex adaptive systems. *Emergence: Complexity and Organization*, 8(4), 2-12.
Mainzer, K. (1997). Thinking in Complexity: The Complex Dynamics of Matter, mind and Mankind, Springer editions, 3rd edition, ISBN: 3-540-62555-0.
Marchi, J.J., Erdmann, R.H. & Rodriguez, C.M.T. (2014). Understanding supply networks from complex adaptive systems. *Brazilian Administration Review*, 11(4), 441-454.
Martin, C.M. (2011). Distortions, belief and sense making in complex adaptive systems for health. *Journal of Evaluation in Clinical Practice*, 17, 387-388.
Martínez-García, M. & Hernández-Lemus, E. (2013). Health systems as complex systems. *American Journal of Operations Research*, 3, 113-126.
McCarthy, I.P. (2003). Technology management: a complex adaptive systems approach. *International Journal of Technology Management*, 25(8), 728-745.
McCarthy, I.P., Tsinopoulos, C., Allen, P. & Rose-Anderssen, C. (2006). New product development as a complex adaptive system of decisions. *The Journal of Product Innovation Management*, 23, 437-456.
McDaniel Jr., R.R., Lanham, H.J. & Anderson, R.A. (2009). Implications of complex adaptive systems theory for the design of research on health care organizations. *Health Care Management Review*, 34(2), 191-199.
Mežinska, I., Lapiņa, I. and Mazais, J. (2013). Integrated management systems towards sustainable and socially responsible organisation. *Total Quality Management and Business Excellence*, in press, DOI: 10.1080/14783363.2013.835899.
Monostori, L. & Csáji, B.C. (2008). Complex adaptive systems (CASs) approach to production systems and organisations. *In proceedings of Manufacturing Systems and Technologies for the New Frontier, The 41st CIRP Conference on Manufacturing Systems*, M. Mitsuishi, K. Ueda and F. Kimura editors, May 26-28, Tokyo, Japan, 19-24.

Montmain, J., Labreuche, C., Imoussaten, A. & Trousset, F. (2015). Multi-criteria improvement of complex systems. *Information Sciences*, 291, 61-84.
Nan, N., Zmud, R. & Yetgin, E. (2014). A complex adaptive systems perspective of innovation diffusion: an integrated theory and validated virtual laboratory. *Computational and Mathematical Organization Theory*, 20(1), 52-88.
Niazi, M.A. (2014). Complex adaptive systems and computing laws. *Computer*, Letter, Vol. 47, No. 5,16.
Olaru, M., Maier, D., Nicoară, D. and Maier, A. (2014). Establishing the basis for development of an organization by adopting the integrated management systems: comparative studies of various models and concepts of integration. *Procedia- Social and Behavioral Sciences*, 109, 693-697.
Oliveira, O.L., Rezende, D.C. & Carvalho, C.C. (2011). Horizontal inter-organizational networks as a complex co-evolutionary adaptive system: the case study of a supermarket network. *Revista de Administração Contemporânea*, 15(1), 67-83.
Øgland, P. (2008). Designing quality management systems as complex adaptive system. *Systemist*, 30(3), 468-491.
Palmberg, K. (2009a). Complex adaptive systems as metaphors for organizational management. *The Learning Organization*, 16(6), 483-498.
Palmberg, K. (2009b). Beyond process management: Exploring organizational applications and complex adaptive systems. Doctoral Thesis, Luleå University of Technology, Department of Business Administration and Social Sciences, Division of Quality Management, Sweden.
Pathak, S.D., Day, J.M., Nair, A., Sawaya, W.J. & Kristal, M.M. (2007). Complexity and adaptivity in supply networks: Building supply network theory using a complex systems perspective. *Decision Sciences*, 38(4), 547-580.
Phister Jr, P.W. (2010). Cyberspace: The ultimate complex adaptive system. *The International C2 Journal*, 4(2), 1-30.
Pohl, J. (1999). Some notions of complex adaptive systems and their relationship to our world. *In proceedings of InterSymp-99: Advances in Collaborative Decision-Support Systems for Design, Planning and Execution*, 2-7 August, Baden-Baden, Germany, pp. 9-24.
Prewitt, J.E., Weil, R. & McClure, A.Q. (2012). A complex adaptive systems approach to strategic planning. *Asian Journal of Business and Management Sciences*, 1(11), 94-99.
Rammel, C., Stagl, S. & Wilfing, H. (2007). Managing complex adaptive systems- A co-evolutionary perspective on natural resource management. *Ecological Economics*, 63, 9-21.
Rebelo, M.F., Santos, G. and Silva, R. (2014). A generic model for integration of quality, environment and safety management systems. *The TQM Journal*, 26(2), 143-159.
Rogers, E.M., Medina, U.E., Rivera, M.A. & Wiley, C.J. (2005). Complex adaptive systems and the diffusion of innovations. *The Innovation Journal: The Public Sector Innovation Journal*, 10(3), 1-26.
Rowe, A. & Hogarth, A. (2005). Use of complex adaptive systems metaphor to achieve professional and organizational change. *Journal of Advanced Nursing*, 51(4), 396-405.
Sampaio, P., Saraiva, P. & Domingues, P. (2012). Management systems: Integration or addition?. *International Journal of Quality and Reliability Management,* 29(4), 402-424.
Sandia (2015). http://www.sandia.gov/CasosEngineering/ (accessed 12/02/2015).
Schneider, M. & Somers, M. (2006). Organizations as complex adaptive systems: Implications of complexity theory for leadership research. *The Leadership Quarterly*, 17, 351-365.
Simon, A., Yaya, L.H.P., Karapetrovic, S. and Casadesús, M. (2014a). An empirical analysis of the integration of internal and external management system audits. *Journal of Cleaner Production,* Volume 66, pp. 499-506.
Simon, A., Yaya, L.H.P., Karapetrovic, S. and Casadesus, M. (2014b). Can integration difficulties affect innovation and satisfaction?. *Industrial Management and Data Systems*, Vol. 114, No. 2, pp. 183-202.
Sutherland, J. & van den Heuvel, W.-J. (2002). Enterprise application integration encounters complex adaptive systems: A business object perspective. *In proceedings of the 35th Hawaii International Conference on Systems Sciences*, Hawaii, USA.
Viste, M. & Skartveit, H.-L. (2004). Visualization of complex systems- The two-shower model. *PsychNology Journal*, 2(2), 229-241.
Wheatley, M.J. (1993). Chaos and complexity: What can science teach?. *OD Practitioner*, Fall, 2-10.
White, B.E. (2010). Complex adaptive systems engineering. *IEEE Aerospace and Electronic Systems Magazine*, 25(12), 16-22.
Woods, D.D. and Branlat, M. (2011). Chapter 10- Basic patterns in how adaptive systems fail. In E. Hollnagel, J. Pariès, D.D. Woods, & J. Wreathall (Eds.), Resilience Engineering in Practice. Farnham, UK: Ashgate.
Wycisk, C., McKelvey, B. & Hülsmann, M. (2008). “Smart parts” supply networks as complex adaptive systems: analysis and implications. *International Journal of Physical Distribution and Logistics Management*, 38(2), 108-125.

The trajectory deviation, a new methodology for automotive systems evaluation

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Abstract

Vehicles contain many accessory systems not specifically for driving, but for supplementary functions such as air conditioning, radio/multimedia, and more. Functions such as satellite navigation, hands-free cell phone, seat adjustments, and on-board computers are some other examples of functions actually available. As technology evolves, supplementary functions are added. Inevitably, the complexity of the function controls and their physical interfaces also increases, which can increase the probability of having an accident. This has been a great challenge for car manufacturers around the world, as they try to create the perfect solutions without compromising the driving safety. Driver distraction defines the deviation of focus from the primary task of driving a vehicle, to a secondary task, consequently diminishing the performance of the primary one. The causes for this distraction can be of unlimited sources, but they emerge from the effects of perturbation of certain human resources required for driving. There are three types of driver distraction that can affect drivers in different ways: (1) Visual distraction, tasks that require the driver to look away from the roadway to visually obtain information; (2) Manual distraction, tasks that require the driver to take a hand off the steering wheel and manipulate a device; (3) Cognitive distraction, tasks that require the driver to avert their mental attention away from the driving task. The tasks performed by drivers can be of one, two, or all three of these distraction types at a time. The main objectives of the present work were to understand: (a) How much are the actual automotive central consoles safe and helpful to the driving task; (b) How effectively can we measure the driver distraction while driving and performing tasks on the central consoles. It is expected that from this analysis some conclusions could be achieved that should lead to an improvement opportunity, that could result from a combination of the systems, or could even give opportunity to develop an alternative new solution or a good practice guide for future developments. The used methodology employed a driving simulator to present a highly immersive driving experience, with physics accuracy and telemetry exportation of the acquired driving data. The main metric indicators used were trajectory deviation, eyes-off-the-road time and self-perceived workload. The presented methodology was proven valid to evaluate in-vehicle systems that depend on human interaction, but the realism and immersion of the experience must be as high as possible. This methodology provides a way to relate the most important indicators about the driving performance and their retrieved data, in order to create a classification system that allows the definition of a system performance. This relation makes possible to evaluate human-machine interaction systems in terms of physical and psychological factors in a realistically simulated driving environment, without accident risk and with a low budget solution. The presented solution allows the acquisition of a large amount of data not only about the driving task itself, but also of all the associated tasks and systems that may be created and tested in a realistic driving environment.

Keywords: Automotive interfaces; Mental workload; Driver distraction; Interface evaluation; Eye tracking.

1- INTRODUCTION

Inside the car there are a lot of considerations to take in account in order to develop a functional environment. Designing a vehicle involves the design, development and integration of a large number of systems and subsystems within a vehicle (Bhise & Pillai, 2006). This is a very complex process which involves multidisciplinary teams, working together in order to fit all the features within the existing limited space, nevertheless fulfilling the function for which they were designed, providing the vehicle the ideal combination of all the needed attributes such as appearance, performance, safety, ride and comfort (Bhise & Pillai, 2006).

One of the most complex assemblies within an automobile is the centre console. They are function populated areas where there are instruments and information systems, HVAC ducting and all interaction driver-vehicle features, all of them struggling for space and driver attention.
A vehicle consists of many systems that are not specifically for driving, but are, instead, for supplementary functions such as air conditioning, radio/multimedia, and more (Jonghyun Ryu, Jaemin Chun, Gunhyuk Park, Seungmoon Choi, & Han, 2010). Functions as satellite navigation, parking help, cell phone hands-free and accessories, seat adjustments, ride adjustments, engine and mechanical adjustments, and on-board computers are other examples of functions actually available in the automobiles.
As technology evolves, an increasing number of supplementary functions are added. Inevitably, the complexity of the function controls also increases. A recent solution for the problem has been the Driver Information System (DIS): a multifunctional system that provides a unified interface to control the vehicle electronics (Simões, 2011).
All these systems need physical interfaces in order for being manipulated by the driver during various driving conditions. Ryu et al. (2010) also refers that these kinds of systems require the driver´s visual attention for selecting the desired functions, which can increase the probability of having an accident.
Fai, Delbresine and Rauterberg (2007) (apud Simões(Simões, 2011)) Also refers that the most important concept in automotive industry is safety, and Simões (2011) refers that for that each component designed must be able to reduce injury to the occupants during a collision.
Murata and Moriwaka (2005) also argue that the use of additional in-vehicle information systems to promote safer driving should avoid distracting the driver from their main sources of visual information outside the vehicle. As suggested by Burns, Harbluk, Foley and Angell (2010) is glances away from the road scene prior to critical events that predominate in real-world crashes and near-misses.

1.1- Contemporary interfaces development
This has been a great challenge for car manufacturers around the world, but until today there hasn't been a consensus about the perfect solutions, and some solutions that seem ideal in some situations, became hardest or dangerous in other cases as suggested by Rydström, Broström, and Bengtsson, (2011) arguing that in terms of task completion time and the number of glances made to the display, there is not one input device that is always the best choice, since certain interaction devices are more suitable for certain kinds of tasks.
So in this search for the balance for the perfect system, the carmakers developed their own ideal interaction interfaces.

1.2- Driver distraction
Driver distraction is a term that defines the deviation of focus from the primary task of driving a vehicle, to a secondary task, consequently diminishing the performance of the primary one. The causes for this distraction can be of an immense range of possibilities, but they emerge from the effects of perturbation of certain human resources required for driving, so they can be arranged in a few types.
According to the National Highway traffic Safety Administration (NHTSA) there are three types of driver distraction that can affect drivers in different ways (Department of Transportation, 2014): Visual distraction: Tasks that require the driver to look away from the roadway to visually obtain information; Manual distraction: Tasks that require the driver to take a hand off the steering wheel and manipulate a device; Cognitive distraction: Tasks that require the driver to avert their mental attention away from the driving task.
The tasks performed by drivers can be of one, two, or all three of these distraction types at a time.
Torkkola, Gardner, Schreiner, Zhang, Leivian, Zhang, & Summers (2008) defined that in addition to interacting with on-board systems, drivers are also choosing to carry in mobile devices such as cell phones to increase productivity while driving. They argued that because technology is increasingly available for allowing people to stay connected, informed, and entertained while in a vehicle, many drivers feel compelled to use these devices and services in order to multitask while driving (Torkkola et al., 2008). As seen, drivers often engage in various parallel activities inside the car while driving, exploring the world of multifunctional environment

the cars provide nowadays. When using the central console interfaces to perform tasks, they give away very important part of their human driving resources.
According to NHTSA the impact of distraction on driving is determined by, the type and level of distraction, the frequency and duration of task performance and the degree of demand associated with a task. Even if performing a task results in a low level of distraction, a driver who engages in it frequently, or for long durations, may increase the crash risk to a level comparable to that of a more difficult task performed less often (Department of Transportation, 2014).
Authors hope to get clues where the centre consoles are getting badly designed, and thus a central console design guide could be further developed, in order to allow the carmakers, and designers to understand the main directions in creating a more user-friendly automotive environment, and to improve driving safety.

2 - MATERIALS AND METHOD

2.1 – Interface selection criteria

In this study the physical interfaces were the chosen systems, because the objective was to measure how much the interaction with the interfaces can hazard the driving performance. In order to test a wide range of central console interfaces, the simulator must have a representation of a centre console in which should be mounted all the interfaces to be used during the tests.
The centre console for this study had reunited all the major systems used in console interaction, and it was positioned in the simulator, with an ergonomically adjustable range of positions which combined with the seat adjustments, were the ideal conditions to match the subject's anthropometric requirements.

2.2- Driving simulators

For the realism of the experience and to achieve more reliable results, a very good driving simulator is needed, with a highly immersive driving experience, physics accuracy and the ability to have telemetry to export the acquired driving data. The flexibility to customize the simulator is also one very important feature in order to control the driving environment and create an experience with a minimized influence from environment events.
After some extensive testing it was decided that rFactor® was the best solution, because it has an engine that allows customization of a greater variety of factors than the other available options, and it was the only that allowed the level of customization and data acquisition needed for this study. Beyond all the programming capabilities, its physical outputs are very accurate and lots of professional race teams use it for testing and training (Birch, 2014).

2.3- Metric indicators definition

As suggested by Minin (2012) An indicator reflects driving performance when it detects the behavioural changes caused by the impact of a secondary task.
As North Atlantic Threaty Organization (NATO) Geddie, Boer, Edwards, Enderwick, Graff, Pfender, Ruisseau and Van Loon (2001) supposed, two systems with the same level of overall performance may impose quite different levels of workload on operators. This suggests why is important to measure not only the driving performance, but also the workload users experience during the double task operations. As pointed by NATO, the workload data is evaluated by analytical techniques, which can be used already in the design phase of a system (Geddie et al., 2001).
As suggested by Young, Regan and Hammer (2003) using a range of distraction measurement techniques, rather than a single technique, would be appropriate in evaluating HMI design concepts and prototypes in vehicles.
In order to gather important information about this interaction between the driver and the central consoles, a relation between three very important indicators will be analysed: The driving line, the driver's visual attention, and the perceived workload of the driver.
As pointed by Minin et al. (2012) the primary effects on lateral position variations are drivers actions on the steering wheel, so the driving line is the major indicator to identify driving disturbance.
Eye tracking, as indicated by Torkkola et al (2008) is the prevailing method for detecting driver inattention, using the camera to track the driver´s head or eyes. Curry, R., Greenberg, J., & Blanco, M., (2002) and Haigney, D., & Westerman, S. J., (2001) argued that eyes-off-the-road

time is a widely accepted and valid measure of the visual demand associated with the performance of a secondary task and is highly correlated with the number of lane excursions committed during secondary task performance.
Hart and Staveland (1988) suggested that in comparison with other workload assessment methods, subjective ratings (as NASA TLX) may come closest to tapping the essence of mental workload and provide the most generally valid and sensitive indicator.
To achieve this information without any life integrity risks, a driving simulator will be developed, where all the centre console interactions can be replicated, and where the interfaces would be tested in virtual environment. The simulator software allows a good data recording and processing, registering a lot of telemetry data that will give the main clues to understand drivers' distraction caused by a certain interface.
As pointed by Young et al. (2003) an important aspect to consider when measuring driving distraction is the selection of the appropriate baseline measure against which to compare driving performance when interacting with various devices. Thus, for this study, is assumed that the distraction provoked by a certain task involving the centre console, is defined by measuring the amount of trajectory deviation registered during that task, and correlating it with the "eyes-off-the-road" mean time. Thus, this result is correlated with a workload measuring RAW NASA TLX method (RTLX), that gives us a result about the driver self perception of workload, and makes possible to relate if the recorded data, is compliant with the drivers feelings when exposed to double task danger situations.
For the NASA RTLX procedure, the drivers will perform an enquiry about each task indicating the values of the self-percept workload. The task workload measure will be indicated by the mean resultant from the perceived workload values indicated.
The most effective way to implement optimizations on minimising the interface-based distraction is to design the Human-Machine Interface (HMI) in an ergonomically ideal way. Using this combination of methods it is expected to obtain reliable data about the effectiveness and safety of the in vehicle interfaces on the automotive centre console, and then identify strengths and weaknesses in order to establish a guideline of good practices in automotive centre console interfaces design and development.

2.3.1- Driving line deviation comparison

Theoretically, the ideal trajectory in terms of safety is the centre of the driving lane, which is named in this study as "Theoretic driving line". The normal everyday driving of the majority of the subjects is not accurate and everyone has his individual driving way, acting according to an infinite amount of causes and past experiences, causing them to use different approaches to every situation that happens on the road. These differences doesn't mean they´re driving in a wrong way, but instead, that there´s an immense amount of correct ways do drive a car along a road. These approaches vary according to the driving perception and life posture of an individual, state-of-mind, self-respect, respect for life and integrity of others, monetary issues, and in an infinite way of safety affecting issues, that can be safer or dangerous for the driver, for the others, or for the surrounding environment. This issue and its problematic, takes us to the first lap of the test.
In this first lap the habitual trajectories without performing tasks of each driver are recorded, to get the without task "real driving line reference" which represents their everyday driving with their everyday way of getting a vehicle along a road. This first lap is hereafter compared with the theoretic reference lap, which will give us the deviation of the everyday driving without tasks of the subject from the ideal theoretic line (centre of the driving lane). This deviation is afterwards subtracted to the second lap, to achieve to each test subject the "real deviation" that is performed in the tasks lap, and is representative of the task deviation from their normal everyday driving. Following, the second lap is compared to the "theoretic reference lap" to achieve the theoretic deviation when performing tasks, and to measure the maximum deviation from the centre of the lane, which will tell us if the extreme point of the vehicle will cross or not the roadside or the central line in the road that limits the traffic directions. This is needed in order to identify, whether or not, the drivers at some point of the circuit invaded the opposite traffic lane. If that happened, there is an imminent danger of collision.
In all the trajectory deviation measurements, the deviation will be compared with the mean speed along the sectors, providing a way of understanding the effects of the speed on the deviations, and allowing to adjust the results and make them speed independent, comparable and valid between every test subject. This information is needed because the speed that the drivers use, along each task, wasn´t equal for everyone, and each test subject have different

approaches in terms of speed. Various studies suggested that the speed at which an individual drives, affects seriously the performance during tasks, and the faster a person drives, the more important is the far ahead part of the road, or lane keeping performance deteriorates (Knappe, Keinath, Bengler, & Meinecke, n.d.).

2.3.1.1-The trajectory deviation measurement

The trajectory deviation indicator is probably the most important indicator measurement that needs to be quantified in this study, because it will give the exact amount of distance a car travels laterally, in order to understand how negative the effects of the interfaces in the car path while driving are. The lateral deviation of the car, when surpassing certain values, is an indicator of imminent danger of collision, and injury to the vehicle, its occupants or to the surrounding world.
To understand the trajectory deviation between telemetry exported files, an Excel Spreadsheet algorithm application has been developed that makes a comparison between the reference laps and the ones performed by the study subjects. The simulator software outputs the information about the mean deviation through each sector, the maximum deviation present in each sector, and outputs the information about the mean speed thorough the sector.
The trajectory deviation is measured mathematically using a vector between two of the points of the reference lap, and using a perpendicular vector through the midpoint of that one, to intercept the deviated line, retrieving the value of the deviation (Figure 1). The sum of all deviation values is then related to the number of measured points through the sector distance, to have a mean deviation value. The amount of vectors used, is the amount of points present in each sector of the reference lap, and that value is sector size dependant and thus is fixed and is the same for every test that is compared to that reference lap.

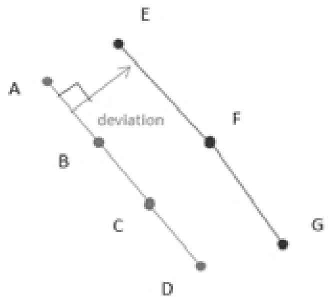

Figure 1 - Deviation measurement scheme.

The maximum deviation value per sector is known, presenting the vector with the maximum value of them all inside that specific sector.
The telemetry measures obtained are outputted in millimetres, which can be directly related in 1:1 scale with the real world dimensions The measures were confirmed using a screenshot of the simulator, defined in a vehicle in the road situation with a good perspective that allowed a good perception of distances, and measures were obtained relating a vector with the vehicle width between mirrors, with a vector with the road size. Using a rule of three, the car vector was related with the road vector, achieving the approximate road width. The measurement was done as shown in Figure 2:

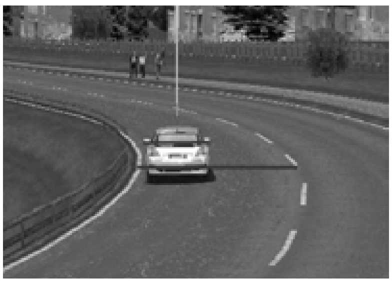

Figure 2 - Vector measurement of the track width.

The maximum width of the simulator road in simulator units is 10000 units, which means each driving lane has 5000 units in the simulator. The out-of-towns mean road width in Portugal is 7 meters, divided in 3,5 meters for each driving lane. The road used in the simulator was developed for the simulator with 10000 millimetres wide, which means each driving lane has 5000 mm. The car was 1928 mm wide between mirrors according to the manufacturer's owner's manual. These measures were considered acceptable as they are not too far between the simulated drive, and the real world drive, and they allow compensation about the subjects' lack of habitude of the simulated driving.

2.3.2- The workload

The workload experimented by an individual can be defined as the cost of accomplishment of certain mission requirements for the human operator (Hart, 2006) or the portion of human resources an operator expends when performing a specified task (Geddie et al., 2001).
As humans, the operators are not perfect beings with machine performance, which in this case means that there are numerous factors that influence the difficulty of getting the tasks demands perfectly accomplished. Since humans cannot do everything perfectly done, perfectly fast, with no difficulties and no errors, there is a need to measure and understand the workload caused by systems and its interfaces, in order to get those who are interested in systems development and performance, in touch with the user's difficulties. Understanding how a certain system demands resources from a human operator, and understanding how effectively he accomplishes them, is a crucial part of the design improvement process, as it allows researchers to understand which difficulties appear, and how strongly they affect the accomplishment of the task by the human operator.
The driving task is one of the most demanding tasks, concerning human resources demand from the operators, as it requires physical, visual, cognitive, temporal and psychomotor resources, sometimes, all at once. Performing tasks during this situation is considered to be an extremely hazardous activity, as it decreases driving ability, and may cause traffic accidents.
To understand the tasks performed while driving and how they affect the driving ability, there is the need to acquire data about the performance of the subjects during the tasks performed in the simulator test, expecting that the results will indicate if the workload caused by a certain task is directly related to the trajectory deviation, or the "eyes off the road" time.

2.3.2.1- Methods for workload measurement

Despite of its subjectivity, the process of acquiring workload data is somewhat scientifically explored, and in the past few years some methods reached notable success. For evaluation of workload under driving task situations, there are proper methods that better diagnose the workload of the user. A research made by NATO´s Research and Technology Organization (RTO) shown that "for human engineering testing and evaluation, subjective methods, especially rating scales, which access operator or observer judgements of a task, have many advantages and relatively few disadvantages in measuring operator workload compared to the other approaches". These methods present high validity, minimal costs, easy implementation in a high variability of tasks, can be done by an external observer, and can be used preventively in development phases of a system design.
NATO´s RTO, expresses as the most indicated methods to measure the workload of tasks while driving are: NASA TLX (Nasa Task Load Index), SWAT (Subjective Workload Assessment Technique), and ZEISS (Sequential Judgement Scale). All these methods have their strengths and weaknesses, which were analysed and compared in order to understand which one is the recommended to measure the workload while driving and performing tasks on the interfaces presented during the simulator tests. The choice for was the NASA TLX.

2.3.2.2- NASA task load index (NASA TLX)

The NASA Task Load index is a subjective assessment tool, which assesses the perceived workload of an individual while performing tasks, in order to evaluate system effectiveness, in terms of task completion and the human effort needed to accomplish it.
The normal NASA TLX works with a two stage test structure: In the first part each user defines which weight has each contributing factor, to the workload of a specific task and this is made by a pair-wise comparison system.
According to the NASA TLX manual (NASA - Human Performance Research Group, 2013), there are 15 possible pair-wise comparisons of the six scales. Each pair is presented on a card.

Subjects select the member of each pair that contributed more to the workload of that task. The number of times a factor is selected is its weight for the workload of that task.
The second part is a set of six scales which represent six human factors relevant to the workload measurement. In each scale, the user must define how much workload they´ve experienced through the task and classify it in a 100 point scale which will give us a value in 5 point steps.
The final task score calculation of workload is computed by multiplying each rating by the weight given to that factor by the user. The sum of the weighted ratings for each task is then divided by the amount of weights: 15.

2.3.2.3- The adapted NASA TLX: NASA Raw TLX (RTLX)

The Original NASA TLX method uses a weighting process that has been criticised amongst different authors. A vast majority of new studies suggest that using an unweighted version of the test can lead to very similar results and better reliability.
As suggested by Geddie et al. (2001) an increase in between subject variability could not be noticed in contrast to the assumptions of the authors of NASA TLX. Geddie et al. (2001) also argues that from the results obtained, the paired comparison can possibly be dropped. Nygren (1991) also suggests that the weighting process is ineffective and recommends ignoring it. Bustamante and Spain (2008) argued that NASA TLX lacked scalar invariance. Consequently, analysis of mean differences (between weighted and unweighted procedure) was meaningless and misleading (Bustamante & Spain, 2008).
The removal of the weighting process with no major impact on the results is an advantage, because the validity and practicability of the test remains, while the application time and simplicity is severely improved.
The test can be applied using a simple rating of the six scales of the second phase, and then by calculating the mean result of them all, the overall workload for that task can be achieved.
This method can be applied with improved practicality, much faster, and much easier to the operator, with no impact at the results level.
This method, as cited in various studies, will be mentioned as the NASA RTLX.

2.3.3- Eye tracking method

The test subjects of this study were evaluated about the total percent of “eyes-off-the-road” time while performing tasks in the centre console. The proposed method was doing the eye tracking manually with a high time cost but very low budget solution.
The method used for gathering this data was using a video recording camera positioned in the central console, assembled with a custom made wood support fixed with Velcro to the console, and pointed to the driver’s head (needed adjustment to every subject in each test). The camera was connected using a firewire cable directly to the driving simulator computer for video date and time synchronization with the simulator telemetry plugin. This synchronization allows for better definition of the time intervals where the eye tracking would be performed. The data and time information were recorded in the video, so there could be no chance of losing the relation between the images recorded and the time information. The video was recorded in background in the same computer that was running the simulations using the camera native software (iSpy®), that is freeware, and is very low on consuming computer resources and assures great video quality with low file size and date info implementation on video images. As the simulator room needed the windows covered, and the light used was artificial fluorescent lighting due to console illumination issues, the video recording was performed using the infrared mode, in order to eliminate shadows in video. This mode produced images that enhanced the eye contours and iris, that allowed to a better identification and detection of the eye glances away from the road made by the drivers.
The video recording was performed since the subjects entered in the simulator, and they were previously warned about being filmed. During the test, the telemetry software recorded at which time the driver entered the task sector, and at which time leaved, and that gives us the information about the time intervals to control and obtain the total eyes-off-the-road time measurements in each sector on the video. The total eyes-off-the road time is obtained by observation of the video while using chronograph software to analyse it. The total time of the eye glances in that sector, is then divided by the time that the subject took to complete the sector, giving us the percentage of eyes-off-the-road time for each sector. The chronograph software used is named Chronme®, and is a free tool available online that registers a list of the

glances away from the road, and allows an output of the recorded data in a Comma Separated Values (CSV) file.

2.3.4- The inquiries

When testing human factors, and when trying to understand how these human factors may or not be related with the results acquired, there is a need to acquire individual information about the subjects that will collaborate with the study. The most direct mean of obtaining this data is by performing enquiries to the individuals.

2.3.4.1- Pre driving test inquiry

In this phase, data about the age, gender, and experience, and data for identifying possible partial driving impairments like vision or hearing problems, information about their previous experiences with central consoles, opinions on difficulties or other issues was gathered. Information about their self opinion as drivers was also gathered in order to understand and compare their self perception to their general results of the test. As affirmed by Torkkola et al. (2008) "almost all the drivers rate their driving ability as superior than others,(...)They believe that they have sufficient driving control to take part of their attention away from the driving task and give it to multi-tasking". This behaviour is understood as risky, and from this result of the inquiries some conclusions on this problematic are expected.

2.3.4.2- Simulator validity test inquiry

In order to understand how realistic the simulated driving experience was felt by the subjects, were carried out a series of questions about their self percept experience and how they felt it would be representative of their everyday driving style. Were posed some questions about the source of information they allocated more attention, about the instructor orders, about the ergonomics, the simulator equipment, if there were any surprising situations, and about the double task situation difficulties. This inquiry was only distributed randomly to some subjects in the first series of tests, just to understand how real the simulator experience was being perceived, and to try to understand if the whole testing procedure needed some further adjustments. This inquiry sheet was analysed right immediately after the subject left from the simulator room.

2.3.4.3- After test inquiry

A simple four question section was inserted, to perceive how well subjects understood the orders from the instructor, and how well they perceived the driving environment. They were also questioned if they had previous knowledge of the test roads, to ensure it was the first time subjects were driving them, and to keep possible simulator practitioners apart from the sample.

2.3.4.4-NASA RTLX inquiry

In order to obtain the perceived workload data, the NASA RTLX method was applied, and the subjects indicated in a scale of 1 to 20 how much they perceived each of the subscale measures. For each task, a group of 6 subscales considering the human factors that influence workload were presented to the subjects.

3- RESULTS & DISCUSSION

After the post processing of the tests collected data - route deviation, eyes-off-the-road time, NASA RTLX, and inquiries – it was performed a statistical analysis of the obtained results. The indicators results will be related directly between each other average results, creating a correlation for each task (Figure 3). These related results should be used to define the classification for each system.

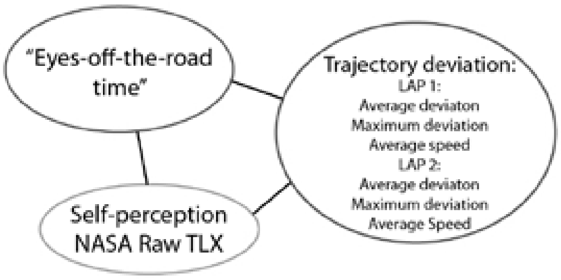

Figure 3 - Indicators interrelation.

This method provides a way to relate what was found as the most important indicators about the driving performance and their achieved data, to create a classification system that allows the definition of a system performance in a mathematical way. This relation between indicators makes possible to evaluate human-machine interaction systems in terms of physical and psychological factors in a realistically simulated driving environment, with no dangerous situations associated and with low budget solutions, that allow the acquisition of a great amount of data not only about the driving task itself, but of all the associated tasks and systems that may be created and tested in a driving environment.

3.1-Simulator validity

The inquiry for validation of the simulator was delivered to 16 subjects, and the results were indicators that everything was OK for the test implementation. An important result was obtained, about the self-perception of the subjects, that 75% of them considered this test conditions to be very representative of their real driving behaviour (Figure 4).

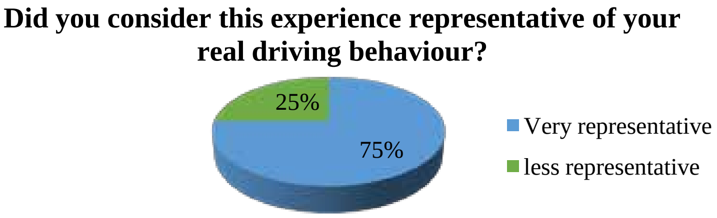

Figure 4 - Self-perception about the representativeness of the test.

3.2-Subjects summary

The field of subjects present in this study was composed by individuals of both genders, in the proportions of 70% Male individuals and 30% Female ones as seen in Figure 5. They were drivers with experience between 1 and 33 years of driving, representing respectively the proportions of 21% from 17 to 33 years of experience, and 79% between 0 to 16 years, leaving us with experienced drivers as well as younger ones, that will let us evaluate the influence of experience in the performance of tasks while driving (Figure 6). A percentage of 94% of the subjects have regular driving habits as shown in Figure 7.

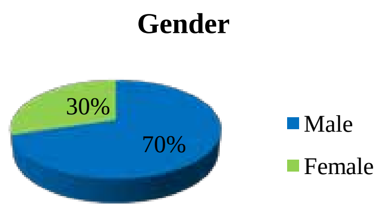

Figure 5 - Gender of the subjects' field.

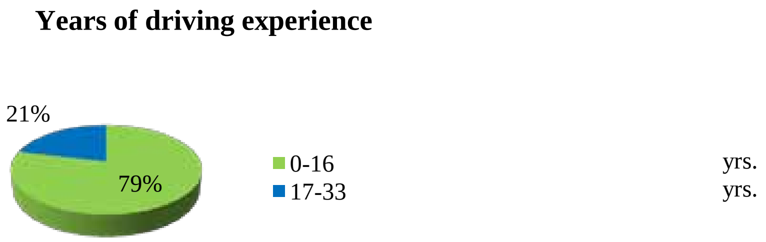

Figure 6 - Years of driving experience.

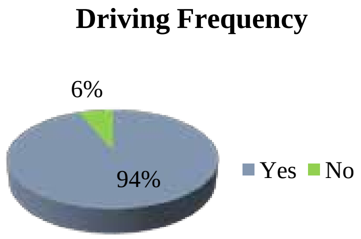

Figure 7 - Driving frequency of the subjects.

The subject's perception about their driving ability was questioned, and 91% of the drivers consider themselves as good drivers. Only 9% admit that they are not good drivers as reflected in Figure 8.

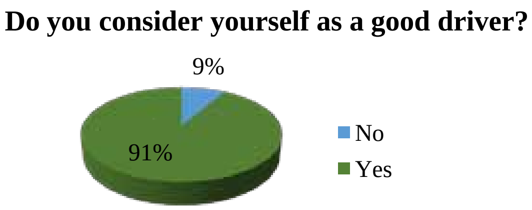

Figure 8 - Self perception about driving quality.

A majority of 80% of the subjects confirm to have habitual interaction with the central console while driving as seen in Figure 9.

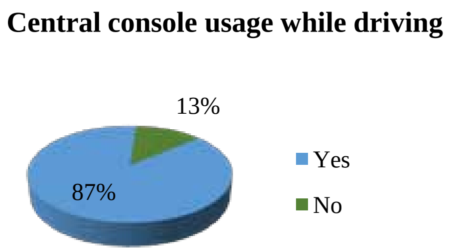

Figure 9 - Central console usage by subjects.

The subjects in the field were all mobile phone users, and the kind of mobile phone used in the respective tasks was controlled, to split the phone tasks results in touch screen interaction phones, and the keypad ones. This information allowed having perception on which is the most dangerous kind of phone interaction while driving. The majority of the subjects presented a touch screen phone against 42% of the subjects with keypad ones (Figure 10).

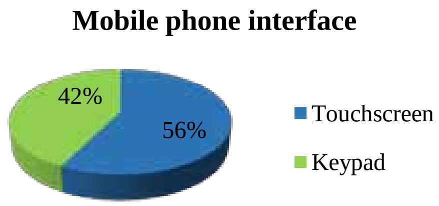

Figure 10 - Subjects mobile phone interfaces.

The opinion of the subjects about their impressions of the most dangerous tasks while driving was inquired (Fig. 11) and the results show that Cell phone tasks were considered the major menace to the driving task. However, interacting with touch screen interfaces has not been mentioned as a major problem.

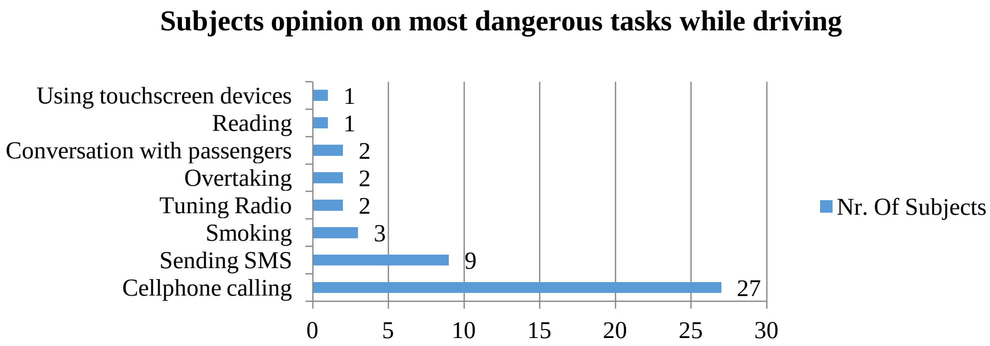

Figure 11 - Subjects opinion about the most dangerous tasks while driving.

4- CONCLUSIONS

The development of a driving simulator is a valid method to evaluate in-vehicle systems that depend on human interaction, but the realism and immersion of the experience must always be as better as possible. The presented methodology provides a way to relate what was found as the most important indicators about the driving performance and their retrieved data, in order to create a classification system that allows the definition of a system performance. This relation between indicators makes possible to evaluate human-machine interaction systems in terms of physical and psychological factors in a realistically simulated driving environment, without accident risk and with a low budget solution. The presented solution allows the acquisition of a great amount of data not only about the driving task itself, but also of all the associated tasks and systems that may be created and tested in a realistic driving environment.

Although this study provided relevant results, the methodology should be applied in more situations and alternative systems evaluation. Further studies should be made in order to improve its validity, and to confirm the applicability of the method on different systems inside the car, as well on different scales of participants. Authors already have applied this methodology to evaluate some of the systems used on an automotive cockpit, in order to have further validation of the method, results can be found elsewhere.

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6- REFERENCES

Bhise, V., & Pillai, A. (2006). A parametric model for automotive packaging and ergonomics design. *University of Michigan-Dearborn, USA*.

Birch, Stuart. (2014). Ferrari changes course on track simulation software - *SAE International*. Retrieved August 11, 2015, from http://articles.sae.org/13603/

Burns, P., Harbluk, J., Foley, J. P., & Angell, L. (2010). The importance of task duration and related measures in assessing the distraction potential of in-vehicle tasks. In *Proceedings of the 2nd International Conference on Automotive User Interfaces and Interactive Vehicular Applications* (pp. 12–19). New York, NY, USA: ACM. doi:10.1145/1969773.1969776.

Bustamante, E. A., & Spain, R. D. (2008). Measurement Invariance of the Nasa TLX. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *52*(19), 1522–1526. doi:10.1177/154193120805201946.

Curry, R., Greenberg, J., & Blanco, M. (2002). An alternate method to measure driver distraction. Intelligent Transportation Society of America's Twelfth Annual Meeting and Exposition, USA.

Department of Transportation. (n.d.). Visual-Manual NHTSA Driver Distraction Guidelines For In-Vehicle Electronic Devices. National Highway Traffic Safety Administration.

Geddie, J. C., Boer, l. C., Edwards, R. J., Enderwick, T. P., Graff, N., Pfendler, C., … Van Loon, P. A. (2001). NATO Guidelines on Human Engineering Testing and Evaluation. *North Atlantic Threaty Organization - Research and Technology Organization*, (RTO-TR-021).

Haigney, D., & Westerman, S. J. (2001). Mobile phone use and driving: a critical review of research methodology. Ergonomics, 44, 132-143.

Hart, S. G. (2006). NASA-Task Load Index (NASA-TLX); 20 Years Later. *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting*, 904–908.

Hart, S. G. & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. A. Hancock and N. Meshkati (Eds.) Human Mental Workload. North Holland Press.

Jonghyun Ryu, Jaemin Chun, Gunhyuk Park, Seungmoon Choi, & Han, S. H. (2010). Vibrotactile Feedback for Information Delivery in the Vehicle. *IEEE Transactions on Haptics*, *3*(2), 138–149. doi:10.1109/TOH.2010.1

Knappe, G., Keinath, A., Bengler, K., & Meinecke, C. (n.d.). DRIVING SIMULATOR AS AN EVALUATION TOOL - ASSESSMENT OF THE INFLUENCE OF FIELD OF VIEW AND SECONDARY TASKS ON LANE KEEPING AND STEERING PERFORMANCE. National Highway Traffic Safety Administration.

Minin, L., Benedetto, S., Pedrotti, M., Re, A., & Tesauri, F. (2012). Measuring the effects of visual demand on lateral deviation: A comparison among driver's performance indicators. *Applied Ergonomics*, *43*(3), 486–492. doi:10.1016/j.apergo.2011.08.001.

Murata, A., & Moriwaka, M. (2005). Ergonomics of steering wheel mounted switch–how number and arrangement of steering wheel mounted switches interactively affects performance. *International Journal of Industrial Ergonomics*, *35*(11), 1011–1020. doi:10.1016/j.ergon.2005.04.004.

NASA - Human Performance Research Group. (2013). NASA TASK LOAD INDEX (TLX) v.1.0 Paper and Pencil Package. NASA Ames Research Center.

Nygren, TH. E. (1991). Psychometric properties of subjective workload measurement techniques: Implications for their use in the assessment of perceived mental workload. Human Factors, 33 (1), 17-33.

Rydström, A., Broström, R., & Bengtsson, P. (2011). A comparison of two contemporary types of in-car multifunctional interfaces. *Applied Ergonomics*, *ePub*(ePub), ePub. doi:10.1016/j.apergo.2011.08.004.

Simões, P. (2011). Car Driving Integrated Auxiliary Equipment Design-Thesis Plan For Doctoral program.

Torkkola, K., Gardner, M., Schreiner, C., Zhang, K., Leivian, B., Zhang, H., & Summers, J. (2008). Understanding Driving Activity Using Ensemble Methods. In D. Prokhorov (Ed.), *Computational Intelligence in Automotive Applications* (pp. 39–58). Springer Berlin Heidelberg. Retrieved from http://link.springer.com/chapter/10.1007/978-3-540-79257-4_3.

Young, K., Regan, M., & Hammer, M. (2003). Driver Distraction: A Review of the Literature. *MONASH UNIVERSITY ACCIDENT RESEARCH CENTRE*, (206), 29.

Occupational safety in a globalised construction industry: A case study on Polish workers in Norway

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Abstract

The number of migrant workers in Norway is continuously increasing. Polish workers are the largest group of migrant workers in Norway, and particularly well represented in the construction industry. Research and statistics show that migrant workers are more prone to occupational accidents than native workers. This difference is often attributed to poor communication and lack of lingual skills. There are however several other factors influencing the occupational safety of migrant workers, such as culture, organisational aspects and individual factors. A study was conducted to explore how the use of migrant workers in the construction industry influences communication and thus occupational safety with emphasis on culture and language. To get a broad perspective both migrant workers, represented by Polish workers, and native workers, represented by Norwegian workers were interviewed. It was found that the focus in the construction sector in Norway concerning migrant workforce is mainly on language as an issue, as most measures were found to be related to language. Culture is seen as a contributing factor, but is somewhat neglected and few measures are being implemented for cultural issues. Furthermore, Polish workers are often seen as a homogeneous group, whereas in reality there are large differences between individuals. Factors that affect occupational safety for migrant workers are compound, and must be seen together in a broader, more complex perspective. A sole focus on language is too narrow. To cope with these challenges and improve safety in the sharp end involvement of the governmental, organisational and individual level is needed throughout all phases of a project.

Keywords: migrant workers; culture; language; communication

1. INTRODUCTION

A moving workforce is globalising the construction industry. After the expansion of the European Union (EU) in 2004, the number of migrant workers from the new member countries across Western-Europe rose. In this study, we wish to analyse the effects of this development for the risk of being involved in occupational accidents. Previous studies (Salminen, 2011; The Norwegian Labour Inspection Authority, 2012) have shown that foreign workers have an increased risk of being injured or killed at work. While we already know a great deal about the differences in risk for the afore-mentioned groups, we know less about the underlying factors *causing* these patterns in risk. It is the ambition of this paper to shed light on these underlying factors.

In Norway, Poles represent the largest group of migrant workers. The number of Polish workers in Norway is continuously increasing, even after 10 years with open borders in Europe. A study carried out by Friberg and Eldring (2011) shows that 84 percent of the Polish men coming after 2004 in Oslo are employed in the construction industry, which is also known to be one of the sectors with the highest risk for occupational accidents. More than one-third of the reported injuries among migrant workers in Norway in 2012 involved Polish citizens (The Norwegian Labour Inspection Authority, 2012) even though they only constituted 15 percent of the employed migrant workforce in Norway[1]. As a consequence of this, the present study focuses on Polish workers in the Norwegian construction industry.

It is important to understand challenges concerning a more international workforce. The aim of the paper is to explore how the use of Polish workers influences occupational safety in the industry with focus on culture and language. Previous research on the field shows that language is affecting safety at a work place (Lindhout, Swuste, Teunissen, & Ale, 2012). When it comes to cultural influences some studies shows that culture does not play a decisive role for

[1] Numbers from Statistics Norway (SSB), Employment among immigrants, register-based. Available from: www.ssb.no/en/statistikkbanken

occupational safety (Guldenmund, Cleal, & Mearns, 2013), other that different labour cultures and traditions, and different work habits of foreign workers are among factors that can affect occupational safety (Kartam, Flood, & Koushki, 2000).

2. BACKGROUND

2.1. The Construction Industry

Construction projects are complex socio-technical systems that can take many different organisational forms. The industry is project-based and operates in an ever-changing environment (Lingard & Rowlinson, 2005). One dimension of the complexity is related to the many actors involved in a construction project, that all have impact on safety, e.g. authorities, clients, designers, specialist consultants, contractors, subcontractors and suppliers. Another dimension of the complexity is related to the labile characteristics of the portfolio of projects in the industry. Each project is unique related to type of project (a house, a railway or a bridge), ways of doing work, partners and techniques for construction. The interactions and collaborations between different project phases and involved actors are complex. Many different actors and stakeholders are involved with different rationalities, purposes and knowledge. For example a client's main focus is on design and functionality of the end product rather than safety. Lack of focus on safety in design and planning is named one of the key challenges to safety management in the industry (Frijters & Swuste, 2008; Jørgensen, 2013). Behm (2005) made a study of fatal accidents in the construction industry that showed that the design of a project links to 42 % of fatalities reviewed in his study.

Increased globalisation of workforce is one of the key contributing factors to the risk picture in the construction industry. The globalisation of the workforce is related to market mechanisms as well as periods of work peak where temporary appointments are applied.

2.2. Migrant workers

Worldwide, the labour market is affected by guest workers emigrating to work abroad. After the expansion of the European Union (EU) in 2004, the number of hired workers in Norway and the rest of Western Europe have grown rapidly. The trend with migrant workers is also present in United States, Canada, Asia and Australia.

There are many reasons for both migration of workers and employment of migrant workers. For the hosting countries such as Norway, some of the reasons for employing migrant workers are lack of qualified workers in the local marked and more flexible and cheaper workforce. The migrant workers on the other side usually look for a job opportunity and a better salary.

In Norway per 2013, 13% of the employed labour force are immigrants (Olsen, 2013) which is twice the number for 2002. The majority come from the EU-countries in Eastern Europe and Asia including Turkey. The largest group of migrant workers in Norway are from Poland, which in particular works in the construction industry. A study by Friberg and Eldring (2011) show that most of these are men over 35 years with family and they have on average lived in Norway for 4 years. Most of them have limited language skills in Norwegian and English.

International studies show that migrant workers have a higher risk for work-related accidents than native workers (e.g. Starren, Hornikx, and Luijters (2013)). Salminen (2011) has in his studies found that the risk of occupational injury is 2.13 times higher for foreign workers than for native workers. Numbers from The Norwegian Labour Inspection Authority (2012) show the same tendency; that foreign workers have a 1.46 times higher chance of severe accidents than native workers. Several studies point at communication, language and culture as significant contributing factors to safety challenges related to foreign workers. Lindhout et al. (2012) emphasise in particular lingual challenges, potential misunderstandings and low risk awareness as main challenges.

Other studies have found that there is a relationship between safety and national culture (Helmreich and Merrit, 1998 in Mearns & Yule, 2009) and that different cultures have different risk perceptions and attitudes towards risk (Kouabenan, 2009). Håvold (2007) has found that national culture influences safety orientation. He also found that there are differences between national and regional cultures when it comes to safety factors. A study comparing Filipino and Norwegian seafaring professionals found that national culture seems to have impact on the probability of occupational accidents (Lamvik & Bye, 2004). A study on Pakistani construction workers based on Hofstede's theory shows that there is a strong correlation between cultural dimensions, safe work behaviour and risk perception which can be explained by attitudes

(Mohamed, Ali, & Tam, 2009). The study also revealed that the safety culture at work influence the safety of on-site behaviour.

2.3. Framework conditions

A first step in understanding why migrant workers are more exposed to occupational risk is to study the framework conditions influencing their work situation. The term framework conditions here refer to the "the conditions that influence the opportunities an organisation, organisational unit, group, or individual has to control accident risk" (Rosness, Blakstad, Forseth, Dahle, & Wiig, 2012)[2]. Framework conditions are external or contextual factors that influence the way work is performed, decisions are made and safety is upheld. Contractual relationships, economic incentives, the formal division of labour and distribution of power between groups are examples of framework conditions. In the construction industry the framework conditions will vary from project to project. There will be differences in contractual relationships, the number of subcontractors involved, the scale and timeframe of the project and so on. One will also find variations in the framework conditions of different actors within each project, as they can have different contractual and employment relationships.

Research on migrant workers' occupational risk shows the importance of several such framework conditions. Guldenmund et al. (2013) claim that migrant workers are more involved in occupational accidents than local workers because they carry out more dangerous work, and are therefore exposed to higher risks. Paul (2013) relates the increased risk among migrant workers to long working hours, high work tempo and acceptance of questionable or dangerous working condition to the desire of work. Another aspect is on circumstances around the working conditions. As migrant workers often do not speak the language and want to keep their jobs, they do not complain about working conditions even if they are bad or unsafe (Guldenmund et al., 2013). Many also believe that if they report injuries or other things, and are staying illegally, they will be sent back to their country (Guldenmund et al., 2013). McKay, Craw, and Chopra (2006) report that many migrant workers are recruited through agencies and are often paid less, have long working hours and have to work worse shifts. They also highlight that migrant workers get less opportunities than local workers, which show different treatment. In their studies they concluded that in some cases in England and Wales migrant workers were not offered safety training courses. Similarly Paul (2013) states that many migrant workers do not have any experience in the job sectors and they do not receive job training, which makes them prone to accidents.

Many migrant workers are hired on a short-term basis, whether hired by contractors, subcontractors or recruitment agencies, they often change work places and employer and will therefore find limited opportunities of establishing social relationships at the work site. According to Mayhew and Quinlan (1997) temporary work arrangements may give higher risk of occupational injury. Numbers from The Norwegian Labour Inspection Authority (2012) show that most of the injured migrant workers were not employed on regular contacts, but either hired or temporary employed.

Economic reward pressure, disorganisation, inadequate regulation and the lack of social and cultural integration are factors that are likely to influence occupational risk. Furthermore, temporary contracts can create ambiguity regarding responsibilities (Burgess & Connell, 2006) as there might be weaker relationship to the employer.

3. CULTURE AND SAFETY

The merging of the concepts of (organisational) culture and safety is usually credited the investigations performed in the aftermath of Chernobyl (e.g. IAEA, 1991). The interest in safety culture had an obvious predecessor in the research on safety climate (e.g. Zohar, 1980) and the seminal works of Barry Turner (Turner, 1976, 1978). The broader field of organisational science saw a wave of research into organisational culture from the early 1980s and onwards, while the preceding work on organisational climate can be traced back to the 1960s (e.g. Litwin & Stringer, 1968). A common denominator in all these strands of research is that they treat culture or climate as intra-organisational properties in the sense that they are oriented at understanding the inner workings of organisations by describing their uniqueness as social systems. Apart from the research on professional culture the ways organisations are connected with their broader cultural context, is an under-researched field. In an increasingly globalised labour

[2] Rosness and colleagues use the term "environmental conditions" instead of "framework conditions". Both terms translate into the Norwegian word "rammebetingelser" and are therefore treated as synonyms.

market, the possible influence of national cultures on organisational cultures will be an important topic for organisation science in general, and safety science in particular.
In particular, the inclusion of multiple nationalities in single organisations and work groups is likely to create new dynamics related to communication and interaction. As such, it can introduce new challenges and opportunities for organisations' ability to maintain safety. This involves a slight change in focus for safety culture research, from describing the predominant frames of reference and social conventions within a presumed homogenous group, to describing the differences between the members of a given group or between different groups.
In a workforce consisting of multiple nationalities, inter-cultural or cross-cultural communication becomes an important challenge. Hofstede (1984) is among the researchers describing how cultural differences between different nationalities make their presence felt in the world of work and organisation. Hofstede identifies six different dimensions along which different cultures can be classified (The hofstede centre, 2015). The dimensions are:

1) Power distance (the degree to which the members of a culture accept and expect inequalities in the distribution of prestige, wealth and power)
2) Uncertainty avoidance (the degree to which uncertainty in terms of rule orientation, employment stability and stress is tolerated)
3) Individualism vs. Collectivism (whether the members of a culture expect to take care of themselves and no one else, as opposed to a preference for more collective values where society or groups have a responsibility for taking care of the individual)
4) Masculinity vs. Femininity (the role distribution between the sexes and the degree to which traditional masculine ideals related to competition, achievement and assertiveness are valued)
5) Long term vs. Short Term Normative Orientation (whether the members of a culture like to hold on to norms and traditions or are open for new knowledge to prepare for the future)
6) Indulgence vs. Restraint (the extent to which the society have strict norms or more freely allows to enjoy life according to desires and impulses)

Hofstede's dimensions can be easily criticised for involving stereotypes painting generalised caricatures and overlooking obvious differences inside the groups that appear to be similar in Hofstede's classification. Nevertheless, his taxonomy points to the fact that cultures do vary and that multinational organisations and work places will have to deal with this variation in communication and interaction. In this paper we will explore the way this form of cultural complexity can influence on safety.
Cultural differences based on nationality should, however, not be exaggerated. As has been shown by Wenger (1998) and other researcher on so-called "communities of practice", being involved with the same activity and having the same craft can be a source of common identity and meaning. In other words, a multinational group of say carpenters will most likely be characterised by both differentiation and integration, where integration comes from sharing a profession and an activity.

4. RESEARCH METHODOLOGY

A qualitative study was conducted to obtain knowledge that can shed light on the risk of occupational injuries among migrant workers in the construction industry. Data was collected through semi-structured interviews. The study involved migrant workers represented by Polish workers in Norway, and focused on Polish workers coming to Norway after 2004.

4.1. Research design

Scientific research papers were used as background information for the study. An interview guide was prepared with nine key categories of questions; background information, safety, cultural aspects, communication, training and follow-up, hiring and inclusion, responsibilities, measures and further work. The interview guide consisted of around 30 questions. Some questions were adapted according to the informant's position. The interviews were conducted as semi-structured interviews with open questions. The advantage with semi-structured interviews is the possibility of basing the questions on themes and asking additional questions according to information coming up (Bryman, 2012).
Both migrant workers, represented by Polish workers, and native workers, represented by Norwegian workers, in different positions were interviewed.
Reflecting on and describing aspects of culture requires an attempt to explicate frames of reference, norms and conventions that are to a large extent taken for granted. This is a

methodological challenge in many different respects (see Antonsen, 2009a, 2009b), but has particular implications when it comes to language. It is hard enough to explicate cultural assumptions within your mother tongue and likely to prove very hard to do so in a foreign language. To counter this challenge, all interviews were conducted in the informants' native languages, respectively Polish and Norwegian.

The interviews were conducted in March 2014. The length of the interviews varied between 15 minutes up to an hour, where the majority lasted around 30 minutes. Most of the interviews were recorded and then transcribed in form of a structured, detailed memo. Notes were taken during the interviews for the ones that were not recorded. Further the interviews where systematically analysed, resulting in main findings organised in the following four categories; lingual skills, communication, culture and safety. The data was treated confidentiality and published anonymously.

4.2. Sample

The informants were employed by contractors, sub-contractors and temporary working agencies in the construction industry. The sample consisted of 10 Norwegian and 8 Polish employees. Six companies were represented and the informants were employed in four different positions as presented in Table 1. The informants were recruited through a contact person in a construction company, via local contacts and also through "snowball sampling" with tips who to contact from other informants. Also "open sampling" was used as random informants available at the construction site were interviewed. These sampling methods together give varied and thorough data, and a saturation point was reached as several points of view were represented and no new concepts emerged from the interviews (Corbin & Strauss, 2008).

Table 1: Informant sample

Position	Norwegian	Polish
Manager	4	1
Supervisor	3	-
Skilled worker	1	6
Union representative*	2	1

*Union representatives were also skilled workers

4.2.1. Polish informants

The Polish informants were between 35 and 55 years old and had all started to work in Norway after 2004. Most had been working in Norway between 7 and 8 years. The shortest work experience in Norway among the informants was 2 years, the longest 10 years. The skilled workers had technical school as education from Poland.

The terms of employment varied between the Polish informants. Some were permanently employed for a contractor or a subcontractor, some had time-limited contracts and some worked in temporary employment agencies and were hired out. Most of the informants lived in Norway. Some were settled in Norway with family, others had their family in Poland. A few were commuting between Norway and Poland every second week.

4.2.2. Norwegian informants

The age of the Norwegian informants varied between 35 and 55 years. The education varied between technical school and higher education and the skilled workers had at least 15 years of experience in the industry. All the Norwegian informants were permanently employed by contractors.

4.3. Translation

Interviews transcribed in Polish were by the interviewer translated into Norwegian during coding of the data into categories. This was done to have a proper basis for comparison without language confusions. Translation of data can influence the sense and meanings of the data. Therefore the focus for the translations was on correct interpretation, rather than on a literal translation. The interviewers' cultural knowledge about Norway and Poland, and the lingual skills in both languages assure a good translation without meaning being reduced as the cultural contexts and language differences are well known to the interviewer. As the raw data were transcribed in Polish, it was possible to go back and find the exact wording if necessary.

4.4. Analysis

Thirteen of the interviews were recorded and transcribed in form of a structured note. Five of the interviews were documented by notes taken during the interviews. The interviews were transcribed in Norwegian and Polish.

The transcriptions were coded according to categories with subcategories based on "open coding" (Corbin & Strauss, 2008). This allows for a structured comparison of the similarities and differences from the collected data. The data was systemised in a matrix of informants and categories and systematically examined. The study resulted in findings separated according to Polish and Norwegian informants. This data was structured in four main categories with subcategories as presented in Table 2.

Table 2: Codes for results

Category	Lingual skills	Communication	Culture	Safety
Subcategories	About Norwegians About Poles Courses	Language Common practice	Understanding Behaviour/Attitudes	Rules and procedures Compliance Reporting Hazards Training

4.5. Transferability

This study has looked at the case of Polish workers in the construction industry in Norway. Many of the findings coincide with other both Norwegian and international studies about migrant workers when it comes to issues arising when using migrant workforce. The findings have been validated against other articles and books; therefore the study is a reliable source of information. This study adds knowledge to previous Norwegian studies (Friberg, 2011; Friberg & Eldring, 2011; The Norwegian Labour Inspection Authority, 2012), and together they give a broad picture of the situation in Norway and in other European countries where Polish workers represent a large part of the migrant workforce. The study represents the construction industry, but may however be valid for other industries with migrant workforce and similar conditions.

5. RESULTS

The main results of the interview study are presented. The focus is on how communication influences safety when migrant workforce is used at constructions sites. Two main factors are emphasised; namely language and culture.

5.1. Language

Language is the most obvious source of difference between workers of different nationalities. It can create misunderstandings and usually influences the access to information, knowledge about work processes, rules and rights. Norwegian and English language skills varied among the Polish informants in this study. The stereotype "migrant worker" conceals great variation within the group both related to language skills and integration in Norwegian society at large. English language skills depended highly on the age of the informant, where the younger generation had better English skills. The Norwegian language skills however, seemed to depend on several other factors more than on the age factor. The skills in Norwegian of the Polish workers were highly depended on the informants' expectations for their stay and their working arrangements. The informants with no Norwegian skills lived permanently in Poland and commuted to work in Norway every second week. There was no need for them to learn Norwegian as they mostly worked 12 hour shifts when they were in Norway, and did not need to communicate in Norwegian outside work. At work they had someone that could translate for them, or they knew the few basic terms needed to do their job. The informants that were originally planning to work in Norway only a few years to improve their economic situation and then to move back had some skills in Norwegian. The informants that had moved to Norway with their families and established spoke Norwegian on a higher level, even after only a couple years in Norway.

Some companies organised language courses for migrant workers. Some of the informants had been to language courses, but found it demanding and time-consuming to learn Norwegian.

> *"The course was quite hard. It was after work in the evening, from 8 pm to 10 pm. You are tired after a whole day at work, and you need to wake up early the next day again to go to work".* [Polish skilled worker]

The level of integration in the work place and in society at large, as well as framework conditions was thus seen as a strong influence on whether the Polish workers were able to communicate in Norwegian. It is common practice to organise Polish workers together in teams with one supervisor that knows both Polish and Norwegian or English, and is used as translator. Non-verbal communication in form of drawings of pointing is also common. Written information is often available in Polish and English in addition to Norwegian.

The impression the Polish workers themselves had, was that communication at work was okay, either they spoke Norwegian themselves or they had messages translated to them. Several informants mentioned that it is more important to be a good craftsman, than to know the language well for getting a job. In some cases those doing a very good job, have good careers, despite the lack of proficiency in Norwegian. In practice several qualities are valued, as the goal is to get the work done and lingual skills are just one of them.

> *“The ones that know the job get to stay. The language is not the most important. A real professional worker will manage without language. Then it is enough with some words and gesticulation”.* [Polish skilled worker]

The interviews indicated that Norwegian workers at the sharp end perceive language barriers as a larger risk factor than Polish workers. Many of the Polish workers had the opinion that they had a satisfactory level of Norwegian to perform their work. Nevertheless, the opinion was that it would have been useful to have further skills in the Norwegian language. However, the informants clearly stated that communication became easier and language was less of a barrier, when colleagues know each other and have worked together before.

5.2. Different kinds of "yes" - language and culture

There is more to communication than only understanding words. Cultural differences can influence the way things are said and how things are understood.

> *"One understood Norwegian very well and spoke Norwegian. He understood the terminology and the tone Norwegians use when they speak. Most of the others however, neither understood what I said, nor why I said it!"* [Norwegian supervisor]

Both Norwegian and Polish informants had experienced that their Polish colleagues had answered “Yes, yes”, without really understanding the question. One of the migrant workers admitted to having answered in this way when he did not yet speak and understand Norwegian well. Others said that they were asking if something was unclear. It was also pointed out that the Polish workers tend to answer "Yes", but there were different types of "Yes", for example said with a different tone, depending on if the message was understood or not. Several informants said it is important to reassure that the message is understood correctly by asking "what or how" questions instead of "yes or no" questions.

The cultural differences are especially visible in the management hierarchy and understandings of each other's positions. For the Polish workers the manager has a lot of authority, whereas the Norwegian power structure is generally regarded as more flat. Both groups of informants agreed that the Norwegians and the Polish have different views when it comes to relating to superiors. Norwegian informants had observed that Polish workers like to call their superiors for "boss", whereas the Norwegian superiors were not comfortable with the term. For the Polish informant calling the superior for "boss" was a way to show respect for older and more experienced workers. Some of the Norwegians interpreted that as getting more responsibilities, which they did not want. However, after getting the explanation of the way Poles talk and the reasons behind it, some of the Norwegians got an understanding and were fine with being called "boss".

> *"I think I have never been called boss before. Yes, boss. Like a cotton plantation. I am your supervisor, not your boss. You are your own boss for the next week. You have to plan your own week, not me. I can just help you arrange it and explain. The rest you have to do on your own".* [Norwegian supervisor]

Similarly, as the management was observed to be more hierarchic among Poles, the communication patterns among Poles are also observed to be influenced by this top-down structure where information comes from the top. The Norwegian informants had an impression that communication with Polish workers needed to be harsh, which was quite unfamiliar with them.

> *"He (a Polish supervisor) communicated with his guys in a very harsh manner as for me. We don't do that. We can speak loudly, but to me it seems wrong to yell and howl: "You should be finished HERE!" We are used to include and involve in planning in Norway. "What do you think, and how?" But with the guys from Poland we need to communicate in a totally different way. More like a loudmouthed control centre. That is totally wrong to me"*. [Norwegian supervisor]

The Norwegian informants had observed that Polish workers must get specific orders to perform their job, whereas Norwegian workers were by themselves described as more used to doing things on their own. However, the perception from the Polish workers themselves was not in accordance with the Norwegian workers' perception. According to some of the Polish workers they were more observant and solution-orientated, and thus able to do things alone.

5.3. "What the boss says, the boss gets" - rules and compliance

Polish informants described that HSE and work with safety is seen as important and performed seriously in Norway. Several underlined that safety comes first in Norway. All workers had been on HSE-training arranged by developers and contractors and some also from their own company. Regulations and procedures from developers, contractors and sub-contractors were perceived as strict and clear. Most of the Polish informants perceived regulations and procedures somewhat looser in Poland, though many commented that they had not been working in Poland for several years, and did not know how it actually is today.

According to the Polish informants they were respecting and complying with rules and regulations. However, examples given show that certain behaviour was regarded as accepted, even though it was breaking the rules. The Norwegian informants had different opinions regarding Polish workers' compliance; some said it varies among Polish workers, as it does among Norwegians, some said Polish workers comply well, others said it was terrible. Several said that rules needed to be repeated, but after some time the Polish workers got better on the compliance. It was also pointed out that if they were confronted, they usually listened at once.

> *"When you confront them with it; "You need to wear PPE", they do it at once. So that is not a problem. I believe they are quite afraid for their job and that if they don't act as they are told, they might lose it".* [Norwegian union representative]

Reasons given by the Polish workers for complying with rules and regulations varied between taking care of own safety and to not to get consequences for non-compliance. Several of the informants mentioned keeping their job as a reason for complying with rules and regulations before taking care of their own safety as a reason.

Examples of non-compliance of safety regulations included not using PPE if it was hindering work accomplishment. Other examples were short-cuts as using a ladder instead of scaffolding if time was short.

> *"Sometimes all the PPE is an obstacle. For example if you need to weld something, and you cannot reach the place with a helmet on because there is not enough space, then you need to take the helmet off to be able to stick your head up. But that are sporadic incidents".* [Polish skilled worker]

Another example that might affect safety linked with culture and communication is that Polish workers usually do not say "no" to the manager. Both Norwegian and Polish informants agreed that mostly Polish workers have a focus on getting the job done, especially if the boss required it. For this reason safety considerations may have to give way to work execution.

> *"Polish mentality is a bit different. What the boss says, the boss gets. Poles are more loyal. If there is a job that must be done, we do it without excuses".* [Polish skilled worker]

However, expectations from superiors also play a role in safety concerning migrant workers. A Polish informant had experienced that expectations were higher towards him to perform risk related work because he was a migrant worker.

> *"They are used to Polish workers doing everything, and mostly not saying no. Sometimes the employer also expects it. The employees are scared to lose their jobs, so they do what they are told".* [Polish skilled worker]

5.4. Snitching and incident reporting

Both Polish and Norwegian informant pointed out that Polish workers were not very good and did not like to write discrepancy reports, as that was perceived as snitching. Some had clearly understood that there are differences in how Poles and Norwegians perceive reporting.

> *"Polish mentality is like, we don't like to snitch or report others. They (the Norwegians) simply look at it differently. For them it is not snitching but about safety, while we perceive it different".* [Polish skilled worker]

However, one of the informants had after some time in Norway adapted to the safety culture at work and started to report. Another informant also reports that attitudes and behaviour change after being in Norway some time.

> *"I usually write notes, because after a while I realised that it is not accusation or reporting, it is about safety. And there is a prize draw".* [Polish skilled worker]

> *"The attitudes differ between different groups of workers. A person who came to Norway to work for the first time ever, doesn't understand that HSE is very important in Norway".* [Norwegian manager]

5.5. Safety measures

The differences between different nationalities were recognised as a challenge to safety management. However, most of the measures aiming to deal with challenges related to migrant workers had to do with language. The informants reported that the most common measure at the work site were translations (of documentation, safety courses etc.) and language courses. In most cases workers were also set together in working groups based on mutual language and had one person translating work instructions and other information to the rest. The authorities also use translation as a measure, e.g. The Norwegian Inspection Authority has available information in four languages on their web-pages. Additionally they have a phone service available in Polish in addition to English and Norwegian. They have also has given out a brochure with information about the most important workplace regulations and information about rights and obligations as employees in Norway. The brochure is called “Welcome to Norway as a new employee!” and is mainly made for building and construction sector and given out in 8 languages. For Norwegian employees The Norwegian Inspection Authorities has given out a language guide on communication with migrant workers in Norwegian (The Norwegian Labour Inspection Authority, 2014).

6. DISCUSSION

Communication is in a large degree influenced by cultural factors such as norms, beliefs, perceptions and customs, and language can therefore be seen in close relation to culture. Ultimately, language is about conveying meaning between actors. Language consists of a system of signs to which a certain meaning is ascribed. Thus, a sign always *signifies* something. As famously stated by Saussure (1983), the relationship between the sign and the signified is "arbitrary" in the sense that it is established by social convention. This is most likely what is in play when Norwegians are frustrated when experiencing that Polish workers say "yes" when they mean "no", and when Polish workers state that there are "different kinds of 'yes'". The sign is the same (the word "yes"), but the *meaning* of the sign is difficult to grasp without knowledge of the cultural background of the person using the sign. Also Trajkovski and Loosemore (2006) point out that messages or hints can be hidden in the speech. This may seem like splitting hairs, but can actually make a big difference in the way safety challenges are framed. Often, the challenges involved with having multiple nationalities working together at a construction site are seen as language issues. They are seen as problems related to *signs* in the sense that the simple solution is language training or having all nationalities communicating in English. This, however, is only solving one half of the problem. The problem should also be recognised as a problem of *meaning*, that is, as a cultural challenge.

Another example of culturally influenced communication is the way some Polish workers call their supervisor for "boss", where the Polish see it as a form of respect, while the Norwegian foremen at first glance do not appreciate the term, as for them it is associated with negative characteristics. Positions and statuses are perceived in very different ways in the two cultures. This is also indicative of a asymmetrical power relationships, in the sense that the perception of being subordinated the authority of others can be perceived as barriers towards communicating worries related to safety, or even as pressure towards taking undue risks (Antonsen, 2009c).

Similarly, it is described by a Norwegian supervisor that the way of communicating between a Polish supervisor and a Polish worker was very harsh and direct. These are also signs that are culturally determined; as you need to know the culture to understand the way of communicating and to be able interpret the meaning in the right way. A harsh and direct communication from a superior is a way to show power and control. This can further be related to the more hierarchic management seen in a Polish working group, where there are expectations of clear leadership with a designated "boss". Examples were given that Polish workers do not say "no" to their boss and that Norwegian superiors expect workers to have an option. These examples clearly show that managers' knowledge about culture and communication affects safety of migrant workers. Norwegian managers expect workers to speak out if work tasks collide with safety, whereas Polish workers rather put the instruction first.

From Hofstede's theory about cultural dimensions that includes "power distance" as an aspect to classify cultures, it can be seen that there is a quite large difference when it comes to the power distance in Norway and Poland (The hofstede centre, 2015). Norway scores low which according to Hofstede testifies a culture with decentralised power where decisions in large degree are taken together with employees rather than by the boss alone. On the other hand, Poland scores higher on the scale, clearly showing that the society is hierarchical, where subordinates are expected to get clear instructions. The cultural dimension theory can be argued on and is by several criticised (Gerhart & Fang, 2005; Guldenmund et al., 2013) to be too generalising; however the described aspects can give a better understanding about common factors within a national culture.

Nevertheless, individual differences should not be neglected. The differences within a country might be larger than between countries (Gerhart & Fang, 2005) and individual differences also play an important role. The interviews of the Polish informants show that there are huge differences between individuals, as do the interviews and statements of the Norwegian informants as well. Very often Polish workers in Norway are looked at as a homogeneous group. There are however differences in life situations, age, lingual skills, education and practical skills. Some are keen to learn the language fast, others not all. Some comply with all safety rules, others do not. This shows that there are individual factors influencing behaviour and practices and underline the importance of resisting the temptation to create cultural stereotypes of different work groups. Previous research (Bust, Gibb, & Pink, 2008) however shows that people from different cultures understand health and safety differently. This points to the importance of meaning in understanding the relationship between culture and safety: There may be important differences in the practices, rules and decisions which stand out as meaningful ("makes sense") for members from different cultures. This makes communication and safety management more complex (Bust et al., 2008), and thus communication will need to be adapted to the receiver of the communicated message.

6.1. Implications

As already indicated, most of the safety measures aiming to deal with the multinational nature of a construction site are aimed at overcoming language difficulties. The analysis presented in this paper suggests that this only solves part of the problem. Understanding the words in a language is important, but the cultural aspect that comes with it must also be considered. Culture must not be simplified to be treated as a lingual issue, but this is often the case. A Dutch study by Schubert and Dijkstra (2009) for instance show that cultural issues tend to be neglected. The study points out the tendency of safety mangers to deny cultural differences, not to discriminate and to treat everyone equally, as the Dutch social ideal desires. That might be one reason why cultural challenges have received less attention in Norway as well. Another reason might simply be that the cultural challenge is more demanding to deal with, and that it is not entirely clear what measures to take to deal with this challenge.

In safety management, however, the cultural aspect cannot be neglected as it in high degree influence safety through for example behaviour. Managers need cultural competence not to fall into the pitfalls that are created by cultural differences. By stressing and being aware of cultural aspects and the complexity different aspects together generate, this awareness can be applied in safety management tasks such as safety training, participation in the execution of Job Safety Analyses and learning processes after minor and major incidents.

7. CONCLUSIONS AND RECOMMENDATIONS

The factors behind safety challenges arising from the use of migrant workers are complex. Some of them are closely related to the construction industry, which is characterised by its dynamic nature, temporality, variability and uniqueness of each project. Other safety challenges are directly related to the use of migrant workers independent of industry, concerning communication, individual factors and organisational factors.

The presented study focused on aspects related to culture and language as underlying factors for accident risk at work in multicultural work sites. Communication is an important contributing risk factor with lack of lingual skills as one of the most obvious reasons. Culture is however at least as important, though more ambiguous and harder to recognise, i.e. you realise you do not understand each other if you speak different languages, but cultural misunderstandings are harder to perceive as they might be more hidden.

Lingual problems are emphasised by safety managers in the industry and most measures implemented in the sector concern language. Common measures are translation of documents, use of translators and language courses, which in many cases are only short term solutions. For cultural challenges there are not as many measures. Developing and implementing lingual measures is easier than trying to change cultural aspects. However, focusing solely on language as a problem might take away the focus from other important causes. Solving lingual issues is only one of the many solutions, and will therefore not solve the whole problem. Therefore a focus on cultural differences is as important.

Neither Polish migrant workers, nor migrant workers in general, are homogenous groups where all members are alike. They have a certain culture, a common language and a set of attitudes and habits, but there are also large individual differences. This should also be taken into consideration. The interviews indicated other underlying factors concerning the use of migrant workers and occupational safety. These were influencing factors such as individual factors; age, education, experience, family circumstances, level of integration in Norway, and organisational factors; terms of employment and training. These factors are not stressed enough and should be elucidated further.

Safety challenges in relation to migrant workforce mainly appear in the sharp end. Nevertheless, the challenges must be dealt with at all levels of the construction industry, from the authorities via the organisational level and down on individual level.

8. REFERENCES

Antonsen, S. (2009a). The relationship between culture and safety on offshore supply vessels. *Safety Science, 47*(8), 1118-1128. doi: http://dx.doi.org/10.1016/j.ssci.2008.12.006

Antonsen, S. (2009b). Safety Culture Assessment: A Mission Impossible? . *Journal of contingencies and crisis management, 17*(4), 242-254. doi: 10.1111/j.1468-5973.2009.00585.x

Antonsen, S. (2009c). *Safety culture: theory, method and improvement*. Farnham: Ashgate.

Behm, M. (2005). Linking construction fatalities to the design for construction safety concept. *Safety Science, 43*(8), 589-611. doi: http://dx.doi.org/10.1016/j.ssci.2005.04.002

Bryman, A. (2012). *Social research methods*. Oxford: Oxford University Press.

Burgess, J., & Connell, J. (2006). Temporary work and human resources management: issues, challenges and responses. *Personnel Review, 35*(2), 129-140. doi: doi:10.1108/00483480610645786

Bust, P. D., Gibb, A. G. F., & Pink, S. (2008). Managing construction health and safety: Migrant workers and communicating safety messages. *Safety Science, 46*(4), 585-602. doi: http://dx.doi.org/10.1016/j.ssci.2007.06.026

Corbin, J. M., & Strauss, A. L. (2008). *Basics of qualitative research: techniques and procedures for developing grounded theory*. Los Angeles, [Calif.]: SAGE.

Friberg, J. H. (2011). Culture at work: Polish migrants in the ethnic division of labour on Norwegian construction sites. *Ethnic and Racial Studies, 35*(11), 1914-1933. doi: 10.1080/01419870.2011.605456

Friberg, J. H., & Eldring, L. (2011). Polonia i Oslo 2010: Mobilitet, arbeid og levekår blant polakker i hovedstaden [Polonia in Oslo 2010: Mobility, work and living conditions among Poles in the capital] *Fafo-rapport 2011:27*. Oslo: Fafo.

Frijters, A. C. P., & Swuste, P. H. J. J. (2008). Safety assessment in design and preparation phase. *Safety Science, 46*(2), 272-281. doi: http://dx.doi.org/10.1016/j.ssci.2007.06.032

Gerhart, B., & Fang, M. (2005). National culture and human resource management: assumptions and evidence. *The International Journal of Human Resource Management, 16*(6), 971-986. doi: 10.1080/09585190500120772

Guldenmund, F., Cleal, B., & Mearns, K. (2013). An exploratory study of migrant workers and safety in three European countries. *Safety Science, 52*(0), 92-99. doi: http://dx.doi.org/10.1016/j.ssci.2012.05.004

Hofstede, G. (1984). *Culture's Concequences*. Newbury Park: Sage.
Håvold, J. I. (2007). National cultures and safety orientation: A study of seafarers working for Norwegian shipping companies. *Work & Stress, 21*(2), 173-195. doi: 10.1080/02678370701424594
IAEA. (1991). *Safety culture. International Nuclear Safety Advisory Group Safety Series 75, INSAG-4*. Wien: IAEA.
Jørgensen, K. (2013). System design integrated in the building delivery system. *Safety Science Monitor, 17*(1).
Kartam, N. A., Flood, I., & Koushki, P. (2000). Construction safety in Kuwait: issues, procedures, problems, and recommendations. *Safety Science, 36*(3), 163-184. doi: http://dx.doi.org/10.1016/S0925-7535(00)00041-2
Kouabenan, D. R. (2009). Role of beliefs in accident and risk analysis and prevention. *Safety Science, 47*(6), 767-776. doi: http://dx.doi.org/10.1016/j.ssci.2008.01.010
Lamvik, G., & Bye, R. (2004). National culture and safe work practice — A comparison between Filipinos and Norwegian seafaring professionals. In C. Spitzer, U. Schmocker, & V. Dang (Eds.), *Probabilistic Safety Assessment and Management* (pp. 1315-1321): Springer London.
Lindhout, P., Swuste, P., Teunissen, T., & Ale, B. (2012). Safety in multilingual work settings: Reviewing a neglected subject in European Union policymaking. *European Journal of Language Policy, 4*(2), 137-170. doi: 10.3828/ejlp.2012.10
Lingard, H., & Rowlinson, S. (2005). *Occupational Health and Safety in Construction Project*. London: Spon Press.
Litwin, G. H., & Stringer, R. A. (1968). *Motivation and Organizational Climate*. Boston: Harvard University.
Mayhew, C., & Quinlan, M. (1997). Subcontracting and occupational health and safety in the residential building industry. *Industrial Relations Journal, 28*(3), 192-205.
McKay, S., Craw, M., & Chopra, D. (2006). Migrant Workers in England and Wales: An assessment of migrant worker health and safety risks. London: Working Lives Research Institute.
Mearns, K., & Yule, S. (2009). The role of national culture in determining safety performance: Challenges for the global oil and gas industry. *Safety Science, 47*(6), 777-785. doi: http://dx.doi.org/10.1016/j.ssci.2008.01.009
Mohamed, S., Ali, T. H., & Tam, W. Y. V. (2009). National culture and safe work behaviour of construction workers in Pakistan. *Safety Science, 47*(1), 29-35. doi: http://dx.doi.org/10.1016/j.ssci.2008.01.003
Olsen, B. (2013). Innvandring økte sysselsettingen; Sysselsatte innvanderer 2002-2012 [Immigration increased employment; Employed immigrants 2002-2012]. *Samfunnsspeilet 5/2013*. Retrieved from: https://www.ssb.no/sosiale-forhold-og-kriminalitet/ssp/_attachment/157015?_ts=143715dfa88
Paul, J. A. (2013). Improving communication with foregin speakers on the shop floor. *Safety Science, 52*, 65-72.
Rosness, R., Blakstad, H. C., Forseth, U., Dahle, I. B., & Wiig, S. (2012). Environmental conditions for safety work – Theoretical foundations. *Safety Science, 50*(10), 1967-1976. doi: http://dx.doi.org/10.1016/j.ssci.2011.12.029
Salminen, S. (2011). Are Immigrants at Increased Risk of Occupational Injury? A Literature Review *The Ergonomics Open Journal, 4*, 125-130.
Saussure, F. d. (1983). *Course in general linguistics* (R. Harris, Trans.). London: Duckworth.
Schubert, U., & Dijkstra, J. J. (2009). Working safely with foreign contractors and personnel. *Safety Science, 47*(6), 786-793. doi: http://dx.doi.org/10.1016/j.ssci.2008.02.001
Starren, A., Hornikx, J., & Luijters, K. (2013). Occupational safety in multicultural teams and organizations: A research agenda. *Safety Science, 52*(0), 43-49. doi: http://dx.doi.org/10.1016/j.ssci.2012.03.013
The hofstede centre. (2015). The hofstede centre. Retrieved 08.07.2015, from http://geert-hofstede.com/countries.html
The Norwegian Labour Inspection Authority. (2012). Arbeidsskader blant utenlandske arbeidstakere [Workplace injuries among foregin workers] *Kompass Tema nr. 2 2012*. Trondheim: Direktoratet for arbeidstilsynet.
The Norwegian Labour Inspection Authority. (2014). Forstår du hva jeg sier? Krav til kommunikasjon og språk på bygge- og anleggsplassen [Do you understand what I am saying? Requirements for communcation and language at the construction site]. Trondheim: Direktoratet for arbeidstilsynet.
Trajkovski, S., & Loosemore, M. (2006). Safety implications of low-English proficiency among migrant construction site operatives. *International Journal of Project Management, 24*(5), 446-452. doi: http://dx.doi.org/10.1016/j.ijproman.2005.11.004
Turner, B. (1976). The Organizational and Interorganizational Development of Disasters. *Administrative Science Quarterly, 21*(3), 378-397. doi: 10.2307/2391850
Turner, B. (1978). *Man-Made Disasters*. London: Wykenham Science Press.
Wenger, E. (1998). *Communities of practice: learning, meaning and identity*. Cambridge: Cambridge University Press.
Zohar, D. (1980). Safety Climate in Industrial Organizations: Theoretical and Applied Implications. *Journal of Applied Psychology, 65*(1), 96-102. doi: http://dx.doi.org/10.1037/0021-9010.65.1.96

Risk Governance of Hazardous Industrial Areas by Legal Rules and Negotiated Social Contracts

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Abstract

Efforts to prevent major accidents are of great importance to safety and health for company on-site employees, contractor on-site personnel, emergency responders as well as local citizens. There is ample evidence that improving government regulation, industry self-regulation, and safety management could be proactive means. With industrial areas including logistic hubs, harbors and larger groups of individual firms, negotiation with communities and interest groups becomes an additional means of preventing major accidents and emergency response and thereby protecting the workforce and the neighbors.

This paper assess two innovative approaches for preventing major accidents and improving emergency response to determine if, in addition to protecting the public, whether they can also have the effect of more effectively safeguarding workers. The first approach is an enhanced state regulation model and the second a negotiated agreement model with both approaches involving engagement between companies and local stakeholders. Our objective is to explore how risk can be managed and conflicts avoided with risk governance fostering company engagement with its workforce as well as with the local community in a collaborative effort. The empirical basis for the analysis is comprised of three case studies; two involve state regulation of industrial harbor developments and logistics hubs in urban areas in Norway and one involves negotiations regarding a petroleum refinery in a US city. The findings and discussion underpin that the two approaches we have assessed for managing industrial risks of concern to host communites and their diverse stakeholders can coexist and serve as complementary components of risk governance for communities that host hazardous industrial activities. Each approach calls for close cooperative engagement of the parties and has potential for improving the safety and health of communities and on-site employees, contractor on-site personnel, and public sector emergency responders. Both approaches are logical extensions of progressive policies that aim at improving corporate social responsibility to the public and the workforce and can remedy the deficiencies of conventional regulation. Although they differ in structure and mode of implementation, they have many common features such as transparency of proceedings, local stakeholder involvement, information sharing, and respect for community concerns and local knowledge.

Keywords: Hazardous industry, risk governance, negotiated contracts.

1. INTRODUCTION

Hazardous industrial activities pose risks of major accidents and the history of major accidents shows that workers are the most endangered persons. As shown by major accidents at petrochemical plants at AZF-Toulouse (2001), BP-Texas City (2005) and Chevron-Richmond (2012) and in offshore operations Piper Alpha (1988) and Macondo (2010), three categories of workers are usually among those injured or killed by major accidents; company on-site employees, contractor on-site personnel, and public sector emergency responders. Norway and the US have many worker safety regulations, but these are not primarily directed at preventing major accidents and are more narrowly focussed on existing workplace conditions involving exposure to chemicals, electricity, noise, heat, etc. Norwegian and US laws also empower unions to negotiate with employers about improving workplace conditions, but the improvements sought also address workplace exposure issues and often given lower priority than wage and job security issues. Nor do they sufficiently encompass non-union contractors and public emergency responders. In this paper we have analyzed two innovative approaches for preventing major accidents and improving emergency response to determine if, in addition to protecting the public, whether they can also have the effect of more effectively safeguarding workers: an enhanced state regulation model and a negotiated agreement model with both approaches involving engagement between companies and local stakeholders. The empirical basis for the analysis is comprised of three case studies; two involve state regulation of industrial harbor developments and logistics hubs in urban areas in Norway and one involves negotiations regarding a petroleum refinery in a US city.

2. ANALYTICAL FRAMEWORK

Risk governance (Renn 2008, Aven and Renn 2010) is made up of many types of social controls, including regulation, self-regulation, liability law, values and behavioral norms, and decision-making by investors, insurers, and consumers. Each of these controls is a dynamic subsystem of risk governance that co-exists with, but does not necessarily complement the other controls, and some are international in scope, such as the collective wisdom of experts in a particular knowledge domain who contribute to the development of standards and industrial safety management systems (Baram and Lindøe 2014). Our research framework and analysis combine an enhanced state-managed regulatory model enforcing safety management and a negotiated agreement model involving local stakeholders such as workers, emergency personel, citizens groups, etc. Characteristics of the industry actor's involvement include its property rights, relationships with suppliers, investors, and customers, its membership in an industrial sector with other industry actors, and its management of risks for regulatory compliance and for going beyond compliance within economic and technological parameters. The local stakeholders can be similarly characterized, especially with regard to their organizational membership, risk burdens, legally established rights to property and safety, and their resources and capacity to engage with companies.

Figure 1 illustrates our analytical framework with the three entities and their relationships.

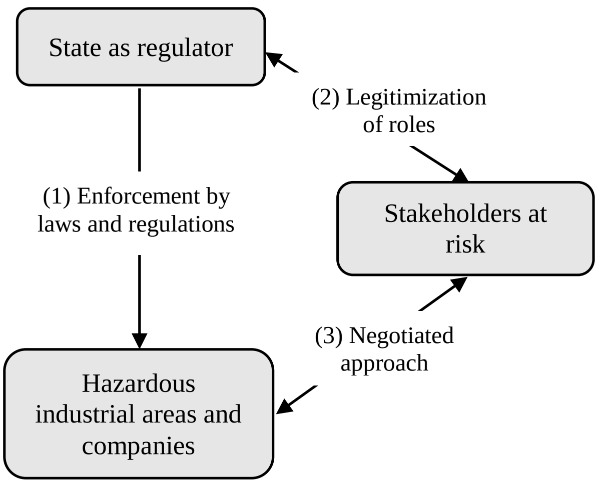

Figure 1. Analytical framework

The left side of the figure represents the state as regulator with enforcement authority based on laws and regulations, and as provider of resources for industrial use and of state services regarding preparedness for public emergencies (1). The state as regulator constitutes the most highly institutionalized form of social control for hazardous industrial activities. For many industrial sectors, national regime co-exists with global regimes. Regulators develop and enforce rules and standards as mechanisms of control and impose sanctions on non-compliant industrial actors, based on their legitimate role in society (Baldwin, et al. 2012). Their role can be characterized as compensating for market failure in handling risk, informing public opinion by influencing political priorities and decisions, and influencing stakeholders and their power structure (Hood, et al. 2001).

The right side of the figure represents the stakeholders affected by the risk, foremost in-house and contracted personnel, but also citizens groups and other civil society entities. The legitimate role of these actors in proactive risk management depends on the legal frame of laws and regulation as well as administrative practise at national, regional and local levels (2) (Bevir, 2011). The third relationship is the proactive role of stakeholders in negotiating an agreement that we call a new social contract with the industry or enterprises (3). Response to the perceived risk from these stakeholders could be reactive with protests or complaints directed to regulators

and industrial enterprises. The basis, content and effectiveness of such contracts depends on the legal rules (1) and the power-bases and legitimate role of the stakeholders (2).
Given this understanding of the inter-relationship of the actors, our research examines the enhanced model of state regulation designed by the International Risk Governance Council (IRGC) and the negotiation of a social contract model as a supplement to state regulation. The first approach, based on the IRGC-frame and the two Norwegian cases addresses the state-managed regulatory process and its potential for preventing accidents and thereby improving workforce safety. The second, negotiation approach, is based on social contract experience in the US and a US case study.

3. IRGC-APPLIED TOWARDS THE NORWEGIAN CASES

3.1 The IRGC-framework

The International Risk Governance Council (IRGC) framework, has received considerable attention and approval as a paradigmatic approach for conceptualizing and conducting risk governance processes. The "Core Risk Governance process" contains four phases as presented in figure 2: (1) pre-assessment, (2) appraisal, (3) characterization and evaluation of risk and (4) risk management. Communication is involved in all phases of addressing and handling risk. However, the sequence of phases and steps is primarily logical and functional and will not always correspond to how the process works out in reality. A more detailed description of the content of the framework is presented on the IRGC-homepages:// http:irgc.org.
The framework includes the wider institutional and societal context within which the risk governance processes take place. Four contextual layers add to the "Core Risk Governance Process" (Renn, 2008 p.353); *Organizational capacities* at different levels, within the involved actor network (enterprises, stakeholders, regulators, NGO's etc.), political and regulatory culture, and social climate (e.g. level of trust in society, risk appetites etc.).

Phases:	**Core Risk Governance Process**	
Pre-Assessment	Problem framing: What the major actors (e.g. governments, companies, the scientific community, and the general public) see as risks Early warning: Systematic search for hazards and threats Screening or monitoring of risk-related information Scientific conventions for how risk assessment and concerns are defined	
Risk Appraisal	Hazard (threat) identification of potential events Cause and consequence analysis, including assessments of exposures and vulnerabilities Risk description, quantitative and qualitative Concern Assessment including (1) perceptions, (2) social concerns and (3) socio-economic impacts	Risk Communi-cation
Tolerability and Acceptability Judgement	Risk characterization includes (1) the creation of a risk profile (expressed by probabilities and expected values) and (2) judgment on the seriousness of the risk. Risk Evaluation where societal values and norms are applied to the judgment on tolerability and acceptability.	
Risk Management	Implementation of the (1) option realization, (2) the monitoring and control of the consequences and (3) the collection of feedback from risk management practice. Decision Making includes (1) option identification and generation and (2) option assessment interdependent with the tolerability and the acceptability judgment step	

Figure 2. The IRGC Risk Governance Process (adapted from IRGC 2005: 13)

A radical OHS regulatory shift took place within the European countries in the 1970s. The change was inspired and based on the Robens Report (1972) recommending that, rather than specifying standards and procedures to ensure the safety of workers, legislation should specify the *OHS goals* to be reached and require employers to ensure the safety of their workers. The Nordic legislation adopted these principles as well as strengthened the emphasis on *participation* of the workforce and thereby strengthening their legitimate position and role in risk management. A common feature of Nordic OHS regimes, introduced concurrently in the Nordic countries in the 1970's, is the in-house use of an "occupational health and safety organisation" that offers three different collaborating structures (Karlsen and Lindøe 2006). First, "working environment committees" provide opportunities for employer and employees to meet and discuss relevant issues. Second, there are independent and autonomous «institutions» in the form of "safety deputies" elected by the workforce. Third, there are OHS expertsas either an in-house service or as external consultants. This modus, often referred to as a «Nordic Model», was different from the European continental tradition, where the parties have a lesser pull with the regulation and where the legislation has greater importance as the regulatory instrument. These regulatory principles from the Nordic countries, UK, and the offshore petroleum activity in the North Sea gave input to emerging efforts by the European Union to guide its members to introduce «risk assessment» and "participatory approaches", as seen in the Norwegian Framework Directive 89/391 (Vogel 1994). Fifty years later the industrial environment in many European countries is radically changed. A fragmentation of prescriptive labour market arrangements and increasing levels of part-time employment and temporary employment are distinctive features.

Public and citizen involvement in risk governance is safeguarded through the Seveso Directive obliging member states to ensure that operators have a policy in place to prevent major accidents. Further adaptation of the provisions on major accidents occurred on 4 July 2012 with publication of a replacement directive - 2012/18/EU, which member states have had to transpose and implement by the 1 June 2015. Important new elements in the revised version are: (1) Better access for citizens to information about risks resulting from activities of nearby companies, and about how to behave in the event of an accident, (2) more effective rules on participation, by the public concerned, in land-use planning projects, (3) access to justice for citizens who have not been granted appropriate access to information or participation and (4) stricter standards for inspections of establishments to ensure more effective enforcement of safety rules.

When regulators and companies fail sufficiently in addressing these issues, a troubled relationship develops and impairs company performance and community well-being. As a result, the community may impose more stringent local requirements for company operations, revoke or deny a company's permit to operate, individuals may bring lawsuits and groups may engage in negative campaigns against the company. In a growing number of communities the company and local stakeholders have taken the proactive approach of engaging in negotiation of an agreement that provides for company implementation of mutually-acceptable risk-reducing measures in addition to their compliance with applicable state regulations. In some cases, the negotiated agreement is contractual and enforceable, in other cases the agreement is one based on trust.

In a parallel development since the 1970s, public concern about social control of risk has become a global issue and led to a vibrant discourse about modes of regulation and industrial responsibilities, and to a proliferation of activist environmental and human rights NGO's which continuously challenge national regulators and industry sectors with their demands (Beck 1992). Increasingly, they bring emerging concerns about corporate social responsibility and climate change by means of political and legal processes to regional and global institutions such as the EU and the UN. The outcome of these political and legal processes are new laws and regulations that promote public and occupational health and safety, safeguard public infrastructure, and protect natural resources and the environment. Thus, in addition to negotiated agreements between companies and local stakeholders, policies promoting corporate social responsibility grow in importance.

3.2 The Norwegian cases

The two Norwegian cases involve hazardous industry activities such as production, storage and transport of gas, oil and chemical products where leakage, loss of control, and other foreseeable circumstances could lead to explosion, fire, and harmful discharges resulting in loss of lives, injuries and severe health consequences among workers and citizens. The cases differ in some respects as shown in the table below.

Case:	Risavika, Sola	South Harbor, Oslo
Activity	LNG-production, storage of goods, harbor and passenger terminal.	Storage and transport of chemicals, gas and oil products
Industrial structure	LNG producer and many minor companies.	Many major and minor companies
Governmental actors	LNG-producer and harbor owned by inter-municipal enterprises. Local planning authority. State regulators.	Harbor owned by municipal enterprise. Local planning authority Several state regulators.

Table 1. Characteristics of the Norwegian cases

Risavika, Sola

Risavika is a regional, national and international logistics hub in Sola municipality at the southwest coast of Norway. It is covering 400,000 square meters and including more than 120 enterprises, including a base for the offshore industry, and some 8,500 workplaces. A new ferry terminal operates international ferries for goods and passengers. In 2005, the Lyse Group, which is a large energy company owned by 16 municipalities in the south area of Rogaland County, informed Sola municipality (one of its owners) about the Group's plans to establish an LNG plant in Risavika, and the plan was approved in December 2006. Protests and complaints raised by citizens during the public consultation process requested more specific analyses of possible impacts and risks. Formal complaints were addressed to the County Governor and state agencies, notably the Directorate for Civil Protection (DSB), which is responsible for the fire and explosion legislation and for coordinating the enforcement of the Seveso directive, as the plant would clearly be subject to these regulations. Series of meetings, consultations, complaints and decisions took place involving a number of actors, from local citizen groups to responsible ministries and even the EFTA Surveillance Authority (ESA). The public debate in the press between these key actors opened a public space for risk communication and mobilized more stakeholders in the local community (Vinnem 2010). Lyse engaged experts organizing public consultations in which focus group meetings were organized, including residents living close to Risavika, enterprises located in the area, emergency services, and experts on risk appraisal and evaluation. Criticisms spanned the whole spectrum of conditions, decision-making processes, and perceived risks. In particular, the quality of the initial risk assessments was questioned in terms of assumptions and scope, and the availability of information and the involvement of stakeholders in the process were severely criticized. Contracted risk experts reviewed the existing risk assessments and how the planned and implemented measures would reduce the risks to a presumably tolerable level (Vatn 2010).

South Port, Oslo

The South Port of Oslo is located just south of the city centre, with well-established residential areas to the south, and a large residential area is in progress to the north. The port comprises most of the industrial activities in the Oslo harbor area as; the largest container port in Norway, the largest terminal for the storage and distribution of petroleum products with 40% of the national consumption of road traffic fuel. The South Port is thus one of Norway's most important logistics and transport hub.

The South Port comprises some 35 firms with port-related activities. Apart from the oil and container terminals, these include a variety of industries, such as the import of cars, building materials, cement, fertilizers, salt, etc. Some 1,600 ships arrive each year, half of which carry dry bulk, one-third carry containers and one-fifth carry petroleum products. Nearly 7,000 trucks transport products from the port area every week, of which nearly 2,000 are container trucks and some 1,500 are tankers. Jet fuel is transported by train to the Oslo Gardermoen airport. Approximately 2 640 000 m3 of petroleum products were transported from the South Port in 2012. Some 800-900 people (mostly employees) stay in the South Port area during ordinary working hours and approximately 1,500 people live in the residential area to the south, whereas the emerging residential area to the north will include some 4-5,000 apartments. The distance to downtown Oslo is about 3 km. The downtown area comprises a number of workplaces (some 20 000) and several thousand visitors during the day. No survey of risk perceptions of the neighboring populations has been carried out. Risks related to the petroleum activities have not been on the agenda. Missing surveillance has been explicitly addressed by the emergency services, such as the fire service and the police, not only for detection purposes, but also to provide updated and knowledge-based information in the case of an emerging situation in order to to facilitate adequate response.

3.3 Lessons learned from the state-managed appraoch

Analysis of the Norwegian cases underpin that frameworks for addressing risk often fall short of addressing complex and trans-boundary features that characterize many risk domains. Risk management models as well as statutory regulation normally address the individual enterprise or organization, leaving inter-organizational issues in a vacuum where the risk often exceed the boundaries of single policy domains and regulations. The IRGC framework facilitates a broader depiction of challenges when dealing with more complex and trans-boundary risk issues as found in the cases. Lessons learned can in particular be related to four interrelated features (Lindøe and Kringen 2015).

Firstly, multiple and partly conflicting goals, as critical aspects of both cases and in particular at the level of local government, may create role conflicts. As ports are normally part of developmental schemes and ambitions for municipalities, the tradeoff between benefits and risks must be addressed, as value creation and socio-economic considerations may tend to overshadow risk concerns. Secondly, the conditional and potentially controversial nature of risk assessments represent critical challenges in terms of both the normative and factual/scientific issues. Critical considerations exceed organizational boundaries and public attention creates challenges in terms of trust and competence. Contested views on risk does not only reflect a simple lay-expert divide, as one of the cases illustrates, but also an expert-expert divide. Thirdly, mechanisms and thresholds for triggering public attention seem to be highly variable, and stakeholder engagement may only incidentally reflect risks, to the extent that these can be described in any comprehensive and objective manner. Therefore, risk communication and stakeholder involvement cannot be conducted in any straightforward manner but must be adapted to the particular social climate. Finally, industrial areas and harbors as logistic hubs involves many actors and weak mechanisms for coordination and addressing overall risk challenges. Fragmentation exists in the institutional hierarchy where actors are subject to different legal rules and regulations enforced by different agencies. Therefore, regulators should be addressed as having the prime coordinating and proactive role in the governance process including the overall risk challenges.

In sum, the complexity of technical, economic, organizational, and political conditions underline that one cannot characterize risk independently of established institutional and practical arrangements in the local context. The multifaceted and complex risk governance processes in hazordous industrial areas represents a challenge. Important issues are if theres is sufficient governmental and industrial capacity to integrate all concerns and how the workforce and other affected stakeholders could be empowered by having a legitimate role in the process.

4. THE NEGOTIATION APPROACH

Negotiated agreements have been used by local stakeholders in many US communities addressing industrial companies risks to public health and safety. Such agreements could include emissions and accidental discharges of toxic pollutants, impacts on water supply, hazardous material spills, fires and explosions, and to also have companies improve pollution monitoring, do safety audits, provide access to company risk information and inform residents about operational changes. (Kenney et al., 1998; Macey 2003,2004; Murdock et al., 2002; Spitzer et al, 2009; and Gotlieb, 2012). Negotiation typically involves addressing a cluster of concerns over diverse risks and impacts, unlike traditional risk regulation that requires a separate agency-managed proceeding for each risk or impact. It therefore requires more extensive company preparedness and transparency, and often involves demands for company internal information that exceed what is required in regulatory proceedings. It draws the attention of the media and the entire community. Agreements with such commitments have been negotiated with many types of companies, including global majors with US facilities such as Shell, Rhone-Poulenc, and Chevron.

4.1 Good Neighbor Agreements

One illustrative example of the negotiation approach is “Good Neighbor Agreements” (GNA’s) between companies and community groups (Lewis and Henkels, 1998; Sexton, 2002; Macey and Susskind, 2003; Kenney et al, 2004). This approach has been used to address many concerns about proven as well as perceived risks and impacts, requests for information about company operations and management functions, and financial needs of a community that arise from company activities. GNA studies are informative about the types of company commitments agreed upon and the extent of their implementation. For example, the GNA between Rhone-Poulenc and an environmental NGO regarding the company's chemical plant in Manchester, Texas was negotiated in the aftermath of an SO2 release, which caused 27 residents to be hospitalized. Written agreement could include the company's commitments to pay for an independent environmental and safety audit by an expert selected by a committee whose members are chosen by the community. Issues could be to: Putting company documents on its hazard and risk assessments, accidents and near misses, corrective actions taken, and waste management practices in the town library for public review; subsequently "negotiate in good faith on the audit recommendations"; to allow citizens to accompany the auditor and inspect the facility; to monitor SO2 offsite; and to accept that the GNA agreement will be legally-binding. Over 90% of the commitments in this GNA were met by the company. (Lewis and Henkels, 1998).

Some GNA's have a much broader range of company commitments and have encountered implementation problems. For example, the GNA negotiated by Unocal and three citizens groups regarding operation of the company's refinery in Rodeo, California followed two accidental releases, one lasting sixteen days, the other involving deadly hydrogen sulfide gas that sickened children and teachers at a school. As challenges to the permits sought by the company for its expansion, lawsuits, and other adversarial activities by labor and residents commenced, Unocal reluctantly agreed to negotiate. Several other groups joined the difficult negotiations over eight months of weekly meetings, and the county government decided to make the GNA outcome a condition for its granting permits to the company (op.cit).

The negotiated GNA includes Unocal commitments to pay for a medical clinic and the medical needs of the injured, fund several emergency service improvements and a study of public health impacts. Furthermore it pay for an independent safety audit of the plant overseen by a community committee and determine whether and how to implement its recommendations, develop an advanced air monitoring system and stop "fugitive emissions" of certain air pollutants, reduce traffic impacts and contribute several millions to fund local road improvements. Approximately 60% of the commitments have been met after several years.

Overall, studies of GNA's show that a majority or more of company commitments were implemented, especially commitments which focused on preventing the recurrence of a prior injurious event and improving emergency response services. Perhaps the most notable achievements of many GNA's are informational and involve company commitments to allow and pay for independent health and safety audits of the company's operations, to act upon audit recommendations for improvements, and to accept public involvement in the audit process and public review of relevant documentation (Macey et al., 1998).

Given this legacy, the negotiated agreement model shows that bringing about the direct engagement of a company with its host community and local stakeholder groups for risk reduction can be an effective supplement to government risk regulation. It follows that when such negotiations improve community safety and health, they usually improve the safety of on-site workers and emergency responders as well as their quality of life in the community. However, improvements are needed to make negotiation a more effective approach to risk reduction and major accident prevention.

4.2 The Chevron, Richmond case

The huge Chevron Refinery in Richmond, California has had many incidents that threatened public health and safety. Reports on its operations from 1992-1994 showed an average of 45 "episodes" (accidental releases and spills) per year (Macey 2004). An explosion and fire at the plant in March 1999 resulted in authorities issuing "shelter in place" orders and hundreds of residents exposed to the pollutants sought medical attention. In 2007, a corroded pipe failed at the Refinery, "shooting 100-foot flames into the sky for 10 hours. Thousands were ordered to shelter in place because toxic gas was released" (Rogers 2013).

These incidents occurred despite several agreements on improving operations that had been negotiated between Chevron and local stakeholders since the early 1990's, despite numerous US and California regulations applicable to the plant, and despite Richmond's adoption of an Industrial
Safety Ordinance (ISO) in 2000.The city's ISO requires Chevron to:

- Submit a Safety Plan to Contra Costa Health Services

- Comply with the Human Factor Guidance Document developed by Contra Costa Health Services
- Perform a “root cause analysis” for chemical accidents or releases
- Submit to incident investigations by Contra Costa Health Services
- Comply with the California Accidental Release Prevention Program
- “Consider Inherently Safer Systems for new processes or facilities”
- Submit to routine audits, inspections, and review of all submitted safety plans by county and city officials

In 2012, another major fire at the refinery sent exposed workers and thousands of residents to local hospitals and triggered public outrage, lawsuits, and intensive investigations by regulators including the state’s workplace safety agency (Cal/OSHA). The US Chemical Safety Board (CSB 2014)) found that a small leak was observed in a corroded carbon steel pipe containing hydrocarbon process fluid. The plant manager had responded by calling in Chevron technicians to troubleshoot the leak but did not shut down operations. After several repair attempts failed, the decision was made to shut down the refinery; however, prior to shutdown, “hot work” repairs on the corroded pipe caused an explosive release of a vapor cloud that immediately ignited, engulfing 19 Chevron employees. While the employees made it to safety, the fire continued to burn for over four hours, sending “a large plume of unknown and unquantified particulates and vapor traveling across the Richmond, California, area” (CSB 2013 [2]). Nearby residents were instructed to shelter in place with their windows and doors closed (SFGate 2012). 15,000 people from the surrounding community and the exposed workers subsequently sought medical attention for respiratory complications due to the fire (CSB 2013 [2]).

The CSB investigation went further. It determined that the ruptured pipe had been installed in 1976 and had failed due to sulfidation corrosion, a frequent problem at refineries of which Chevron was well aware, especially regarding the effect on its carbon steel pipes. Moreover, the CSB learned that the pipes in the Richmond Refinery had been inspected and recommended for replacement several times in the preceding years, but had never been replaced. The CSB concluded that “the pipe should have been replaced much earlier with an inherently safer corrosion-resistant alloy” (CSB 2013 [1]). Ultimately, the CSB concluded that the core problem was the deficient safety culture at the Chevron Richmond Refinery.

Richmond residents recall that hearing the results of these investigations after the 2012 fire was “a jaw dropping moment for them.” Though they were used to occasional incidents at Chevron, people assumed that Chevron was serious about safety; after the 2012 investigations, however, they started to see the refinery as “literally duck-taped” together. In 2014, an RPA activist described the daily public anxiety of living within range of such industry as the “toxicity of being scared.”

A year after the fire, CSB produced a report calling for *Inherently Safer Systems*, and proposed major regulatory reforms not just for the Chevron refinery but also for the City of Richmond, county government, California state regulators, the U.S. Environmental Protection Agency, and Chevron USA (CSB 2013 [2]). In a public meeting in Richmond on January 15, 2014, the CSB explained that they believed that “we have a fundamental refinery safety problem in the United States,” that refineries are the most incident-prone of all facilities regulated by the EPA, and that such refinery incidents in Europe were far less frequent. They recommended that U.S. and state agencies act in coordination to adopt a “Safety Case regime” based on the approach taken by the U.K. This model, which has been shown to have certain inadequacies and excludes transparency in the U.K., is being considered by state and federal officials and faces opposition. The CSB investigation has also sparked intense discourse in Richmond about many aspects of safety management at the Refinery, including, for example, the need to improve inspection and the inclusion of workers, unions, and communities in safety decisions (CSB 2014 [2]; Rogers 2014).

City residents also demand that Chevron be more committed to running their refinery with a strong culture of safety. Because of the 2012 fire and prior incidents, the community has lost trust in Chevron’s commitments to safety. The Chemical Safety Board’s reports were particularly damning; not only did they show that the pipes that failed were known to be compromised for several years, but their reconstruction of the sequence of events found that recommendations to shut down the Refinery on the day of the fire were overruled until it was too late (CSB 2013 [2]).

4.3 Lessons learned from the negotiation approach

The negotiated agreement between a company and its host community or group should be designed to serve as a supplement to other social controls over risks and impacts in the community (such as regulations, municipal ordinances and permits, property rights, and self-regulation). Safety and health risks to be addressed should either be proven, or considered to be plausible on the basis of monitoring data, audits of company activities, or information on community or group exposure levels, or local knowledge; and commitments for addressing them must not conflict with or undermine existing federal, state and local regulations.

The negotiation process needs to be inclusive of diverse stakeholders, many of whom have been previously disregarded by the company and regulators, such as the low-income residents commonly living in close proximity to the facility, and respect local concerns, values, grievances, and local knowledge. It requires that company-held information and plans be shared and explained, with special arrangements to ensure the confidentiality of information that is proprietary or essential for security. Sound ethical principles need to be followed by the company and community participants, especially to ensure that financial donations offered by the company are not used to divide the local participants or secure compromises on significant risks that have been proven. Finally, to avoid situations leading to outrage and mistrust, as in the Chevron case, the company must be prepared to meet local expectations regarding their safety performance and accept stakeholder oversight and monitoring progress on its commitments.

5. CONCLUSION

The paper has identified two approaches for managing industrial risks of concern to different stakeholders. Each approach calls for close cooperative engagement with the parties and has potential for improving the safety and health of communities and on-site employees, contractor on-site personnel, and public sector emergency responders. Both approaches are logical extensions of progressive policies that aim at improving corporate social responsibility to the public and the workforce and can remedy the deficiencies of conventional regulation. Although they differ in structure and mode of implementation, they have many common features such as transparency of proceedings, local stakeholder involvement, information sharing, and respect for community concerns and local knowledge. Thus, they can coexist and serve as complementary components of risk governance for communities that host hazardous industrial activities.

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7. REFERENCES

Aven, T. and O. Renn (2010). Risk Management and Governance. Heidelberg, Springer.

Baldwin, R., et al. (2012). Understanding Regulation. Oxford, Oxford University Press.

Baram, M. and P. Lindøe (2014). Modes of Risk Regulation for prevention of Major Industrial Accidents. Risk Governance of Offshore Oil and Gas Operations. M. Baram, P. Lindøe and O. Renn. New York, Cambridge University Press.

Beck, U. (1992). Risk society : towards a new modernity. London, Sage.

Gottlieb, G. (2012): Regulating Natural Gas Development through Local Planning and Land Use.

Hood, C., et al. (2001). The Government of Risk. Oxford, Oxford University Press.

Hopkins, A. and Hale A. (2002): Issues in the Regulation of Safety. In B. Kirwan, Hopkins A. & Hale A. (Eds.) *Changing Regulation* (pp 1-12). Oxford: Pergamon.

Karlsen, J. E. and P. H. Lindøe (2006). "The Nordic OHS Model at a Turning Point?" Policy and Practice in Health and Safety **4**(1): 17-30..

Kenney, D., Chavez, J., Fitzgerald, A. (2004): Evaluating the Use of Good Neighbor Agreements for Environmental and Community Protection, Natural Resources Law Center, U. Colorado Law School

Lewis, S.,Henkels, D. (1998): Good Neighbor Agreements: A Tool for Environmental and Social Justice, Social Justice, v. 23, n. 4

Lindøe, P. and J. Kringen (2015). "Risk governance of hazardous industrial ports and areas: a case study of industrial areas and harbors in Norway." Journal of Risk Research. **http://dx.doi.org/10.1080/13669877.2015.1017829**

Macey, G., Susskind, L. (2003): Seeking Good Neighbor Agreements in California, US EPA, report 300R03004

Macey, Gregg P. 2004. “Seeking Good Neighbor Agreements in California.” Cambridge, MA: *Consensus Building Institute*.

Murdock, B. And Sexton, K. (2002): Promoting Pollution Prevention through Community-Industry Dialogues: The Good Neighbor Agreement in Minnesota, Env. Sci.& Technology, v. 36, pp. 2130-2137.

Peterson, Mark A. 5 August 2013. News Release: Chevron USA Inc. Enters No Contest Plea To Labor Code And Health And Safety Code Violations For August 6, 2012 Fire At Richmond Refinery. *Office of the District Attorney, Contra Costa County.*

Renn, O. (2008). Risk Governance. Coping with Uncertainty in a Complex World. London, Earthscan.

Robens Lord A. *Report of the Committee of Inquiry into Safety and Health at Work.* Cmnd 5034. London: HMSO, 1972.

Rogers, Robert. 10 August 2013. "Chevron refinery fire one year later: Fallout, impact show no signs of waning." *Contra Costa Times.* http://www.contracostatimes.com/news/ci_23833917/chevron-refinery-fire-one-year-later-fallout-impact

U.S. Chemical Safety Board. 2013 [1]. *Chevron Richmond Refinery Fire Animation.* Available online at: http://www.csb.gov/mobile/videos/chevron-richmond-refinery-fire-animation/

--------. 2013 [2]. *Interim Investigation Report: Chevron Richmond Refinery Fire.* Available online at: http://www.csb.gov/assets/1/19/Chevron_Interim_Report_Final_2013-04-17.pdf

--------. 16 January 2014. "Richmond: Federal board rejects safety recommendations stemming from Chevron refinery fire." *Contra Costa Times.* http://www.contracostatimes.com/contra-costa-times/ci_24922079/richmond-federal-board-at-odds-over-recommendations-stemming

--------. 2014 [1]. Chevron Refinery Fire Investigation. U.S. Chemical Safety Board. Accessed March 2014 from: http://www.csb.gov/chevron-refinery-fire/

--------. 15 January 2014 [2]. "Chevron Richmond Refinery: Public Meeting." Neal R. Gross and Co., Inc. Available online at: http://www.csb.gov/assets/1/19/Transcript6.pdf

Vatn, J., Ed. (2010). Issues related to localization of an LNG facility. Risk and Safety: Theory and Applications. Leiden, Taylor & Francis.

Vinnem, J. E. (2010). "Risk indicators for major hazards on offshore installations." Safety Science **48**: 770-787.

Vogel, L. (1994). Prevention at the workplace : an initial review of how the 1989 Community framework Directive is being implemented. Brussels, European Trade Union Technical Bureau for Health and Safety.

A resource guide for developing and implementing science-based stakeholder involvement (V1/2013). http://stakeholder.irgc.org/resource-guide/The Seveso III Directive 2012/18/EU which member states have to transpose and implement by 1st June 2015, http://ec.europa.eu/environment/seveso/index.htm.http://www.cpn.org/topics/environment/goodneighbor.html;

Improving safety through changes in work place culture: a study from the oil and gas industry in Denmark

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Abstract

The Danish offshore industry at the North Sea has a strong tradition of safety and of reducing work-related accidents, and new policies and practices are continuously developed. A major challenge is to implement new policies into practice. In particular, routines, norms and cultural perceptions may be difficult to alter in the process of implementing new policies. This study aims to explore the implementation process of a new safety mindset in a Danish oil company and focuses on 1) the contents and methods of the mindset (programme) and 2) how employees perceive the new safety mindset. The results of study showed that the implementation of the programme was successful in some areas, but there were also some challenges. The employees perceived the programme as positive, particularly because they felt that it respected their everyday work routines and that their perspectives were taken into account. However, cultural changes take time and are further complicated by frequent staff transitions. In addition, one disadvantage was that there was a lack of resources to follow up on all activities introduced through the programme. Moreover, safety representatives indicated that they lacked concrete and systematic tools to promote and improve safety.

Keywords: Accident prevention, offshore, safety culture

1. INTRODUCTION

Work accidents and injuries can have serious consequences for victims, for the environment and for society. The societal pressure to prevent accidents and improve safety in the oil and gas industry is strong, and the industry has correspondingly had a strong tradition of safety in the workplace. Major disasters, such as Chernobyl in 1986 and Piper Alpha in 1988, gave reason to focus attention on management systems, procedures, organisational factors and safety culture (Hale & Hovden, 1998). Improvements in safety and accident prevention can be performed on micro (individual attitudes and behaviour toward safety practices); meso (the structure, culture and practice of local organisations); and macro (national and international legislation related to minimising hazards, design improvement and employee protection) levels.

The most common approach in the oil and gas industry is the behaviour-based approach (BBA), which focuses on, among other issues, training employees in safety (Tharaldsen, Olsen, & Rundmo, 2008; Tharaldsen, 2011). However, the latest research provides evidence that a BBA is not sufficient to improve safety (Lund & Aaro, 2004). A review by Aaro and Lund found that the most effective improvement in safety includes both structural changes within the organisation and employee training (Lund & Aaro, 2004).

Currently, the concept of a safety culture is widely used within safety research and is a promising step toward understanding the social processes that takes place at the meso level, (for example, when new safety practices are implemented) (Antonsen, 2009; Cox & Flin, 1998; Guldenmund, 2000; Hale, 2000; Mearns & Flin, 1999).

The oil and gas company involved in the present study had until recently primarily used BBA to improve safety. Their safety performance has increased from when the company first started production, but for the last 10 years, the rate of injuries has been stable and not subject to further decrease. The company therefore decided to try another approach toward safety that focuses on changing the organisational culture rather than merely being concerned with changing individual behaviours. Viewing the change in a theoretical framework based on organisational culture, this study aims to explore the implementation process of the new safety mindset and focuses on 1) the contents and methods of the mindset (programme) and 2) how employees perceive and practice the new safety mindset. These insights will be discussed in relation to the challenges faced when implementing new safety practices in organisations.

2. THEORY

Implementation of a new policy, practice or idea has been approached differently over time. Traditional information campaigns rely on the presumed causality between knowledge, attitude and behaviour—the so-called KAB model (Bettinghaus 1986). However, information campaigns have proven inefficient to truly change individual behaviour because they fail to acknowledge and address individual preferences, meanings and the social, cultural and political environments that individuals are part of (Chambers 1997). A comprehensive review of implementation research concludes that there is evidence that information dissemination and training alone are ineffective implementation methods (Fixsen et al. 2005). There is, however, a lack of evidence for what is effective. There are suggestions that the success of implementation of a new policy, practice or idea depends largely on the system and organisational factors, the contents of the policy, how meaningful it is to the inhabitants of the setting, and whether time and resources allow inhabitants to adapt to it (Ibid). The adaptation of new ideas by a community is illustrated in a diffusion of innovation theory, which identified 5 factors that influence the speed and success of an innovation: the characteristics of potential adopters, the rate of adoption, the nature of the social system, the characteristic of the innovation, and the characteristics of change agents (i.e., individuals who are advocating for change) (Rogers 1983). Over the last decade, a variety of implementation models have been developed to address local environments, organisations, specific groups or smaller settings where behavioural changes are needed. These models commonly acknowledge that unless a community recognises that a change is needed and does not conflict with existing norms, the innovative policy is likely to fail (Petersillia 1990). The benefit of knowing the needs and strengths of organisations in implementation processes guides our attention to participation. Collaboration or participation by community members is crucial to gain a community's trust and knowledge of its characteristics. Participation is, however, a contested concept (Cooke and Khotari 2001). While it is promising in the sense that it allows us to access local knowledge and thus adjust policies to the local context, it challenges the ways we approach and understand a local community (Ladekjær, Larsen & Stock 2010).

The concept of organisational culture is broad and can be approached in different ways. For example, a key perspective is the distinction between functionalist and interpretative approaches (Glendon & Stanton, 2000). According to functionalist approaches, an organisational culture exists as an ideal that organisations should try to achieve. The primary function of an organisational culture is to support management strategies, systems, and goals. This approach is thus expert-driven and gives little attention to member's perspectives. The interpretative approach, on the other hand, understands organisational culture as a complex phenomenon that aims to assist members of the organisation in interpreting their collective identities, beliefs, and behaviours. Organisational culture is not the property of any one group or individual but is created by all members of an organisation. The interpretative approach is more likely to be considered a "bottom-up" approach and allows for the existence of subcultures within organisations (Glendon & Stanton, 2000). Several other perspectives of organisational culture can be identified in the existing literature, including the integration perspective, where culture is viewed as the 'glue' of an organisation and a 'compass' that provides direction to its members who share cultural understandings (Alvesson, 2002; Antonsen, 2009; Richter & Koch, 2004), and the differentiation perspective, which focuses on the coexistence of subgroups within the organisation and attempts to uncover conflicts and power relationships within organisations. While the integration perspective focuses on consistency, the differentiation perspective focuses on inconsistency among different aspects of the culture of an organisation (e.g., differences among words, action, official values, and real-life practices). This inconsistency could be compared with Goffman's concepts of the front stage and back stage of social life (Antonsen, 2009; Goffman, 1959).
Finally, the fragmentation perspective views an organisational culture as a "web of individuals, sporadically and loosely connected by their changing position on a variety issues" (Martin 1992:153). In this perspective, members of an organisation construct their own definition of reality, and there is no predefined cultural script that provides guidance for behaviour (Antonsen, 2009). In summary, organisational culture is more or less shared by and shaped by its members. The organisational culture has a significant impact on how safety is practiced in organisations. This is known as safety culture, which is:
"the product of individual and group values, attitudes, perceptions, competencies and patterns of behaviour that determinate the commitment to and the style and proficiency of, an organisation's health and safety management. Organisations with a positive safety are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety and by confidence in the efficacy of preventive measures" (Advisory

Committee on the Safety of Nuclear Installations(Advisory Committee on the Safety of Nuclear Installations (ACSNI), 1993).
This definition acknowledges that culture is shared by and shaped by its members and thus is building upon an approach that calls for member participation in the implementation processes.
The understanding of organisational culture has a significant influence on how the understanding of safety is practiced and perceived and thus affecting how safety programmes are designed and implemented. Our approach in this study follows the safety culture definition, which allows us to investigate the relationship between a safety programme and workers' comprehension and practices of that programme.

3. METHODS AND DATA

The current study is a qualitative, in-depth study of the processes related to the implementation of a new safety mindset in a Danish oil company. The study focuses on 1) the contents and methods of the mindset (programme) and 2) how employees perceive/practice the new safety mindset.
One operating company in Denmark was included in the study. Data collection took place onshore at the University, at the company onshore and in one interview at an airport. The reason for only collecting data onshore was that the present study is a follow-up study with limited time available. The first author has been on the installations in connection to the previous study and has knowledge and understanding of the work on offshore installations.
The data are drawn from several sources:

- Six interviews lasting from 30 minutes to 1 hour were conducted:
    - Three individual interviews with management onshore
    - Three focus group interviews with management level and regular offshore employees
- Observations of onshore safety meetings (18 meetings)
- Four 4-hour workshops with offshore employees onshore:
- In total, 40 offshore employees participated in the workshop. During each workshop, employees were divided into two groups (employees from the same installation were not assigned to the same group if possible).
- Documents: internal journal that is published 4 times a year from the period 2011-2014; safety programmes from the period 2011-2014.

The interviews were carried out following a semi-structured interview guide on the following topics: mindset evaluation, communication, attitude toward safety, management's commitment to the programme, procedures, accident prevention and the near-misses system. The first author conducted interviews from October to December 2014. The interview participants were chosen based on their position in the company, represented different departments both onshore and offshore and were from different levels in the organisations (i.e., management, supervisor). In addition, observations of 18 safety meetings were carried out onshore; representatives from offshore participated by video conference. Observations were made during two workshops about mindset organised by the company and four workshops organised by the first author. The goal of the workshops was to speak with offshore employees about their experiences with the new mindset and their attitudes toward safety, safety culture, and procedures. The participants signed up for the workshops voluntarily. One of the challenges of the voluntary format is that some respondents will be very positive and engage, while others can be critical. The respondents who participated in workshops came from different departments, representing different jobs and positions at the installation; however, there were few volunteers from contracting companies.
All interviews were recorded, transcribed and coded with NVIVO 10. The observations, workshops and documents such as safety programmes and the internal journal were also entered into NVIVO 10 (Bazeley & Jackson 2013).
The interviews and data from workshops were coded through open coding. Then, the open coding underwent a focused coding, and relevant categories were merged together.
Data analysis of the documents identified key terms of the mindset by performing an initial open coding followed by merging the categories.

3.1. Setting description

The oil and gas production started in Denmark in 1972. The production contains 19 oil and gas production fields in the Danish sector of the North Sea, with 55 offshore production installations, 10 of which are manned. A total of 10 companies contribute to the Danish production, but only three of the companies serve as operators (DEA, 2012). The oil and gas industry in Denmark is subject to different legislations. On an international level regulation is in the form of directives from the European Union, while on the national level, regulation is in the form of legislation and executive orders. One of the main pieces of legislation is the offshore safety act, which aims to promote high standards of offshore safety and health (DEA 2012). The oil and gas industry has a different organisational structure than onshore organisations. In Denmark, there are three operating companies that carry out exploration and recovery of hydrocarbons. The operating company participating in this study is responsible for day-to-day operations of an offshore installation. However, the operating company does not provide all staff at the installation; some of the jobs are performed by contracting companies. The operating company provides the core crew, which includes management of the installation, supervisors, and technical employees in the control room, while the rest of the employees come from contracting companies. The number of employees from contracting companies varies and is dependent on activity on the installation. The Danish oil and gas industry is characterised by offshore production, whereas the management, planning, and support of the production are established onshore. The onshore installation is divided into different units, such as support for offshore sites, exploration, production and the Health, Safety and Environmental Department. The main responsibility on the installation belongs to the Offshore Installation Manager (OIM), which is also an administrative function; the OIM reports to the onshore management. The crew consists of different groups, all of which have a supervisor/foreman. The education of offshore employees ranges from uneducated employees to highly specialised technicians. Most offshore employees work shifts of two weeks offshore and three weeks at home. The production on the installation is a constant and on-going process, which means that there are employees present for 12-hour day or night shifts year round. Due to the complicated operations and risk of explosions, the focus is very much on safety. Employees must follow specific procedures at work and are required to conduct a risk assessment before every task. One of the most important elements of the work offshore is the permit to work. The permit to work system ensures that the work tasks are conducted safely and that the employees follow procedures and conduct proper risk assessments. Many of the tasks, which are categorised as high risk, require a valid permit to work. This means that the employees have to complete a form in which they describe the work, assess the risk and describe how the risk can be avoided or minimised. The permit to work has to be signed by the management at the installation; without it the employees are not allowed to proceed with the task.

4. ANALYSIS

4.1 Programme/mindset description

The company involved in the study introduced a new mindset/programme in the beginning of 2011. The programme consists of an introduction, an intervention and maintenance. During the introduction, all employees participated in a one-day workshop that presented the idea of new mindset. The intervention consisted of several local activities at installations and increased focus on the new mindset. The last part of the programme was launched in early 2015 with a refresh workshops for all employees; this part is still on-going and is not part of this follow up study.

The aim of the mindset/programme was to change the existing organisational culture toward a better safety culture. The programme should establish a culture in which:

- the employees take responsibility for themselves and their colleagues, so no one is getting hurt
- strong relations are created among colleagues at the work place, which supposedly drives employee safety
- employees can talk freely and discuss and report incidents without fearing the consequences
- follow up is conducted on good ideas and suggestions
- an attitude that all accidents can be avoided is promoted
- safety behaviour is recognised and rewarded

Overall, the programme emphasised the responsibility for the employee’s own and for his/her colleagues’ safety, which also meant intervening when someone is not following safety procedures. Moreover, the focus is on acknowledging individual vulnerability and the importance of risk assessment before and during the job and on the importance of always having a valid permit to work. Implementation of the programme began in 2011 and is on-going. The programme implementation was divided into three parts:

- Introduction to the programme
- The change process
- Maintaining the programme

Introduction to the programme started in 2011 with the goal of introducing a new way of thinking about safety within the organisation. All employees from both the operating company and the contracting companies participated in a one-day workshop that explained the new programme and new principles. Supervisors received additional training to help them create the dialogue in the organisation. The goals of the first part of the implementation were to make the programme visible in the organisation; motivate the employees and management to share ideas, worries and thoughts; prevent accidents; and promote safety.

The intent of the second part of the implementation process was to continue with engagement of and motivation for the programme. The goal was to improve safety performance and ensure that every employee had knowledge of the importance of safety.

The third part of the implementation focused on maintenance of the programme, learning from incidents and positive dialogue.

4.2 Overall perceptions of the programme

The employees responded positively to the programme. It is expressed in the following interview excerpts:

We have engaged employees and programme ambassadors, we have decreased the number of incidents, it is allowed to report (incidents), the programme has changed the culture, the culture is not the same at it was before.

It is really good, it (the programme) had a good influence, focus on safety, it caught it all.

People have trust and believe that everybody means this, and it is necessary to do it to create a different focus on safety.

During the workshops, the employees emphasised that the biggest success of the programme was that they could see the involvement of the management and that for the first time they felt that the management team was very serious about safety. As one interviewee said:

There was commitment from top management, of course we had some external consultants to help, but the biggest thing was commitment from top management. We did workshops, which were conducted by our own employees, and management was involved all the time and presented at workshops explaining that this is important.

The success of the programme according to respondents was that it was targeted and that the focus was on process and not on results:

It is a journey you have to take on your own, it is the first time we have focused on process instead of results."

Several employees at the workshop and during the interviews mentioned that the programme introduced a new way of approaching safety and had more focus on changing the overall attitude towards safety.

The aim of the programme was to create a different focus on safety, we could see in the statistics that the last 15-20 years there had been no big change, the programme focuses on two areas: process safety and behaviour, but in a different way, we think about taking responsibility for each other, on the soft values, it is something new, we have observed good results and awareness became better in the organisation, we discuss things in a different way, it is a process which never ends, we are on a journey.

It is an enormous change in how people think, people have a different attitude and they take the new employees with them.

One of the new focus areas within company, which was introduced with the programme, was the focus on “soft values.” Soft values refers to the social environment of the workplace, indicating that personal relationships, the well-being of employees, and consideration of work conditions when planning the tasks are of great importance in establishing a sustainable safety culture. The focus on soft values was mostly presented in the internal journal but also mentioned in some of the interviews:

In the last year, safety changed to the better after the implementation of the programme. The programme mindset focus means that we are aware of the soft values to a higher degree.

Table 1 shows the results of the data analysis on the overall positive perceptions of the programme. The results indicate that, at the organisational level, there was a focus on attitude changes and the importance of personal relationships. As mentioned before, the focus on personal relationships was a new approach in the organisation. This shows a change toward more soft values and an increased focus on the organisation’s culture. In this sense, the new mindset is based on the safety culture approach; i.e., that a safety culture is the result of common norms and values and social interactions rather than individual behaviour changes. Other findings emphasised open dialogue, ownership and social well-being, which correspond with participatory approaches that invite members of an organisation to be engaged.

Table 1 Perceptions of the programme

Organisation’s description of the programme	Employees’ descriptions of the programme
Changes in attitudes	Changes in attitudes
Importance of personal relationships	Management really means it
More open dialogue	Visible and engaged management
Fewer accidents	More open dialogue
Change of mindset	Greater focus on safety
Ownership	Changes in management styles
Common responsibility	Common responsibility
Feelings	
Increased reporting	

4.3 Perceived challenges of the programme

As mentioned, the programme focused on values, understanding the present to achieve a better future, knowledge, learning and improvement. However, real-life implementation does not always fit the aims of the model. As one the respondents stated:

We succeeded in some places but not in others.

The employees and managers who were interviewed mentioned several areas that were not successful. One was lack of follow up and evaluation of activities and tools to develop the programme further. One of the responders said:

We realised that you can change peoples’ mindset, and you can be clear about your expectations of them towards safety, but you have to give them tools as well, you can’t tell people that you expect some things of them but not give them means to do it, (…) we have successfully moved some minds, but we really have not given people tools to back it up.

The participants at the workshops had similar opinions. Safety representatives in particular emphasised that they lacked tools to be able to address the changes of attitude that occurred.

Another challenge was the level of communication. One of the respondents said that the communication about the programme could be better. Some of the employees mentioned that the programme was formulated quite broadly, which sometimes confused employees; it was difficult for them to determine the main focus of the programme. Moreover, the amount of information was insufficient as the programme was not easy accessible on the company’s website. The intensity of the programme implantation also changed, from being very intense in the beginning to being almost non-existent:

It was a good process, but it is about focus and maintaining the programme all the time and that can be difficult.

It is a challenge, what worked yesterday does not necessarily work today.

The challenge is to keep the programme going and to engage employees to continue their involvement. As one of the respondents mentioned, the challenge is in defining what the aim of the programme is in the future:

Is it about the path we are supposed to take in the future, or is it changing the mindsets or about what things move us forward?

The discussions about the programme's future are still on-going, and there is no common understanding of the aim of programme in the future.
The programme was mostly implemented offshore, and there was a gap between implementation of the programme offshore and what happens onshore where projects are planned. Some of the respondents describe it in the following way:

We should have the programme in mind when we make the important decisions onshore, but we have not seen it yet.

We should have the programme also onshore and at the corporate level, we focus very much on personal safety, but we do not have enough attention on those huge mistakes that can cause an installation to explode.

Do we make risk assessments of the right things; do we make decisions based on the right background? We are not there yet.

One of the focuses of the programme is on learning from incidents and learning from the past to improve the future; this part was not very successful. The company still has problems with learning from incidents.
We are trying to be a learning organisation; I think we learn from serious incidents, the investigations are conducted when there is a serious incident, especially in process safety, but learning from incidents related to personal behaviour we don't learn.
Another challenge connected to the implementation of the programme is the number of new and inexperienced employees from contracting companies, as they were not properly integrated into the programme. The workforce has expanded rapidly during the past few years, and many new employees do not have the same level of experience or knowledge as longer-term employees. This was challenging for more experienced employees, who felt they had to work harder to compensate:
I don't know where they are finding those new employees (..), they don't know anything.

They think that they can send slaughterhouse employees for a three-week course and that that makes them competent, but it is not true, they don't have the right attitude and we have to struggle with them offshore.

The worst thing with some of the new employees is that they don't care at all; carelessness is very dangerous for safety.

In summary, employees found the greatest challenge to be a clear communication strategy, particularly concerning maintenance and continuation of the programme. Another major concern was the involvement of the new and inexperienced employees as well as short-term contract employees who appeared to be less engaged in safety issues that concerned the entire organisation.

5. DISCUSSION

The results of this study showed that the company to some degree succeeded with the implementation of the new programme. The participants emphasised that they felt supported by management, particularly noting that management took employee safety seriously. Management support and engagement in safety is very important for creating a positive safety culture and improving safety; the evidence of this can be found in many studies (Pidgeon & O'Leary, 2000; Reason, 1997; Mearns & Flin, 1995; Mearns, Flin, Gordon, & Fleming, 1998; Mearns, Flin, Gordon, & Fleming, 2001; Mearns, Rundmo, Gordon, & Fleming, 2004; Mearns & Flin, 1999). Moreover, the employees appreciated the emphasis on the soft values; the programme thus acknowledged that social well-being at work is an important component in being able to practice safety procedures. For example, one of the programme's key messages is that employees should intervene when safety is at risk. The underlying notion is that if employees do not trust or feel comfortable with each other, they are less likely to intervene. It may be argued that this notion is part of the participation paradigm mentioned in the theory section, which calls for a broader perspective in policy implementation and is rooted in locals' everyday life (Chambers 1997). The success of implementation is thus dependent on how well it fits the setting in which it is being implemented and how well the existing culture is characterised by shared ideas and norms (ACSNI, 1993). One important result stands out as causing challenges to the success of the new programme: the number of new and inexperienced employees. According to some of the participants in this study, inexperienced employees jeopardised safety with carelessness and lack of skill. It may be argued that the new employees were not considered proper 'members' of the culture and therefore did not share the 'new safety culture' represented by the mindset. This result indicates that more attention should be paid not only to better educating new employees on the content of the mindset but also to integrating them in the existing work teams, emphasising reciprocity regarding trust and well-being among all employees. This may promote the 'sharedness' of the cultural norms.

The programme has been successful in changing attitudes among the employees and has improved safety. However, the intensity of the programme implementation has been decreasing. It is important to maintain the programme because awareness usually is highest at the beginning of the intervention and slowly disappears over time (Zohar & Luria, 2003). Changing a culture is a slow process, and it is important to recognise the existing culture, what the opportunities are to change it, and who should be involved (Antonsen, 2009; Richter & Koch, 2004). Aaro and Lund have found that the most affective change is a mixture of structural changes and training based on a behavioural approach. It appears that the company represented in this study lacks both a clear structure, particularly regarding communication and maintenance, and a clear educational focus for contract and other short-term employees.

The challenge in changing the culture is who is involved and how much power the company is willing to give its employees. The study has shown that the challenge was that employees did not have enough tools to be able to change the culture.

6. CONCLUSION

The study has shown that building a safety culture as a component in safety and accident prevention programmes is a promising but challenging process. It is crucial that there is a transparent communication strategy throughout the programme so it is clear to the employees what the aim of the programme is and how it can be achieved. Moreover, it is critical to pay attention to the subgroups existing within the organisation to target the programme to all employees, including new hires and short-term employees. Another important issue is an understanding that cultural change takes time, and it is important to maintain focus and encourage employees for changes to take effect.

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8. REFERENCES

Advisory Committee on the Safety of Nuclear Installations (ACSNI) (1993). *Study on group human faktors , Third report: Organising for safety*. London:HMSO.

Alvesson, M. (2002). *Understanding Organisational Culture*. Los Angeles, London, New Dehli, Singapore, Washington DC: Sage.

Antonsen, S. (2009). *Safety Culture: Theory, Method and Improvment*. Ashgate.

Bazeley, P. & Jackson, K. (2013). *Quantitative data analysis with Nvivo*. Los Angeles, London, New Dehli, Singapore, Washington DC: Sage.

Bettinghaus EP (1986) Health Promotion and the Knowledge-Attitude-Behavior Continuum. *Preventive medicine* 15, 475-491

Chambers R (1997) *Whose reality counts? Putting the first last.* London: Intermediate Technology Publications.

Cooke B & Khotari U (eds) (2001) *Participation. The new tyranny?* London: Zed Books.

Cox, S. & Flin, R. (1998). Safety culture: philosopher's stone or man of straw? *Work and Stress, 12,* 189-201.

DEA. (2012). (http://www.ens.dk/da-DK/UndergrundOgForsyning/Olie_og_gas/Oekonomi/Sider/Forside.aspx 22 June 2012 . Ref Type: Online Source

Fixsen DL, Naoom SF, Blase KA, Friedman RM and Wallace F (2005) *Implementation research: A synthesis of the literature.* Tampa, FL: University of Southern Florida, Louis de la Parte Florida Mental Health Institute, The National Implementation Research Network (FMHI Publication #231).

Glendon, A. I. & Stanton, N. A. (2000). Perspectives on safety culture. *Safety Science, 34,* 193-214.

Goffman, E. (1959). *The presentation of selv in evryday life*. Penguin Books.

Guldenmund, F. W. (2000). The nature of safety culture: a review of theory and research. *Safety Science, 34,* 215-257.
Hale, A. R. (2000). Culture's confusions. *Safety Science, 34,* 1-14.
Hale, A. R. & Hovden, J. (1998). Managment and culture: the third age of safety. a review of approaches to organizational aspects of safety, health and enviromental. In A.M.Feyer & A. Williamson (Eds.), *Occupational Injury Risk, prevention and intervention* (pp. 129-167). Taylor & Francis.
Ladekjær Larsen E & Stock C (2010) Capturing contrasted realities: integrating multiple perspectives of Danish community life in health promotion. *Health Promotion international 26*(1):14-22.
Lund, J. & Aaro, L. E. (2004). Accident prevention. Presentation of a model placing emphasis on human, structural and cultural factors. *Safety Science, 42,* 271-324.
Martin, J. (1992), *Cultures Organizations: Three Perspectives*, Oxford University Press, London
Mearns, K. & Flin, R. (1995). Risk Perception and Attitudes to Safety by Personnel in the Offshore Oil and Gas-Industry - A Review. *Journal of Loss Prevention in the Process Industries, 8,* 299-305.
Mearns, K., Flin, R., Gordon, R., & Fleming, M. (1998). Measuring safety climate on offshore installations. *Work and Stress, 12,* 238-254.
Mearns, K., Flin, R., Gordon, R., & Fleming, M. (2001). Human and organizational factors in offshore safety. *Work and Stress, 15,* 144-160.
Mearns, K., Rundmo, T., Gordon, R. F. R., & Fleming, M. (2004). Evaluation of psychosocial and organizational factors in offshore safety: a comparative study. *Journal of Risk Research, 7,* 545-561.
Mearns, K. J. & Flin, R. (1999). Assessing the state of organizational safety - Culture or climate? *Current Psychology, 18,* 5-17.
Petersilia J (1990) Conditions that permit intensive supervision. *Crime and Delinquency* 36(1): 126-145.
Pidgeon, N. & O'Leary, M. (2000). Man-made disasters: why technology and organizations (sometimes) fail. *Safety Science, 34,* 15-30.
Reason, J. (1997). *Managing the Risk of Organizational Accidents*. Ashgate.
Richter, A. & Koch, C. (2004). Integration, differentiation and ambiguity in safety cultures. *Safety Science, 42,* 703-722.
Rogers EM (1983) *Diffusion of innovations*, 3rd edition, Free Press, New York.
Tharaldsen, J. E. (2011). *In Safety We Trust Safety, Risk and Trust in the North Sea Petroleum Industry.* Faculty of Social Science University of Stavanger.
Tharaldsen, J. E., Olsen, E., & Rundmo, T. (2008). A longitudinal study of safety climate on the Norwegian continental shelf. *Safety Science, 46,* 427-439.
Zohar, D. & Luria, G. (2003). The use of supervisory practices as leverage to improve safety behavior: A cross-level intervention model. *Journal of Safety Research, 34,* 567-577.

Reducing airborne noise emitted in work places using materials mainly composed of ceramic industry waste

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Abstract

Every day, millions of workers in Europe are exposed to noise in the workplace, and all the risks that entails. In Europe, one in five workers have to raise his voice to be heard it for at least half the time he is working, and 7% have hearing problems related to their work. According to available data, the hearing loss caused by noise is the most common occupational disease in the European Union.

Many times, the noise does not have to be too high to cause problems in the workplace. It can interact with other risk factors and increase the danger to which workers are exposed, for example, increasing the risk of accidents to neutralize the acoustic warning signals; interacting with exposure to certain chemicals to multiply the risk of hearing loss; or being a trigger of workplace stress.

An appropriate work place design and layout must allow minimize the number of people exposed to noise and the exposure of workers. The noise reduction must be achieved not only through the use of equipment emitting the least possible noise but also by providing places and workers with appropriate elements to minimize noise transmission, both through air and solid structures. Reducing airborne noise emitted by work teams can be achieved, for instance, using noise absorbing materials in the walls of the room.

Furthermore, the accumulation of waste and the need for waste management are also becoming more and more pressing. In Europe the amount of wastes in the different production stages of the ceramic industry reaches some 3–7% of its global production meaning millions of tons of calcined lays per year that are just landfilled. With the increasing restrictions on landfills in the European Union area, the cost of deposition will increase and the industries will have to find ways for reusing their wastes. Although the reutilization of ceramic waste (CW) has been practiced, the amount of waste reused in that way is still negligible. Hence, the need for its application in other industries is becoming absolutely vital. Construction industry as the end user of almost all the ceramic materials is well posed to solve this environmental problem which is partially its own. The nature of construction industry, especially the concrete industry, is such that ceramic wastes can be used safely with no need for dramatic change in production and application process.

The scope of this investigation is to develop a new sound absorbing material mainly composed (80 % p/p) of CW that can be applied as part of noise reducing devices with the aim of reducing accidents and diseases due to exposure to noise. The characterization of the product has been

carried out by measuring the sound absorbing (sound absorption coefficient at normal incidence by using a Kundt tube), physical (open void ratio and density) and mechanical (compressive strength) properties of the recycled product. Additionally, since the noise absorption is strongly related to the open porosity of the product, the influence of the particle grain size of CW on the properties of the final product has been analyzed, as well as the influence of the specimen thickness on the acoustic absorption. The results have been compared to a porous concrete made of crushed granite aggregate as a reference commercial material used in similar applications.

According to the results obtained, compositions with coarse particles showed greater sound absorption that compositions made with finer particles, besides presenting similar sound absorption, or even better, to the porous concrete used for the same application. On the other hand, the open void ratio tended to increase as the particle size become larger, and the opposite tendency was observed with the density. Since the internal structure becomes more porous when coarse particles are used, the compressive strength of the recycled product tends to decrease. The sound absorbing product showed lower density and compressive strength than the porous concrete which it was compared to. Thereby, CW can be potentially recycled by developing a new sound absorbing material with similar results to other products traditionally used in similar applications. Besides that, the thickness of the final product can be selected in order to reach the best sound absorption at the required frequencies that characterize the specific noise.

INTRODUCTION

Noise is one of the most common occupational hazards. In the United States, for example, approximately 35% of workers are exposed daily to average levels equal to or greater than 80 dBA [1]. These noise levels are potentially hazardous to the hearing and can also produce other harmful effects. It is likely that the levels are somewhat higher in less developed countries, where not much use engineering controls, and slightly lower in other countries with control programs more stringent noise, such as Sweden and Germany.

The hearing loss is the most known harmful effect of noise and probably the most serious, but not the only. Other adverse effects including tinnitus (ringing sensation in the ears), interference with speech communication and the perception of alarm signals, changes in work performance, are other harmless and extra-auditory effects [2].

Once the source of noise in an industrial process is identified, the next step should be to choose between the available noise control options. The standard model used to control almost all health risks is to examine the various control options applied at the source, in the transmission medium and receiver.

The first step in the noise control process should be to try any treatment of the source, but often it is not feasible remodeling processes or equipment, or modifying the sound sources. Also, there are situations in which it is virtually impossible to identify the cause of the noise. In such cases, the second step should be the adoption of control measures for the treatment of the sound transmission path as an effective means of reducing the total noise level. The two main measures of suppression transmission routes are acoustical enclosures and barriers, which should be selected with the appropriate material based on the frequency spectrum of the noise source [3].

When some of the measures are impossible or insufficient, as a third step, personal protective equipments should be used. Moreover, the impact of using personal hearing protectors is unclear. Wearing hearing protection by workers with a substantial noise-induced hearing impairment reduces the possibility of hearing moving sound sources, warning signals, or colleagues shouting and hampers localization of moving sound sources because of reduced capacities to determine the direction of a sound source [4].

In the field of prevention of occupational risks, new ideas and techniques of intervention are being generated, which should make possible the effective protection of workers health. This study is focused in this line. The scope of this investigation is to develop a new sound absorbing material mainly composed (80% p/p) of ceramic waste, reaching a two-fold environmental advantage. To the extent possible, the sound absorbing spectra at different frequencies was analyzed with the aim of adapting the sound absorbing properties of the material to an specific noise spectra and reducing the sound level exposure of the workers.

EXPERIMENTAL PROGRAM

In this study, ceramic waste (CW) from a construction and demolition waste plant in Spain has been combined with ordinary Portland cement type II 32.5N (PCII). The test specimens were manufactured following a simple, low-cost procedure. CW was separated into three different particle sizes in order to analyze the influence of the grain size in the properties of the final product. The solid components were placed in a concrete mixer and were mixed until a homogeneous mixture was achieved. Then water was added to the mixture and it was re-mixed until a homogeneous paste was obtained. When the mixing was completed, the paste was placed in moulds (34 mm diameter, of variable thickness) and was compacted twice using a vibrating table. The pastes were then taken out of moulds after 24h and left to cure at ambient conditions for 28 days.

Test methods

When a sound wave strikes a material, a portion of the sound energy is reflected back, another portion is absorbed by the material while the rest is transmitted. The absorption coefficient, α, is the ratio of the absorbed energy to the total incident energy. To determine the acoustic properties of the products, the sound absorption coefficient was determined by the impedance tube method [5]. The circumferential edge of the test sample was carefully sealed with vaseline as recommended by the ISO-10534-2, to ensure a good fit between the sample and the tube. Each value represents the average value obtained after testing three samples. The Noise Reduction Coefficient (NRC) was then obtained by calculating the arithmetic mean of the absorption coefficients at 250, 500, 1000 and 2000 Hz, in order to have single numeric data about the sound absorption to make comparisons.

The open void ratio has been measured because it is strongly related to the acoustic behavior of the products. The method of vacuum water saturation has been followed in the determination of open void ratio (VR %) [6]. The samples were oven-dried at 105±5ºC. Subsequently, they were weighed (W1) and left under water in a vacuum vessel until saturation was reached. After 24 hours they were removed and weighed again (W2). The open void ratio was calculated by VR (%)=VW/VS·100, where VW is the volume in the sample occupied by water and VS is the total volume of the sample. The volume of water can be found as VW=(W2-W1)/ρw, where ρw is the density of water.

The density (ρ) of the mortars was calculated by weight and volume (dimensions) measurements. The compressive strength (CS) of the test samples was found based on the ASTM-C39/C39M-05e2 [7] using a compression test machine (Supezcar, MEM-102/50t). Each result was obtained by testing three specimens.

RESULTS AND DISCUSION

In order to analyze the influence of the particle grain size in the properties of the products made of ceramic waste, specimens with different grain size of CW were manufactured, and compared to specimens of typical porous concrete (HP) [8]. Table 1 shows the nomenclature, composition and water content of the samples manufactured, as well as the results of the physical and mechanical properties measured.

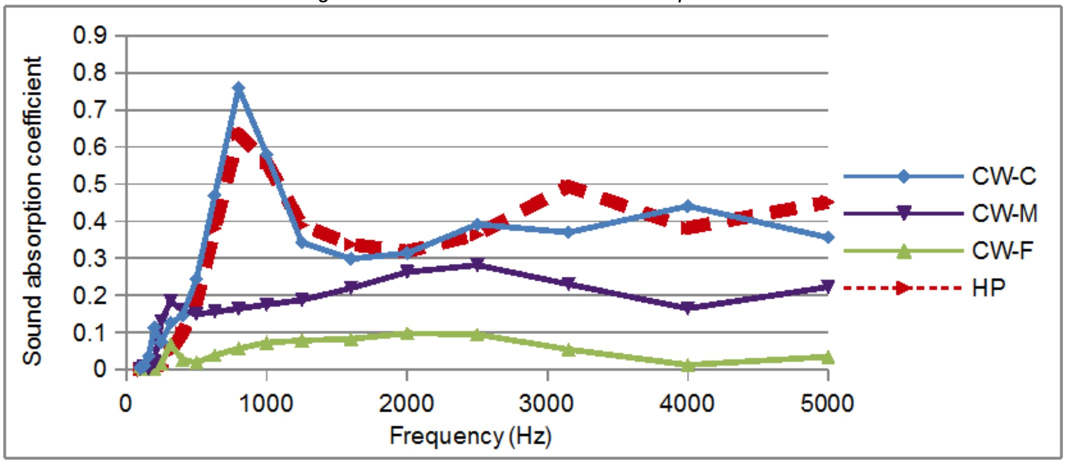
Table 1. Composition (wt%) and properties of CW specimens and porous concrete

	CW-Coarse	CW-Medium	CW-Fine	HP
CW (%)	80	80	80	-
PCII (%)	20	20	20	20
Coarse aggregate (%)	-	-	-	80
Particle size (mm)	$2.5<d_p<4$	$1.25<d_p<2.5$	$d_p<1.25$	$3<d_p<9$
Water/solid (%)	25	28	35	9
Open porosity (%)	30	18	9	26
Density (kg/m^3)	1180	1230	1500	1730
Compressive strength (MPa)	2.9	3.5	4.3	4.1

The water/solid ratio increased when the particle size decreased due to the effect of the fineness of the particles on the workability of the mix. Lower particle size increases the surface area which then requires more water to lubricate the particles [9]. On the other hand, the open porosity of the mortars tended to rise when the particle size was larger. In consequence, CW-C was the product with highest open porosity, followed by HP, CW-M and CW-F, which presented very low open porosity. The density of the products increase as the particle size becomes fines. Although CW-F showed the lowest porosity, it was the densest of the CW products. The porous concrete used as a reference has a void ratio close to CW-C; however, it presented a high density due to the greater specific gravity of the coarse aggregate (2.69 g/cm^3) than the specific gravity of the ceramic waste (2.15 cm^3). The mechanical properties of the CW products showed that the compressive strength of the mortars decreased when the open void ratio increased. Therefore, porous materials had the weakest compressive strength.

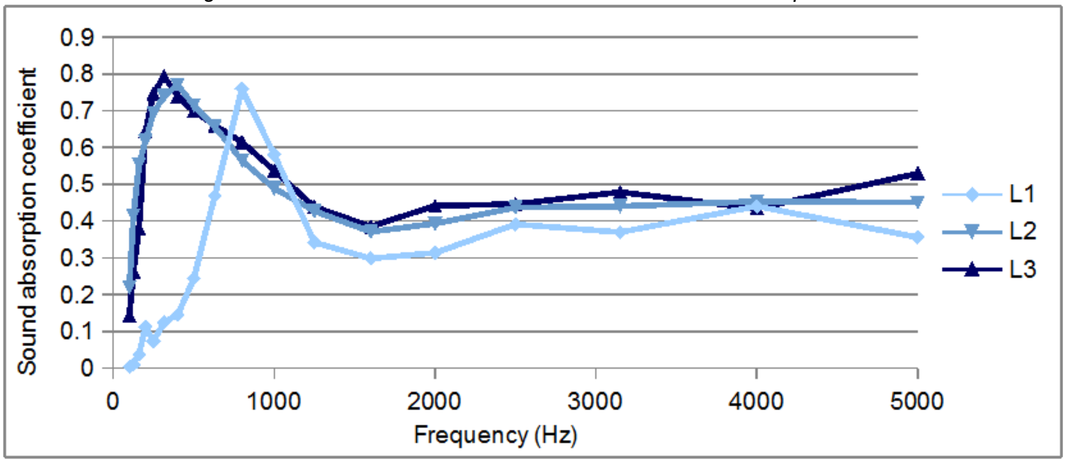
The variation of the acoustic absorption coefficient in the different CW products and porous concrete is shown in Figure 1. The results of the sound absorption coefficient are represented in octave bands. The sound absorption of a porous material is related to the energy loss by friction produced in the walls of its holes. As a result, CW mortars with higher open porosity have given better sound absorption coefficients in the whole range of frequencies. Compared to the porous concrete, it had similar sound absorption coefficients to CW-C, as it happened when comparing the open porosity. The maximum peak of the sound absorption coefficient registered for CW-C appeared at 800Hz, which is positive taking into account that noise at frequencies lower than 1000 Hz are the most difficult to reduce.

Figure 1. Normal incidence sound absorption coefficient



On the other hand, the acoustic absorption of a material depends on the thickness of the specimens tested. Tests on how the thickness on the acoustic properties influences the material were carried out by testing the same compositions of CW products with different thicknesses. Figure 2 shows the sound absorption coefficient curves for 40 (L1), 80 (L2) and 120 mm (L3) thickness of CW-C specimens. The acoustic absorption spectra of CW-C specimens shifted towards lower frequency levels as the thickness of the specimens changed, although the magnitude of the peak absorption coefficients remained practically uniform. This phenomenon could be due to the relationship between the peak frequency and the thickness of the specimens, which can be expressed by an equation obtained from the concept of the absorbing mechanism of a porous material [10].

Figure 2. Influence of the thickness of CW-C on the sound absorption coefficient



$$f_P \cdot l = \frac{(2n-1)c}{4} = constant \qquad (1)$$

Where f_P is the frequency at the peak, n is the number of peaks (constant), c is the sound speed of air (fixed for temperature), and l is the thickness of the specimen. Therefore, there is a chance for designing a specific thickness in order to develop a sound absorbing material which reduces a specific noise. The same tendency were observed in the results of CW-M and CW-F, although in the case of CW-F the sound absorption is so low that very little differences were found in the variation of the thickness.

The Noise Reduction Coefficient (NRC) was calculated in order to clearly identify the effect of the particle grain size of the coarse aggregate and the thickness of the specimen tested in the Kundt tube, see Table 2. The same tendency as the sound absorption coefficient curves was observed for the NRC, and this effect was repeated for all the CW compositions.

Table 2. NRC of CW-C, CW-M, CW-F with different thickness

	CW-C	CW-M	CW-F	HP
L1 – 40 mm	0.30	0.18	0.05	0.27
L2 – 80 mm	0.39	0.25	0.05	-
L3 – 120 mm	0.48	0.30	0.06	-

CONCLUSIONS

The main goal of this experimental study was to develop a product composed mainly by ceramic waste that presented good noise absorption characteristics. In the course of the study the following conclusions were reached.

- The grain particle size of CW influenced the acoustic behavior and the physical and mechanical properties of the products made from CW. The best sound absorption coefficients were measured in products made from the larger CW particle sizes, which developed a more porous matrix. On the other hand, good mechanical properties have been found in the products made from the finest particles.

- The acoustic absorption coefficient spectra depend on the thickness of the specimen tested. The principal maximum of the absorption coefficient displaced to lower frequencies when the thickness increased.

- Ceramic waste could thus be recycled as part of sound absorbing materials in view of the results obtained. Moreover, there is a chance of designing a product with specific grain size and thickness with absorbs a concrete noise, which means noise levels at certain frequencies.

REFERENCES

[1] L. Thiery, C. Meyer-Bisch. Hearing loss due to partly impulsive industrial noise exposure at levels between 87 and 90 dBA. Journal of Acoustic Society of America, 1988, 84, pp.651-659.

[2] C.M. Barreto, A.J. Swerdlow, P.G. Smith, C.D. Higgins. A nested case-control study of fatal work related injuries among Brazilian steel workers. Occupational Environmental Medicine, 1997, 54, pp. 599-604.

[3] J.R. Hasall, K. Zaveri. Acoustic Noise Measurements. Brüel & Kjaer editors, 1979.

[4] L.H. Royster, J.D. Royster. Hearing protection devices. Hearing Conservation in Industry, 1985.

[5] EN-ISO-10534-2:1998. Acoustics determination of sound absorption coefficient and impedance or admittance by the impedance tube. Part II: Transfer function method.

[6] EN-1936:2006. Determination of real density and apparent density, and of total and open porosity.

[7] ASTM-C39/C39M-05e2:2005. Standard test method for compressive strength of cylindrical concrete specimens, ASTM International.

[8] C. Arenas, C. Leiva, L.F. Vilches, H. Cifuentes. Use of co-combustion bottom ash to design an acoustic absorbing material for highway noise barriers. Waste Management, 33, 2013, pp. 2316-2321.

[9] A.M. Neville. Properties of Concrete, fourth ed. Pearson Education Limited, London, 1995.

[10] N. Neithalath. Development and characterization of acoustically efficient cementations materials. Purdue University, 2004.

Learning from successful operations – opportunities, challenges and a paradox

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Abstract

Learning from successful operations has received less attention than learning from accidents and near misses, both among practitioners and researchers. The paper reports intermediate results from a project aimed at reducing this gap. We discuss (1) criteria to identify an operation as successful with regard to safety, (2) implications concerning successful operations that can be derived from current organisational theories of safety, (3) how learning from successful operations can take place in practice and (4) challenges related to learning from successful operations. The paper is based on document studies, qualitative interviews with personnel in two drilling companies, initial observations at a drilling simulator centre and from a workshop in an oil company operating on the Norwegian continental shelf. The criteria used in the research literature to identify successful operations are mainly related to the absence or low frequency of adverse outcomes. This may be problematic because organisations may experience accident-free periods even during the incubation period before a major accident. It is possible to derive a broad array of theoretical perspectives to account for successful operations from current organisational theories of safety. Learning from successful operations can take place either through spontaneous mechanisms or through mechanisms deliberately put in place by management. Managed mechanisms for learning include reporting systems; debrief sessions in simulators and the real world, and workshops. An example of a workshop concerning a successful operation is presented in the paper. Paradoxically, whereas learning from successful operations has received limited attention in the safety science literature, learning from operations that are perceived to be successful appears to take place all the time in the real world. However, the outcome of such learning is not necessarily improved safety. We have therefore identified several challenges related to learning from successful operations. Characterising an operation as successful may be problematic, since the absence of adverse outcomes does not necessarily imply that the risk was well controlled. When describing and analysing a successful accident, it is easy to get captured by "the official version" as prescribed in rules and procedures. As a consequence, learning processes may maintain current dogma and practices rather than trigger new insight and improvements. Successful operations rarely lend themselves to rigorous approaches for establishing causal connections between how operations are performed and the degree of success.

Keywords: safety management; managed learning; spontaneous learning; success; recovery.

1. INTRODUCTION

1.1. Background

A rich array of methods exists to analyse the causes of accidents and critical events, and a great effort is put into such analysis and dissemination of results by the industries and national authorities world-wide. There is, in contrast, a scarcity of methods for analysing successful operations. The project "Learning from successful operations" was initiated to correct some of this shortcoming. The objectives of the project are to provide (1) new scientific approaches to study successful operations, (2) documentation of cases of successful operations that can be used for educational purposes and meta-analysis, (3) new theoretical accounts of successful operations, and (4) methods and guidelines that can be used by companies to analyse and learn from successful operations (e.g. in incident investigations and safety audits). "Success" and "successful" here refers to the safety aspects of an operation.

The paper summarises insights that we have reached at an intermediate stage of the project related to the following issues:

1. What criteria can be used to identify an operation as "successful" with regard to safety?
2. To what extent can implications for learning from successful operations be derived from current organisational theories of safety?
3. How can learning from successful operations take place in practice?
4. What are the challenges related to learning from successful operations?

The study was primarily concerned with prevention of major accidents (sometimes referred to as process safety) rather than minor accidents (sometimes referred to as personal safety).

1.2. Previous research on successful operations

An important early contribution to the understanding of successful operations is Weick's observation that "reliability is a dynamic non-event" (Weick, 1987). Reliability is invisible in the sense that "nothing happens". People do not know how many mistakes they could have made but which they did not make. From the outside, what can be observed are constant outcomes; there is nothing to pay attention to. Weick's statement also implies that reliability "is an ongoing condition in which problems are under control due to compensating changes in components" – for instance operators improvising to compensate for substandard technical equipment. Such compensations are not necessarily codified in procedures or discussed explicitly; adaptations may evolve and be maintained through "reflection-in-action" rather than "reflection-on-action" (Nathanael & Marmaras, 2008).

HRO (High Reliability Organisations) researchers argue that certain organisational properties and practices make an organisation prone to success when it comes to safety. Early studies of HROs addressed complex systems that delivered remarkably reliable performance, such as aircraft carriers (Rochlin, LaPorte & Roberts, 1987; LaPorte & Consolini, 1991), nuclear submarines (Bierly & Spender, 1995) and nuclear power plants (Schulman, 1993a). Early accounts of successful performance include use of *redundancy* to derive highly reliable performance from imperfect human beings (LaPorte & Consolini, 1991), a capacity of the organisation to *reconfigure spontaneously* during crises (LaPorte & Consolini, 1991); the emergence of a collective mind through *heedful interrelating* (Weick & Roberts, 1993), the successful *exploitation of slack*, including conceptual slack and the right to veto decisions (Schulman, 1993b), and *cultures of requisite variety*, facilitating information flow (Westrum, 1993). More recently, Weick & Sutcliffe (2001) proposed that prominent characteristics of HROs can be captured by the notion of "mindfulness", i.e. a *capacity for anticipation and awareness of the unexpected as well as a capacity to contain the unexpected.*

Contributors to the emerging field of resilience engineering have insisted on the need to account more symmetrically for successful adaptations and accidents (Hollnagel, Woods & Leveson, 2006; Woods, 2006; Hollnagel, Pariés & Woods, 2011). They have also argued that it is necessary to learn from normal operations in order to maintain and improve safety in systems that experience very few accidents. Normal operations will always involve variability, and the study of safety requires the study of normal variability. However, the methodical side of the study of normal operations is still in its infancy. This research gap will be targeted by this project.

Successful operations may encompass handling of serious disturbances. Studies of operations where situation control has been successfully regained and a dangerous sequence of events stopped are therefore also of relevance to the understanding of successful operations. Reason (2008) discussed cases of "heroic recovery" where human interventions have prevented disasters. Reason argued that Weick's notion of *collective mindfulness* needs to be complemented by a notion of *individual mindfulness*. Carthey et al. (2003) studied 'behavioural markers' of surgical excellence in Arterial Switch Operations, i.e. the characteristic behaviour of surgical teams and team members with outstanding results. Adaptive strategies, improvisations and negotiations undertaken by actors to achieve reliable performance in highly dynamic settings have also been explored in Mesman's study (2009) of a neonatal intensive care unit and Marc & Rogalski's study (2009) of a French medical emergency centre.

Although a variety of methods have been developed to support accident investigations (e.g. Sklet, 2004), we are not aware of any method that addresses successful operations, nor are we aware of any method to identify and analyse successful operations. However, based on theoretical contributions on resilience and empirical studies of successful recovery of high-risk incidents, Størseth, Albrechtsen & Eitrheim (2010) established a suite of so-called *“Contributing Success Factors (CSFs) for building resilience”.*

1.3. Conceptual framework and research issues for the project

A simple *conceptual model* for the study is shown in Figure 1. The model may be summarised as follows: Safety outcomes in terms of successful operations and adverse events are strongly influenced by how individuals, groups and organisations anticipate, prevent, detect, interpret and handle disturbances that may lead to accidents. These outcomes form a basis for organisational learning, or more specifically for how individuals, groups and organisations describe, analyse and learn from successful operations. These learning processes may change (or maintain or reinforce) the way in which individuals, groups and organisations anticipate, prevent, detect, interpret and handle disturbances that may lead to accidents. Learning processes may also lead individuals, groups or organisations to change the environmental conditions for their safety work. By “safety work”, we refer to all efforts to keep the risk of major accidents and work environment risk under control. According to this definition, safety work is not limited to tasks performed by safety specialists. A technician carrying out his/her daily work in a safe manner and a company board allocating adequate resources to safety critical investments are examples of safety work in action. Environmental conditions influence the opportunities an organisation, organisational unit, group, or individual has to control the risk of major accidents.

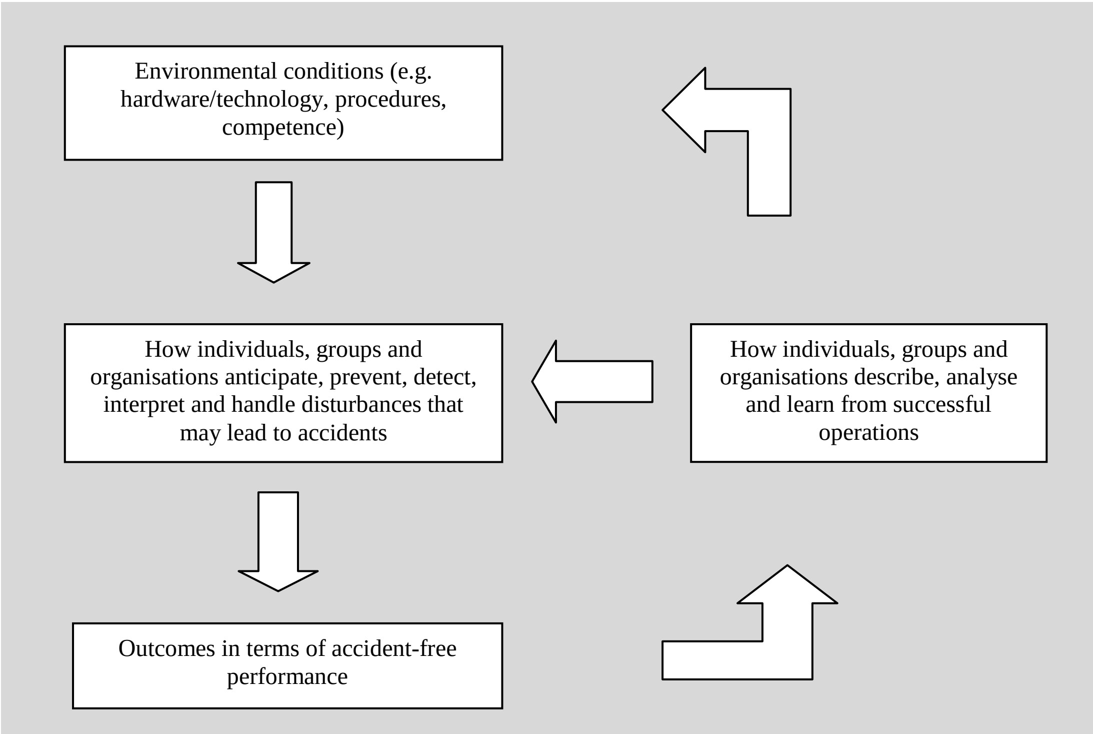

Figure 1 – Conceptual model for the present study.

The conceptual model does not intend to show all possible causal influences. It is restricted to the relations that are of interest to the current study. The analysis of theoretical perspectives on successful operations in Section 4 below is based on issues derived from the conceptual framework.

The term "successful" refers to the safety aspects of the operation. Possible criteria to distinguish successful operations from less successful operations are considered in the Section 3.

2. APPROACH

We have identified different empirical research strategies that we believe are relevant to the study of learning from successful operations:

1. Studies of *normal operations*. These are studies where the researchers do not claim to have identified operations that are particularly successful with regard to safety. The objective is to investigate how people go about to "produce safety" in "normal" or "routine" work situations. (In this context, "normal" means "typical" or "everyday", rather than "in accordance with specific norms".)

2. Studies of *successful operations*. These are studies where the researchers claim to have identified operations that are particularly successful with regard to safety. The researchers typically set out to explain why the identified operations are particularly successful.
3. Studies of *successful recovery*. These are studies of situations where a system was headed for disaster and where this trajectory was interrupted through human intervention.
4. Studies of how people (individually or in collectives, e.g. organisations) *make sense of successful operations or successful recovery.* The focus is not on the researcher's account of successful operations, but rather on the ways in which people involved in the operation themselves account for success. Such knowledge is important as a basis for understanding and improving organisational learning from successful operations.

The project applies an abductive approach in the sense that the cases are "interpreted from a hypothetical overarching pattern, which, if it were true, explains the case in question" (Alvesson & Sköldberg, 2009:4). Abduction involves a mutual interaction between theoretical interpretations and observations, where both are adjusted and refined. The initial interpretation should thus be strengthened and refined by new observations. In accordance with this, we start with a broad and open-ended theoretical framework, and gradually narrowed the theoretical focus in accordance with the results. We adopt multiple perspectives on resilient organisations (Rosness et al., 2010), e.g. a barrier-perspective, a HRO-perspective and an information processing perspective (Turner, 1978). We also seek to be sensitive to the dialectics between prescribed and actual work practices (Nathanael & Marmaras, 2008).

We further employ a case study design to explore the nature of successful operations and the way they can be analysed, described and utilized for learning purposes. Case studies allow us to investigate "a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 1994: 13). A case study design also allows us to explore ambiguities and conflicting interpretations of phenomena.

We utilise a combination of observations, interviews and document studies. Since interview data is dependent on the level of reflection of the informant, it is crucial to gain first-hand information of operations, meetings and situations which are subsequently discussed in interviews. This combination serves as a countermeasure to the "taken-for-granted-ness" that characterizes normal operations, and the hindsight bias that will always be present when a situation is retrospectively described.

During observations of work practice, the researchers mainly act as *interactive observers* (Tjora, 2009). Our role as researchers is acknowledged and we communicate with subjects when we consider this helpful for our understanding and compatible with the work situation. The obvious problem with this approach is the so-called Hawthorne effect - that subjects may modify their behaviour when they know they are being watched. We try to minimize this effect by clarifying that the study is not an audit, and by studying a wide variety of situations.

The interviews involve the whole span of involved actors, both horizontally (offshore and onshore, across professional domains) and vertically (different hierarchical levels). The documents they relate to and produce, such as procedures, risk matrixes, drilling programmes and end of well reports, also provided insight into the incentives for and effects of the work carried out.

Research tools, such as observation guides, interview guides and guides for analysing successful operations, were developed in an iterative manner, reflecting both insights from the literature study and from initial empirical work. The development of research tools is seen as the first step towards developing tools that can be used by practitioners. We employ methods and theoretical constructs that allow the analysis of actions by human and non-human actors within a common framework.

3. DEFINING "SUCCESS"

It may seem straightforward to think of "success" as the opposite of failure. However the notion of "success" may be ambiguous. Several different criteria have been used to identify an operation as successful with regard to safety in the research literature:

1. *Absence of adverse consequences.* An operation may be labelled successful if it did not directly lead to an accident. This view of success seems to be implied when Hollnagel (2013) argues that much more data will be available if we turn from looking at "what goes wrong" to looking at "what goes right". This criterion does not always distinguish between operations that are accident-free due to "pure luck" and operations that are accident-free due to excellent safety work. An organisation may experience a prolonged accident-free

period even during the incubation period before a major accident (Turner, 1978; Turner & Pidgeon, 1997). The incubation period is characterised by danger signals that pass unnoticed or are misunderstood.

2. *Lower frequency of adverse consequences than other similar operations under similar conditions.* We may think of this as a benchmarking perspective. Success implies that an individual, team or organisation performs an operation with fewer instances of adverse consequences than other units performing the same operation under similar conditions. For instance, Carthey et al. (2003) identified surgical teams that performed Arterial Switch Operations with particularly low frequencies of adverse outcomes. This criterion is difficult to apply when the frequency of adverse events is very low, because prolonged observation or a high number of analysis units will be necessary to find statistically significant differences in frequencies of adverse outcomes.
3. *Low frequency of adverse consequences in an absolute sense or compared to a broader range of operations.* This can be exemplified by Hale and Heijer's (2006) study of Dutch railways. These were characterised as "ultra-safe" with regard to passenger fatalities, based on a very low number of passengers killed per person-kilometre compared to other means of transportation such as air transport, private cars or buses. For rare events, such as major accidents, extended observations and/or a high number of analysis units will be necessary to argue convincingly that the frequency of adverse consequences is very low.
4. *Lower frequency of adverse consequences than would be expected, taking into account the nature of the operations.* This seems to be the understanding of success in early studies of high reliability organisations (HROs), as suggested by the title "Working in practice but not in theory" (LaPorte & Consolini, 1991). The argument seems to be that HROs have fewer accidents than one would expect, taking into account the hazards, the complexity, intensity and small margins involved in the operations. Again, extended observations and/or many analysis units are needed if the adverse events are rare.
5. *Successful coping close to the boundary.* An operation is labelled successful if the actors manage to operate with very small safety margins without experiencing an accident. In Roe and Schulman's study (2008) of the management of the California electrical grid, the label "high reliability management" is apparently based on the capacity of operators to cope successfully close to the border of system breakdown. This view of success also seems to be implied in some HRO studies of aircraft carriers (Rochlin, LaPorte & Roberts, 1987; LaPorte & Consolini, 1991).
6. *Successful recovery from an imminent danger.* An operation may be labelled successful if the actors managed to recover from a potentially disastrous trajectory of events. One may prefer to speak of "successful *recovery*" rather than "successful *operations*" in this case. Examples of this kind of success stories can be found in Reason's (2008) compilation of stories of heroic recoveries.

We can also think of a few additional categories of "success" that we have not found in the reviewed literature:

7. *Maintenance of a broad safety margin.* An operation may be labelled "successful" to the extent that a broad safety margin was maintained throughout the operation. We have not noted any instance in the literature where maintenance of a broad safety margin has been labelled "success". However, we include this category because the maintenance of adequate safety margins seems to be a central safety strategy in, e.g., commercial air traffic.
8. *Maintenance of an effective barrier structure.* An operation may be labelled successful if an adequate set of barriers against adverse event sequences was in place throughout the operation. This category resembles "maintenance of a broad safety margin", but may allow for more straightforward operationalization in some contexts, such as oil well interventions or maintenance work in a process unit.
9. *Maintenance of adequate and/or improved safety throughout a prolonged period of time.* One may think of this as the successful prevention of drift into failure. This conception of success implies a learning perspective. Over time, the system will have to adapt to changing conditions, and it will also have to explore the safety consequences of such adaptations.

The diversity of criteria for success implies that the identification of an operation as "successful" with regard to safety is not a matter of simple, "objective" classification. The sensemaking

process involved when practitioners or researchers label an operation as "successful" is an important aspect of learning from successful operations. As researchers, we should be sensitive to how practitioners go about identifying successful performance, but we should also consider the possibility of eliciting new insights by exploring alternative criteria for success.
Most of the criteria used in the literature are related to outcomes, i.e. the absence of or low frequency of adverse events. However, criteria 7 and 8 are related to processes that are assumed to be closely related to the potential for adverse outcomes. These criteria may be applied to a single analysis unit (operation), whereas many of the outcome-related criteria require extensive observations.
A common pitfall when characterising an operation as successful is to generalise from one category of accidents to other categories of accidents that are only weakly correlated. As has been repeatedly pointed out (e.g. Hopkins, 2000, 2008), successful prevention of lost time incidents does not necessarily imply that the risk of major accidents (process accidents) is well controlled.
There is a tension between criteria 5 and 7, since coping close to the boundary implies accepting a narrow safety margin. Criterion 5 seems applicable to systems that have to operate close to the boundary in order to deliver their services (e.g. some cases of brain surgery), whereas criterion 7 seems more relevant to systems where maintenance of a broad safety margin is compatible with adequate performance on other dimensions (e.g. civil aviation). This raises the question of the practices and environmental conditions that are needed for successful coping close to the boundary are different from the practices and environmental conditions that are needed for maintaining a broad safety margin. Another issue is whether both criteria 5 and 7 can coexist in a single system without creating a double bind situation.

4. THEORETICAL PERSPECTIVES ON SUCCESSFUL OPERATIONS

In order to profit from the extensive research literature on organisational aspects of safety, we took as a starting point six perspectives on organisational accidents and resilient organisations proposed by Rosness et al. (2010):

1. The barrier perspective
2. Normal Accident Theory
3. High Reliability Organisation (HRO)
4. Conflicting objectives: Risk taking, adaptation and drift
5. The information processing perspective
6. Resilience Engineering

Table 1 summarises an analysis of the six perspectives with regard to successful operations. The first column provides central references and a summary of the core principles underlying each perspective. A more extensive presentation of the perspectives can be found in the literature referenced in Rosness et al. (2010) and in the references included in Column 1 in Table 1. The other three columns show possible answers derived from the theoretical perspectives to three analytic issues derived from the conceptual framework in Figure 1:

- How do individuals, groups and organisations anticipate, prevent, detect, interpret and handle disturbances that may lead to accidents?
- What environmental conditions are conducive to successful operations?
- How can practitioners describe, analyse and learn from successful operations?

It is obviously impossible to do justice to the rich literature on organisational aspects of safety within a small table. However, the table shows that it is possible to derive a broad array of hypotheses about preconditions for successful operations from this literature. Such derivations should be done with caution, because an adequate account of success needs to include conditions or mechanisms that are not commonly used in accounts of failure. Accounts of failure are often focused on failure to restrict variability, whereas accounts of success should consider how systems achieve requisite variety to handle disturbances that occur during an operation (Ashby, 1981).
We have used results from this kind of analysis to develop observation guides, debriefing guides and interview guides for our own empirical work. We will also explore the feasibility of using such results to develop tool for practitioners for learning from successful operations.

Table 1 – Organisational perspectives on successful operations.

Perspective, references, core principles	How can individuals, groups and organisations anticipate, prevent, detect, interpret and handle disturbances that may lead to accidents?	What environmental conditions are conducive to successful operations?	How can practitioners describe, analyse and learn from successful operations?
Energy and barrier perspective (Haddon, 1970; 1980). Accidents occur when vulnerable targets are exposed to harmful amounts of uncontrolled energy.	Identify potential for vulnerable targets to be affected by harmful uncontrolled energy flows and put in place measure to prevent or divert such energy flows or to minimise their impact.	Successful operations take place in a well-designed context with requisite barriers in place, and without unnecessary sources of potentially harmful energy.	Explore how the actors (including operators) go about to identify hazards and put in place requisite barriers. Utilise experience with occurrences of barrier impairment.
Information processing perspective (Turner, 1978; Turner & Pidgeon, 1997). Major accidents occur due to failure in the organisation's processing of information on physical events that may turn into accidents.	Organisations should monitor and improve their processes for collection, dissemination and interpretation of information. Weick and Sutcliffe (2001:159ff) provide several examples of practices that aim to enhance awareness and anticipation, e.g., *"Restate goals in the form of things that should not happen".*	Organisational structures and incentives that promote sharing of information including "bad news". A good safety culture, which may promote and be promoted by senior management commitment to safety, shared care and concern for hazards.	Focus on conditions and processes/actions that ensure adequate collection, sharing and interpretation of information. Challenge the labelling of operations as "successful" based on the hypothesis that the organisation might be in the incubation phase of the next accident.

Perspective, references, core principles	How can individuals, groups and organisations anticipate, prevent, detect, interpret and handle disturbances that may lead to accidents?	What environmental conditions are conducive to successful operations?	How can practitioners describe, analyse and learn from successful operations?
Normal Accident Theory (Perrow, 1984). System accidents may occur in decentralised systems with tight couplings and in centralised systems with high interactive complexity.	The likelihood of system accidents can be reduced by limiting the amounts of dangerous energy, by reducing interactive complexity, by loosening couplings and by adapting the degree of centralisation to the coupling and complexity of the system.	Low interactive complexity and loose couplings. Centralised control structures in the case of tightly coupled systems, decentralised control structures in the case of loosely coupled systems.	In tightly coupled systems, focus on the achievement of adequate coordination. In systems with high interactive complexity, focus on detection and handling of anomalies, including successful improvisation.
High Reliability Organisations (LaPorte & Consolini, 1991). Some systems deliver extremely reliable performance even under periods of very high peak demand. Explanations for such performance include organisational redundancy, flexible organisation structure and exploitation of slack.	Flexible organisational structure and interaction style that changes between (1) routine mode), (2) high tempo mode and (3) emergency-response mode. Redundancy is used to build reliable systems from less reliable components, both technical and human.	Organisational redundancy. Clear operational goals expressed through Standard Operating Procedures. Resources devoted to socialization efforts aiming to foster agreement on the organisation's mission. Organisational culture supporting flexible decision-making, commitment to reliability.	Use narratives used for experience transfer among operators. Explore the contributions of organisational redundancy and flexible organisational structures to success.

Perspective, references, core principles	How can individuals, groups and organisations anticipate, prevent, detect, interpret and handle disturbances that may lead to accidents?	What environmental conditions are conducive to successful operations?	How can practitioners describe, analyse and learn from successful operations?
Conflicting objectives: Risk taking, adaptation and drift (Rasmussen, 1997; Rosness, 2009; Vaughan, 1996). Under the pressure of conflicting objectives activities/operations tend to migrate toward the boundary of acceptable performance. Repeated handling of anomalies under production pressure may lead "normalisation of deviance".	Make boundaries to unacceptable performance or unsafe states visible and touchable. Train personnel in boundary handling. Establish "counter-pressures" that favour safe performance. Arrange for effective information exchange in situations where each actor has a limited overview of the overall situation.	Visible and touchable boundaries of acceptable performance. Adequate balance between production pressures/incentives and pressures/incentives promoting safety.	Reflect on questions such as: How can the boundary of acceptable performance be identified? Is safety affected by boundaries and gradients of other objectives? Can safety boundaries be made visible and touchable? Is it possible to identify a set of typical decision contexts, and describe how safety boundaries are conceived and represented in these contexts?

Perspective, references, core principles	How can individuals, groups and organisations anticipate, prevent, detect, interpret and handle disturbances that may lead to accidents?	What environmental conditions are conducive to successful operations?	How can practitioners describe, analyse and learn from successful operations?
Resilience Engineering (Hollnagel, Woods & Leveson, 2006; Hollnagel, Pariés & Woods, 2011). Failures and success are seen as outcomes of the same underlying processes of necessary performance variability and efficiency-thoroughness trade-offs. Successful operations are distinguished by the magnitude of functional resonance between the functions and by the management of this resonance.	Resilience can be managed through "The four cornerstones of resilience engineering": 1. Knowing how to respond to regular and irregular disruptions and disturbances. 2. Knowing what is or can become a threat in the near term. 3. Knowing how to anticipate future developments, threats, and opportunities. 4. Knowing how to learn the right lessons from the right experience - successes as well as failures.	Instead of constraining variability of environmental conditions, ensure requisite variety to adapt to and manage the variability, and hence to dampen functional resonance.	Practitioners should not limit themselves to address things that go wrong, but also explore why things go right and strengthen mechanisms that contribute to successful adaptations.

5. HOW CAN LEARNING FROM SUCCESSFUL OPERATIONS TAKE PLACE IN PRACTICE?

5.1. Managed learning from success – an example

By "organisational learning" we understand processes where organisations change as a consequence of experience (Argote & Ophir, 2002). Organisational learning can be managed or spontaneous to various degrees, and may in principle both improve and weaken safety (Rosness, Nesheim & Tinmannsvik, 2013; Rosness et al., 2014, see also Nathanael & Marmaras, 2008). Learning from successful operations can thus take place either through spontaneous mechanisms or through mechanisms deliberately put in place by management. Some examples of managed mechanisms include reporting systems, debrief sessions in simulators and the real world, and workshops. Companies may also recruit persons they consider successful for critical or difficult tasks, based on the assumption that these persons will repeat their success. Spontaneous learning, however, comprises small adaptations and adjustments of work practices taking place all the time (ref. Section 5.2).

We shall present one example of an effort to learn from successful operations in more detail. This is a workshop that was designed to allow the participants to explore the boundaries towards unacceptable risk and the forces driving actors towards that boundary (Størseth, Rosness & Guttormsen, 2010). The workshop was inspired by the "Conflicting objectives" perspective outlined in Table 1. The operation that was discussed took place on an offshore drilling rig located on the Norwegian continental shelf, and included the preparations for a possible disconnection of the riser during a storm, as well as the decision about whether or not to disconnect when wave height was approaching the disconnection criterion for the rig at that specific location. The necessary preparations for a riser disconnection take several hours. The disconnection itself only takes a few minutes to perform, but reconnection takes several days, and involves significant economic loss due to downtime both for the rig owner and for the operating company hiring the rig.

In the case discussed at the workshop, the well had not yet reached hydrocarbons under pressure, so blow-out risk was not an issue. The rig manager planned and prepared for disconnecting the riser in collaboration with the onshore organisation. The offshore personnel monitored the peak storm development closely. They registered two heaves that exceeded the six meter disconnection criterion before the waves subsided. Due to the expectation that the strong part of the storm would last for a very short time, the rig manager concluded that the equipment would be strong enough to handle the situation and he decided not to disconnect.

The workshop lasted for one day (lunch to lunch) and included the following main parts:

1. An *introduction*, where the facilitators emphasised the ambition to build a comprehensive understanding based on contributions from participants with different background. This point was stressed by titling the workshop "Share and Win". The value of disagreement was emphasised, and the groups were urged to record divergent points of view, rather than striving for consensus.
2. The groups constructed *graphical representations of the event sequence* (STEP-diagrams; Hendrick & Benner, 1987). This process elicited extensive sharing of knowledge between group participants.
3. The groups discussed *possible outcomes and consequences* related to the riser case, including the scenario that the rig did not disconnect and the riser was torn off. Several participants were surprised to see how many and how serious consequences were associated with the different scenarios.
4. The groups discussed the *appropriate formulation and interpretation of the disconnection criterion*, trying to take the involved decision makers' point of view; e.g. should the rig manager push the button on 5.9 meters or at 6.1 meters? This discussion brought up the issue of whether the criterion was given in a guideline or a formal procedure.
5. The participants identified possible *improvements, defined follow-up actions and evaluated the workshop*. They noted with some surprise that they had very different opinions on the issues that were discussed, but that they were able to discuss a controversial safety critical issue without clashing together. A few months after the workshop we were informed that the follow-up actions had been implemented unusually promptly, and without any need for reminders.

A more detailed account of the workshop is given by Størseth, Rosness & Guttormsen (2010). The workshop was not originally framed as an effort to learn from successful operations, but rather as an effort to investigate safety critical decision-making. The operation could be labelled a "success", and more specifically "successful coping close to the boundary", based on the argument that no physical harm occurred, and by not disconnecting, the rig manager saved the rig company and the operating company from the cost of several days of downtime. The rig was prepared to perform a disconnection if needed, and the rig manager acted in accordance with his formal procedures, since the six meter disconnection criterion was included in a guideline and not a formal procedure. However, from the viewpoint of the company HSE staff, the operation was problematic, because the six meter criterion in the bridge document was exceeded, and this criterion was based on an analysis of the mooring arrangement at that specific location. These experiences suggest that workshops can be used as arenas for learning from successful operations.

5.2. Spontaneous learning from success – a paradox

Paradoxically, whereas learning from successful operations has received limited attention in the safety science literature, learning from operations that are perceived to be successful appears to take place all the time in the real world. Spontaneous learning mechanisms range from tacit experimentation and adaptation at the individual level (sometimes labelled "intuition" or "reflection-in-action") to informal reflection and coordination at the level of work groups ("interpretation", "coordination", "reflection-on-action"). Such learning processes will by definition take place whether or not they are desired and promoted by management. We should therefore expect spontaneous learning to take place all the time in organisations. This raises two questions; (1) can we expect spontaneous learning from operations perceived as successful to consistently lead to improved safety, and (2) is it possible to influence spontaneous learning processes to increase the likelihood that they lead to improved safety?

Theories of *drift* (e.g. Rasmussen, 1997; Reason, 1997; Snook, 2000; Dekker, 2011) and Vaughan's (1996) related theory of *cultures of deviance* point to a problematic aspect of learning from success. Many unsafe conditions will only trigger or contribute to an accident under specific circumstances. If the absence of accidents is taken as an indication of success, then there is a potential for unsafe conditions and practices to be confirmed, reinforced and repeated, so that they may contribute to an accident on a later occasion. Learning from successful operations thus concerns not only securing and promoting the positive lessons that may be learned. It is also a matter of influencing processes that may lead to drift into failure. The identification of an operation as successful is a critical aspect of learning from successful operations. A possible strategy for influencing the outcome of spontaneous learning processes is thus to promote efforts to critically scrutinise the apparent success of operations, for instance by checking whether requisite barriers were in place at all times during the operations.

It should be emphasised that spontaneous learning processes do not necessarily lead to impaired safety. Dekker (2011, p. 186) argued that complex systems may drift into success as a consequence of *"complex interactions among multiple, diverse, interconnected and interdependent agents who mutually affect each other".* He therefore advocated building preconditions for diversity, attending to relationships that can help bring fresh perspectives to the fore. We propose that so-called high reliability professionals (Roe & Schulman, 2008) contribute to learning from successful operations by sharing their positive experiences within their professional networks.

6. CHALLENGES RELATED TO LEARNING FROM SUCCESSFUL OPERATIONS

We have identified several challenges related to learning from successful operations:

1. Characterising an operation as successful may be problematic, since the absence of adverse outcomes does not necessarily imply that the risk was well controlled. There is thus a need for alternative criteria or approaches to distinguishing between successful and less successful operations.
2. It is easy to get captured by "the official version" or "work as imagined" when describing a successful operation and explaining the success. Those aspects of successful performance that are not included in "the official version" may remain tacit, either because people are not aware of them, or because they lack the language for expressing them, or because they may fear sanctions for deviating from "the official version" as prescribed in rules and procedures. As a consequence, learning processes may maintain current dogma and practices rather than trigger new insight and improvements.
3. Successful operations rarely lend themselves to rigorous approaches for establishing causal connections between how operations are performed and the degree of success, such as true experimental designs.
4. Strategies that contribute to successful operations in one class of sociotechnical systems may prove detrimental in sociotechnical systems with other properties. For instance, success in some systems depends on rapid and decisive interventions, whereas other systems call for careful deliberation before actions are taken (Schulman, 1993a). Centralised management structures that work well in tightly coupled systems with mainly linear interactions may, according to Perrow (1984) fail to control hazards in systems with complex interactions.

From the challenges mentioned above we can derive an agenda for further applied research on learning from successful operations:

1. There is a need for criteria and methods for critically assessing the success of a given operation. Such methods should aim to counteract phenomena such as "practical drift" and "normalisation of deviance".
2. There is a need for techniques or approaches that help organisations create accounts or narratives about successful operations in ways that go beyond "the official version" or current dogma.
3. There is a need for research approaches that help us scrutinise the plausibility of proposed causal connections between how operations are performed and the degree of success.

4. There is a need for criteria to help practitioners and researchers in judging when generalisation from successful operations in one context can be plausibly transferred to a different context.

7. CONCLUSIONS

This paper summarises insights reached at an intermediate stage of a project aiming to promote learning from successful operations.

It is not straightforward to define what constitutes a successful operation with regard to safety. The criteria used in the literature mainly refer to the absence of adverse outcomes. However, an organisation may experience an accident-free period even during the incubation period before a major accident.

It is possible to derive a broad array of hypotheses about preconditions for successful operations from current organisational theories of safety. Such derivations should be done with caution, because an adequate account of success needs to include conditions or mechanisms that are not commonly used in accounts of failure, e.g. adaptive capacity.

Learning from successful operations can take place either through spontaneous mechanisms or through mechanisms deliberately put in place by management. Managed mechanisms include reporting systems, debrief sessions in simulators and the real world, and workshops. Paradoxically, whereas learning from successful operations has received limited attention in the safety science literature, learning from operations that are perceived to be successful appears to take place all the time in the real world. However, the outcome of such learning is not always improved safety. A possible strategy for influencing the outcome of spontaneous learning processes is to promote effort to critically scrutinise the apparent success of operations.

We have identified several challenges related to learning from successful operations. Characterising an operation as successful may be problematic, since the absence of adverse outcomes does not necessarily imply that the risk was well controlled. Learning processes may maintain current dogma and practices rather than trigger new insight and improvements. Successful operations rarely lend themselves to rigorous approaches for establishing causal connections between how operations are performed and the degree of success, such as true experimental designs. Environmental conditions or practices that contribute to successful operations within one category of systems may prove detrimental in systems with other properties.

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9. REFERENCES

Alvesson M. & Sköldberg, K. (2009). *Reflexive Methodology. New Vistas for Qualitative Research.* 2nd. ed. Los Angeles: SAGE.

Argote, L. & Ophir, R. (2002). Intraorganizational learning. Chapter 8 in J.A.C. Baum, Ed.: *The Blackwell Companion to Organizations.* Oxford: Blackwell.

Ashby, W. R. (1981). Self-regulation and requisite variety. In F. E. Emery, Ed.: *Systems Thinking*. Volume One. Harmondsworth: Penguin Education, 100-120. Earlier published as Chapter 11 in W. R. Ashby (1956). Introduction to Cybernetics, Wiley.

Bierly, P. E. & Spender, J.-C. (1995). Culture and High Reliability Organizations: The case of the nuclear submarine*. Journal of Management, 21*(4), 693-656.

Carthey, J., de Leval, M. R., Wright, D. J., Farewell, V. T., Reason, J. T. and all UK paediatric cardiac centres (2003). Behavioural markers of surgical excellence. *Safety Science, 41*(5), 409-425.

Dekker, S. (2011). *Drift into Failure. From Hunting Broken Components to Understanding Complex Systems.* Farnham: Ashgate.

Haddon, W. (1970). On the escape of tigers: An ecological note. *American Journal of Public Health*, *60*(12), 2229-2234.

Haddon, W. (1980). The Basic Strategies for Reducing Damage from Hazards of all Kinds. *Hazard Prevention*, Sept./ Oct., 8-12.

Hale, A. & Heijer, T. (2006). Defining resilience. Chapter 3 in E. Hollnagel, D. D. Woods & N. Leveson, Eds.: *Resilience Engineering – Concepts and Precepts*. Ashgate, Aldershot, 35-40.

Hendrick, K. & Benner, L. Jr. (1987). *Investigating accidents with STEP*. New York: Marcel Dekker.

Hollnagel, E., Pariès, J., Woods, D. D. & Wreathall, J. (2011). *Resilience Engineering in Practice: A Guidebook*. Farnham: Ashgate.

Hollnagel, E., Woods, D. D. & Leveson, N., Eds. (2006). *Resilience Engineering – Concepts and Precepts*. Aldershot: Ashgate, 347-358.

Hopkins, A. (2000). *Lessons from Longford: The Esso Gas Plant Explosion*. Sydney: CCH.

Hopkins, A. (2008). *Failure to Learn. The BP Texas City Refinery disaster.* Sydney: CCH Australia.
LaPorte, T. R. & Consolini, P. M. (1991). Working in practice but not in theory: Theoretical challenges of “High-Reliability Organisations”. *Journal of Public Administration Research and Theory*, *1*, 19-47.
Marc, J. & Rogalski J. (2009). How do individual operators contribute to the reliability of collective activity? In C. Owen, P. Beguin & G. Wackers, Eds.: *Risky work environments: reappraising human work within fallible systems*. Farnham: Ashgate.
Mesman, J. (2009) Channeling erratic flows of action: Life in the neonatal emergency care unit. In C. Owen, P. Beguin & G. Wackers, Eds.: *Risky work environments: reappraising human work within fallible systems.* Farnham: Ashgate.
Nathanael, D. & Marmaras, N. (2008). Work practices and prescription: A key issue for organizational resilience. In E. Hollnagel, C. P. Nemeth & S. Dekker, Eds.: *Resilience Engineering Perspectives.* Volume 1: Remaining Sensitive to the Possibility of Failure. Aldershot: Ashgate.
Perrow, C. (1984). *Normal accidents: Living with high risk technologies*. Princeton University Press.
Rasmussen, J. (1997). Risk management in a Dynamic Society: A Modelling Problem. *Safety Science, 27*(2-3), 183-213.
Reason, J. (2008). *The human contribution: unsafe acts, accidents, and heroic recoveries*. Farnham: Ashgate.
Rochlin, G. I., LaPorte, T. & Roberts, K. H. (1987). The self-designing high-reliability organization: Aircraft carrier flight operations at sea. *Naval War College Review, 40*(4), 76-90.
Roe, E. & Schulman, P. R. (2008). *High reliability management*. Palo Alto, CA: Stanford Business.
Rosness, R., (2009). A Contingency model of decision-making involving risk of accidental loss. *Safety Science, 47*(6), 807-812.
Rosness, R., Tharaldsen, J., Tinmannsvik, R. K. & Wiig, S. (2014). On the relationships between organisational learning and safety. *Working on Safety 2014.* Glasgow, Scotland, September 30-October 3.
Rosness, R., Nesheim, T. & Tinmannsvik, R. K. (2013). *Kultur og systemer for læring.* Report A24120. Trondheim: SINTEF Technology and Society.
Rosness, R., Grøtan, T. O., Guttormsen, G., Herrera, I. A., Steiro, T., Størseth, F., Tinmannsvik, R. K. & Wærø, I. (2010). *Organisational accidents and resilient organisations: Six Perspectives*. Revision 2. Report SINTEF A17034. Trondheim: SINTEF Technology and Society.
Schulman, P. (1993a). The analysis of High Reliability Organizations: A comparative framework. In: K. H. Roberts, Ed.: *New Challenges to Understanding Organisations*. New York: Macmillan.
Schulman, P. R. (1993b). The negotiated order of organizational reliability. *Administration & Society, 25*(3), 353-372.
Sklet, S. (2004). Comparison of some selected methods for accident investigation. *Journal of Hazardous Materials, 111* (1-3), 29-37.
Snook, S. A. (2000). *Friendly Fire. The Accidental Shootdown of U.S. Black Hawks over Northern Iraq.* Princeton: Princeton University Press.
Størseth, F., Albrechtsen, E. & Eitrheim, M. H. R. (2010). Resilient recovery factors: Explorative study. *Safety Science Monitor, 14*(2).
Størseth, F., Rosness, R. & Guttormsen, G. (2010). Exploring safety critical decision making. In R. Briš, C. G. Soares & S. Martorell, Eds.: *Reliability, Risk and Safety. Theory and Applications. Vol. 2.,* London: CRC Press.
Tjora. A. H. (2009). *Fra nysgjerrighet til innsikt. Kvalitative forskningsmetoder i praksis.* (From curiosity to insight. Qualitative research methods in practice.) Trondheim: Sosiologisk forlag.
Turner, B. A. (1978). *Man-made disasters.* London: Wykeham Science Press.
Turner, B. A. & Pidgeon, N. F. (1997). *Man-made disasters*. Butterworth-Heinemann.
Vaughan, D. (1996). *The Challenger Launch Decision.* Chicago: The University of Chicago Press.
Weick, K. E. (1987). Organizational culture as a source of high reliability. *California Management Review, 24*(2), 112-127.
Weick, K. E. & Roberts, K. H. (1993). Collective mind in organizations: Heedful interrelating on flight decks. *Administrative Science Quarterly 38*(3) 357-381.
Weick, K. E. & Sutcliffe, K. M. (2001). *Managing the Unexpected*. San Francisco: Jossey-Bass.
Westrum, R. (1993). Cultures with Requisite Imagination. In J. A. Wise, V. D. Hopkin & P. Stager, Eds.: *Verification and Validation of Complex Systems: Human Factors Issues*. Berlin: Springer, 401-416.
Woods, D. D. (2006). Essential characteristics of resilience. In E. Hollnagel, D. D. Woods & N. Leveson, Eds.: *Resilience Engineering – Concepts and Precepts*. Aldershot: Ashgate, 21-34.
Yin, R. K. (1994). *Case Study Research. Design and Methods*. Thousand Oaks, London and New Dehli, Sage Publications.

Standardization in the field of Nanoparticles

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Abstract

The development of technology based on nanomaterials has led to the emergence of new risks associated with working with nanoparticles, with consequences for the safety and health of workers hitherto unknown. The need to regulate working with nanoparticles is arising recently. It is necessary to have standards incorporating best practices and other recommendations to protect the safety and health of workers handling these materials. Within these practices and recommendations, individual risk protection (personal protective equipment or PPE) is especially relevant. Moreover, compliance with standards (CE marking of conformity or any other mandatory standards) does not guarantee user protection in any situation. In fact, the protection offered by certain PPE during exposure to nanomaterials is a matter of debate and study nowadays. The question is whether there are specific PPE whose effective protection against nanoparticles has been demonstrated. Unfortunately there is not an affirmative answer yet. Beginning with the skin protection and focusing on clothing and gloves, currently existing standards collect various tests to determine the resistance of PPE against the permeation and penetration of chemicals and solid particles, leakage to the interior, and material degradation. In relation to the personal protective devices (masks and filters), the tests contained in the existing standards focus on the evaluation of three parameters: the penetration of particles through the filter, the inward leakage and clogging of the filter. But these tests are not designed to particle sizes of nanometers. Therefore, there are currently no published standards developed specifically to check levels of PPE protection against nanomaterials. However, there is wide work in the field of research and experimentation, which allows the extraction of valuable conclusions and practical recommendations. Research and experimentation in the field of skin protection shows that the conditions for conducting the tests should simulate actual conditions of use clothing and gloves instead of "copying" the conditions of forced flow testing of respiratory material, because the latter conditions lead to a result distorted by excess. In turn, the influence of the type of material is tested by the evaluation of parameters such as fibre diameter, number of pores and their size and volume, air permeability and thickness of the material. Regarding respiratory protection, trials of penetration through the filter show a great variation in the effectiveness according to the particle size, and a maximum penetration size is detected (MPPS: "Most Penetrating Particle Size"). Other aspects that have been evaluated are the influence of flow, the type of mask and the inward leakage factor. Despite everything said, there are specific standards engaged to nanotechnologies that follow the scheme presented in these lines: collecting results of research and experimentation to date of publication, as well as recommendations for risk management in the workplace. Therefore, these documents also fail to set standardized tests to ensure levels of protection for risk control measures. At present, the NanoRISK Project is being carried out, including the development of protocols for evaluating the effectiveness of PPE against Nanos. This protocols could be considered on future standards.

Keywords: Nanoparticles, personal protective equipment, skin protection, respiratory protection, standardized tests.

1. INTRODUCTION

The development of technology based on nanomaterials has led to the emergence of new risks associated with working with nanoparticles, with consequences for the safety and health of workers hitherto unknown. Because of this and the rise in its use, nanotechnology and the use of nanomaterials have been classified as an emerging risk within the European Union (EU) (Commission of the European Communities, 2007).

Given this situation, the need to regulate working with nanoparticles is arising recently (Commission of the European Communities, 2012). It is necessary to have standards incorporating best practices and other recommendations to protect the safety and health of workers handling these materials. Within these practices and recommendations, individual risk protection (personal protective equipment or PPE) is especially relevant, because although it is the last of the preventive measures that should be implemented (after elimination of risk, control in the origin and collective protection), the ease of implementation of PPE makes them widely applied in the workplace.

2. CURRENT SITUATION OF STANDARDIZATION

The effectiveness in protecting using PPE is linked to the selection of an appropriate equipment and proper fit, use and maintenance (Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT), 2015). Regarding the selection, protective equipment must comply with European standards of manufacturing and marketing (CE marking of conformity) or any other mandatory standards from a place outside the EU (Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT), 2015). However, compliance with these standards does not guarantee user protection in any situation. In fact, the protection offered by certain PPE during exposure to nanomaterials is a matter of debate and study nowadays (Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT), 2015).

Regarding accident prevention it is vital to know the efficiency of PPE against nanoparticles because if we are not certain of their degree of protection, we cannot ensure that they avoid damage to the health of workers. And the compliance of certain standard tests should be verified to manufacture successfully PPE with known protection levels. The question is whether there are specific PPE whose effective protection against nanoparticles has been demonstrated. Unfortunately there is not an affirmative answer yet.

Beginning with the skin protection and focusing on clothing and gloves, currently existing standards collect various tests to determine the resistance of PPE against the permeation of chemicals, penetration of liquid and spray, penetration of solid particles, leakage to the interior, and material degradation, and there are certain parallels and similarities between the standard tests at European level and internationally (American Society for Testing and Materials, ASTM).

Table 1 shows the European standard that includes the strength test of the gloves to permeation by chemicals, international American standards (ASTM) and internationals (International Organization for Standardization, ISO) which would be equivalents in terms of the property tested.

Table 1 – Protective clothing. Permeation. European standards vs. International standards.

European Standard	Description	International Standard	Description
UNE-EN 374-3	Protective glove against chemicals and micro-organisms. Part 3: Determination of resistance to permeation by chemicals	ASTM F739	Standard Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact
		ASTM F1194	Standard Guide for Documenting the Results of Chemical Permeation Testing of Materials Used in Protective Clothing
		ASTM F1407	Standard Test Method for Resistance of Chemical Protective Clothing Materials to Liquid Permeation—Permeation Cup Method
		ASTM F1383	Standard Test Method for Permeation of Liquids and

			Gases through Protective Clothing Materials under Conditions of Intermittent Contact
		ISO 6529	Protective Clothing. Determination of Resistance of Protective Clothing Materials to Permeation by Liquids and Gases
		ASTM F2815	Standard Practice for Chemical Permeation through Protective Clothing Materials: Testing Data Analysis by Use of a Computer Program

Table 2 shows the European standards that includes the strength test of the clothing to penetration by liquids and solid particles and the resistance to degradation by chemicals, and international American standards (ASTM) and internationals (International Organization for Standardization, ISO) which would be equivalents in terms of the properties tested.

Table 2 – Protective clothing. Penetration and others. European standards vs. International standards.

European Standard	Description	International Standard	Description
UNE-EN ISO 6530	Protective clothing. Protection against liquid chemicals. Test method for resistance of materials to penetration by liquids	ASTM F903	Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Liquids
UNE-EN ISO 17491-3	Protective clothing. Test methods for clothing providing protection against chemicals. Part 3: Determination of resistance to penetration by a jet of liquid (jet test)	ISO 13994	Clothing for protection against liquid chemicals. Determination of the resistance of protective clothing materials to penetration by liquids under pressure
UNE-EN ISO 17491-4	Protective clothing. Test methods for clothing providing protection against chemicals. Part 4: Determination of resistance to penetration by a spray of liquid (spray test)	ASTM F1359 / F1359M	Standard Test Method for Liquid Penetration Resistance of Protective Clothing or Protective Ensembles Under a Shower Spray While on a Mannequin
		ISO 17491-5	Test methods for clothing providing protection against chemicals. Part 5: Determination of resistance to penetration to a spray of liquid (manikin spray test)
UNE-EN ISO 13982-1	Protective clothing for use against solid particulates. Part 1: Performance requirements for chemical protective clothing providing protection to the full body against airborne solid particulates (type 5 clothing)	ASTM F2053	Standard Guide for Documenting the Results of Airborne Particle Penetration Testing of Protective Clothing Materials
UNE-EN ISO 13982-2	Protective clothing for use against solid particulates. Part 2: Test method of determination of inward leakage of aerosols of fine particles into suits		
EN 374-4	Protective gloves against chemical and micro-organisms. Part 4: Determination of resistance to degradation by chemicals	ASTM F1154	Standard Practices for Qualitatively Evaluating the Comfort, Fit, Function, and Integrity of Chemical-Protective Suit Ensembles

In relation to the means of respiratory protection (masks, half masks, and filters), the tests contained in the existing standards focus on the evaluation of three parameters: the penetration of particles through the filter; the inward leakage (facial leakage through the contact surface between the face and the facepiece); and clogging of the filter. Again there is similarity in trials at European and American level (proposed for equipment certification by NIOSH, National Institute for Occupational Safety and Health), without full equivalence in the certified protection level. Table 3 shows the same comparison of standards for respiratory protective devices.

Table 3 – Respiratory protective devices. European standards vs. International standards.

European Standard	Description	International Standard	Description
UNE-EN 13274-1	Respiratory protective devices. Methods of test. Part 1: Determination of inward leakage and total inward leakage	42 CFR part 84	Approval of respiratory protective devices. Subpart I: Gas masks. Subpart K: Non powered air purifying particulate respirators. Subpart KK: Dust, fume, and mist; pesticide; paint spray; powered air-purifying high efficiency respirators and combination gas masks.
UNE-EN 13274-7	Respiratory protective devices. Methods of test. Part 7: Determination of particle filter penetration		
UNE-EN 13274-8	Respiratory protective devices. Methods of test. Part 8: Determination of dolomite dust clogging		
UNE-EN 143	Respiratory protective devices. Particle filters. Requirements, testing, marking		

But these tests were designed to particle sizes or aerosols of the order of millimeters or microns, in some cases hundreds of nanometers, but not for sizes of the order of units or tens of nanometers. Therefore, there are currently no published standards developed specifically to check levels of PPE protection against nanomaterials. Consequently, you can only make reasoned recommendations based on the known protective characteristics of certain PPE and its applicability to the exposure to nanomaterials. Then, without specific standards, what is the solution for testing PPE against the Nanos?

Fortunately, there is wide work in the field of research and experimentation, which allows the extraction of valuable conclusions and practical recommendations (see Gao et al., 2011; Park et al., 2011; Rengasamy and Eimer, 2011; Rengasamy et al., 2008; Rengasamy et al., 2007; and Wang and Tronville, 2014). These papers guide the way forward to further progress in understanding the nature of the risks associated with nanomaterials and nanoparticles and in the control of these risks.

Research and experimentation in the field of skin protection shows that the conditions for conducting the tests should simulate actual conditions of use clothing and gloves instead of "copying" the conditions of forced flow testing of respiratory material, because the latter conditions lead to a result distorted by excess (Gao et al., 2011). In turn, the influence of the type of material is tested by the evaluation of parameters such as fiber diameter, number of pores and their size and volume, air permeability and thickness of the material, with the next conclusions for "nonwoven fabrics"(Gao et al., 2011):

• The existence of smaller voids in the tissues leads to less penetration (test based on the European standard EN ISO 6529);

• Dry working conditions give less penetration than wet working conditions.

• By increasing the fiber size, volume and pore size, porosity and air permeability, increased penetration is observed;

• By increasing the material thickness, decreases penetration;

• The reduction of fiber size, of the pores and porosity, can compensate for small thickness of material, reducing penetration;

Similarly, for this type of nonwoven materials and as to the influence of particle size, the size of maximum penetration into the fabrics is in the vicinity of 300 nm (Gao et al., 2011), being particles lower and upper to this size more easily retained by different mechanisms, such as diffusion.

Finally, regarding the type of tested material for gloves (latex and nitrile), it has not been detected penetration although clusters was detected in the glove surface. In addition, no differences were observed between the dry and wet conditions (Park et al., 2011).
Should be mentioned that the development of standards for protective clothing is entrusted to the Working Groups of the Technical Committee 162 of the European Committee for Standardization. Currently these groups work on the line to define requirements and tests applicable to a new type of protective clothing that covers the risk exposure to nanoparticles. The preliminary ideas are based on adapting clothes to certain tests coming from the field of respiratory protection.
Regarding respiratory protection, penetration trials through the filter show (see Rengasamy and Eimer, 2011; Rengasamy et al., 2008; Rengasamy et al., 2007):
• A high variation in the effectiveness according to the particle size, and a maximum penetration size was detected (MPPS: "Most Penetrating Particle Size").
• The penetration increases with the increasing flow.
• Finally, the full mask offers greater protection than half masks and masks (in fact, masks do not protect against NP). Although filters coupled to half mask or masks have a low-medium level of penetration (MPPS 40-50 nm), in the market there are few models with this protection level. In the case of the larger sized particles, the influence exerted on efficacy by the inward leakage is greater than the influence exerted by the penetration through the filter. It is noteworthy that, unlike what happens with protective clothing, standardization committees for respiratory protection are not considering drafting rules for specific assay for nanoparticles.
Despite everything said, there are specific standards engaged to nanotechnologies (technical report the case of the European standard). Next tables show the European standard and the American standard related to Nanos and Occupational Health and Safety (OH&S).

Table 4 – European and American standard related to Nanos and OH&S.

Standard	Description
UNE-ISO/TR 12885 IN	Nanotechnologies. Health and safety practices in occupational settings relevant to nanotechnologies
ASTM E2535	Standard Guide for Handling Unbound Engineered Nanoscale Particles in Occupational Settings

These standards follow the scheme presented in these lines: collecting results of research and experimentation to date of publication, as well as recommendations for risk management in the workplace.
The recommendations of the technical report UNE-ISO / TR 12885: 2010 is based on the conclusions of UENanosafe2 Project. These recommendations regarding the protective clothing are:
• The NP can penetrate through gloves available in the market, so the use of double gloves is recommended.
• 'Nonwoven' fabrics are more effective against penetration, so it is recommended not to use cotton fabric clothing.
Regarding respiratory protective devices are:
• For many of the tested filters, MPPS is around 300 nm; in N95 filters, MPPS is between 30 and 100 nm; and in P100 filters, MPPS is between 100 and 200 nm.
• In workplaces with NP is recommended to use full mask with high efficiency filter.
• The facial leakage is the determining factor of the efficiency of respiratory protective PPE.
• The device with supply and purification of air provides maximum protection, since it creates positive pressure in the mask.
In this area also include a recent study by the Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT) of Spain, published in April 2015, which considers progress achieved in this field in recent years. Result of this work, some recommendations for the use of PPE have been proposed, with no reference to standardized tests.

3. FINALS REMARKS

As evidenced by the studied documentation, there are no standards to ensure protection levels for risk management measures.
Currently, it is conducting the NanoRISK Life Project - Best Practices Effectiveness, Prevention and Protection Measures for Control of Risk Posed by Engineered Nanomaterials (LIFE12 ENV/ES/178). The main objective of the project is to define proven Risk Management Measures

(RMMs) to prevent or minimize exposure to engineered nanomaterials (ENMs) during the specific workplace situations of the polymer nanocomposite industry, as well as to support standardization activities concerning the certification of the adequacy of PPE and Engineering Controls (ECs) to protect workers from the risk posed by use of ENMs.
Within this context, the concept of the project in to ensure a high level of protection of human health and the environment from the risks that can be posed by the use engineering nanomaterials.
On the basis of this concept, the following activities are included in the set of the activities carried out at the present:
• To analyze the adequacy of current international standards (ISO /CEN /ASTM) to evaluate the effectiveness of PPE and collective protection measures;
• Design and development of an aerosol testing chamber prototype for the standardized evaluation of the effectiveness of the working procedures, prevention and protection measures to control the risk posed by engineered nanomaterials.
• Define methods and protocols for evaluating the effectiveness of Personal Protective Equipment (PPE) and industrial devices for ventilation and filtration.
• Evaluate the effectiveness of PPE available on the market, based on defined protocols, and using the test chamber developed in this project.
If the results of the experimental phase are favourable, protocols tested will be considered as a basis for future standards.
Based on these objectives, the protocols related to PPE that have been defined to date are:
• Respiratory protective devices. Procedure to determination of inward leakage of nanoparticles
• Respiratory protective devices. Procedure to determination of total inward leakage of nanoparticles
• Respiratory protective devices. Procedure to determination of particle filter penetration by nanoparticles
• Protective clothing. Procedure to determination of inward leakage of aerosols of nanoparticles into suits
• Protective clothing. Procedure to determination of resistance to penetration by spraying a liquid solution of nanoparticles
At the current phase of the project, the tests of PPE available on the market are being conducted, according to the defined protocols. These tests are aimed at validating the protocols and verify the protection level of the devices against nanoparticles considered in this project.

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5. REFERENCES

ASTM E2535. Standard Guide for Handling Unbound Engineered Nanoscale Particles in Occupational Settings.
ASTM F1154. Standard Practices for Qualitatively Evaluating the Comfort, Fit, Function, and Integrity of Chemical-Protective Suit Ensembles.
ASTM F1194. Standard Guide for Documenting the Results of Chemical Permeation Testing of Materials Used in Protective Clothing.
ASTM F1359 / F1359M. Standard Test Method for Liquid Penetration Resistance of Protective Clothing or Protective Ensembles Under a Shower Spray While on a Mannequin.
ASTM F1383. Standard Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Intermittent Contact.
ASTM F1407. Standard Test Method for Resistance of Chemical Protective Clothing Materials to Liquid Permeation—Permeation Cup Method.
ASTM F2053. Standard Guide for Documenting the Results of Airborne Particle Penetration Testing of Protective Clothing Materials.
ASTM F2815. Standard Practice for Chemical Permeation through Protective Clothing Materials: Testing Data Analysis by Use of a Computer Program.
ASTM F739. Standard Test Method for Permeation of Liquids and Gases through Protective Clothing Materials under Conditions of Continuous Contact.
ASTM F903. Standard Test Method for Resistance of Materials Used in Protective Clothing to Penetration by Liquids.
Commission of the European Communities. COM(2007) 62 final. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Improving quality and productivity at work: Community strategy 2007-2012 on health and safety at work, from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0062:FIN:en:PDF.
Commission of the European Communities. COM(2012) 572 final. Communication from the Commission to the European Parliament, the Council and the European Economic and Social Committee. Second Regulatory Review on Nanomaterials, from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012DC0572&from=EN.
EN 374-4. Protective gloves against chemical and micro-organisms. Part 4: Determination of resistance to degradation by chemicals.

Gao, P., Jaques, P. A., Hsiao, T., Angie Shepherd, A., Eimer, B. C., Yang, M., Miller, A., Gupta, B. & Shaffer, R. (2011). Evaluation of Nano- and Submicron Particle Penetration through Ten Nonwoven Fabrics Using a Wind-Driven Approach. *Journal of Occupational and Environmental Hygiene*, 8: 13-22.

Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT) (2015). *Seguridad y salud en el trabajo con nanomateriales*. Madrid: Servicio de Ediciones y Publicaciones del INSHT.

ISO 13994. Clothing for protection against liquid chemicals. Determination of the resistance of protective clothing materials to penetration by liquids under pressure.

ISO 17491-5. Test methods for clothing providing protection against chemicals. Part 5: Determination of resistance to penetration to a spray of liquid (manikin spray test).

ISO 6529. Protective Clothing. Determination of Resistance of Protective Clothing Materials to Permeation by Liquids and Gases.

Park, J., Kwak, B. K., Kim, Y. & Yi, J. (2011). Efficiency of protective dermal equipment against silver nanoparticles with water aerosol. *Journal of Nanoparticle Research*, 13, 3043-3049.

Rengasamy, S. & Eimer, B.C. (2011). Total Inward Leakage of Nanoparticles through filtering facepiece respirators. *Annals of Occupational Hygiene*, 55, 253-263.

Rengasamy, S., Eimer, B.C. & Shaffer, R.E. (2008). Nanoparticle Filtration Performance of Commercially Available Dust Masks. *Journal of the International Society for Respiratory Protection*, 25, 27-41.

Rengasamy, S., Verbofsky, R., King, W. P. & Shaffer, R. E. (2007). Nanoparticle Penetration through NIOSH-approved N95 Filtering-facepiece Respirators. *Journal of the International Society for Respiratory Protection*, 24, 49-59.

UNE-EN 13274-1. Respiratory protective devices. Methods of test. Part 1: Determination of inward leakage and total inward leakage.

UNE-EN 13274-7. Respiratory protective devices. Methods of test. Part 7: Determination of particle filter penetration

UNE-EN 13274-8. Respiratory protective devices. Methods of test. Part 8: Determination of dolomite dust clogging

UNE-EN 143. Respiratory protective devices. Particle filters. Requirements, testing, marking.

UNE-EN 374-3. Protective glove against chemicals and micro-organisms. Part 3: Determination of resistance to permeation by chemicals.

UNE-EN ISO 13982-1. Protective clothing for use against solid particulates. Part 1: Performance requirements for chemical protective clothing providing protection to the full body against airborne solid particulates (type 5 clothing).

UNE-EN ISO 13982-2. Protective clothing for use against solid particulates. Part 2: Test method of determination of inward leakage of aerosols of fine particles into suits.

UNE-EN ISO 17491-3. Protective clothing. Test methods for clothing providing protection against chemicals. Part 3: Determination of resistance to penetration by a jet of liquid (jet test).

UNE-EN ISO 17491-4. Protective clothing. Test methods for clothing providing protection against chemicals. Part 4: Determination of resistance to penetration by a spray of liquid (spray test).

UNE-EN ISO 6530. Protective clothing. Protection against liquid chemicals. Test method for resistance of materials to penetration by liquids.

UNE-ISO/TR 12885 IN. Nanotechnologies. Health and safety practices in occupational settings relevant to nanotechnologies.

United States Government. Public Health Service, HHS. Title 42, Code of Federal Regulations (CFR). Part 84. Approval of respiratory protective devices, from http://www.gpo.gov/fdsys/pkg/CFR-2004-title42-vol1/pdf/CFR-2004-title42-vol1-part84.pdf.

Wang, J., Tronville, P. (2014). Toward standardized test methods to determine the effectiveness of filtration media against airborne nanoparticles. Journal of Nanoparticle Research, 16, 1-33. Retrieved October 30, 2014, from http://link.springer.com/article/10.1007/s11051-014-2417-z#page-1.

Safety climate considerations in the development of a management system for safety, environment, and process control in engineering laboratories at the national university of Ireland, Galway

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Abstract

The College of Engineering and Informatics of NUI, Galway has recently moved into its new engineering building. Management wishes to improve the state of health, safety and quality issues within the College laboratories. For that reason a *bona fide* laboratory safety management system was required. This project firstly surveyed the attitudes to health and safety levels within engineering laboratories by conducting a safety climate questionnaire and interviews and developed a laboratory safety checklist. The safety climate questionnaire was adapted from one that was created by a joint industry and UK Health and Safety Executive research project on the assessment of safety culture in offshore environments (HSE 1999). Our research also resulted in the development of the checklist mentioned above, and a standard operating procedure template that also focuses on environment and process procedure and recommendations to create databases of equipment, chemicals, vaccinations and safety training. All of these if taken together will give management the information they need to bring the safety, process procedures and environment to an acceptable level within the College.

Keywords: Laboratory Safety, Safety Management, Environmental management, Safety Climate Questionnaire.

1. INTRODUCTION

Audits of the engineering laboratories which included an inspection of over five hundred pieces of equipment and the risk assessment of over ninety pieces of equipment raised concerns with respect to housekeeping, maintenance, risk assessment, Standard Operating Procedures (SOPs), and the use of personal protective equipment (PPE), (Broggy and Gaffey 2008). This led management to see the need for a practical and *bona fide* Laboratory Safety Management System (LSMS). Such a system would incorporate documented operations, demanding record keeping, and regular quality and safety audits. This task was a challenge due to very specific nature of laboratory work itself and diversity among the laboratories within the College. Before the work on the development of the LSMS could start the identification of what is a good and standard practice in terms of laboratory work had to be made. For that reason an extensive literature review was conducted on this topic. The first step in the development of a LSMS is to understand the organisation and its culture. In this study it was decided to conduct a questionnaire survey of the two groups working in laboratories: technical staff and research staff. The questionnaire used was a tool prepared by the Health and Safety Executive (HSE) in the UK in conjunction with the oil industry. The next step in the process was to develop a safety management system that could be used for all the laboratories within the College collectively. This task involved the development of a Standard Operating Procedure (SOP) template and testing it on a number of procedures and pieces of equipment. Finally, the last step involved issuing recommendations to the College's management for the implementation of a Laboratory Management System.

2. LITERATURE REVIEW

2.1. Challenges in Laboratory Safety

One of the difficulties in establishing an effective Laboratory Safety Management System is the nature of work in laboratories. The tasks conducted there are quite diverse, and often change. The equipment is frequently made-up or adapted. The people working in laboratories are typically very competent and are likely to be strongly goal oriented, often to the unintended elimination of other aspects (Furr 1990). Also researchers work on varied products with a great deal of independence (Kapin 1999), which makes it hard for a safety officer to encompass everything that is ongoing in the laboratory. Kim et al. (2005) in their article concerning safety in the newly opened research centre noted that while in theory, everyone moving to the new building should have been experienced in the various health and safety requirements and would need no retraining or assistance in setting up their new spaces in a safe manner. In practice, there was concern that “health and safety amnesia” would set in during all of the activity associated with getting labs up and running. Some researchers found that even if the laboratory staff abide by chemical safety rules often general safety issues such as fire safety, electrical safety, emergency preparedness, and others are generally ignored and neglected (Kapin 1999).

2.2. Good Laboratory Practice

There are numerous publications on laboratory safety, including whole books dedicated to this theme (Furr 1990; Committee on Prudent Practices for Handling Storage and Disposal of Chemicals in Laboratories 1995; Fleming 2000), journal articles (Kapin 1999; Foster 2003; Kim, Furr et al. 2005), theses (Connolly 2004) and many internal manuals (Doolittle, Esparsen et al. 1995; The Office of Environmental Health and Radiation Safety 2008). It is outside the scope of this document to go into detail on specific laboratory safety practices, but the main areas where safety rules need to be applied are chemical safety, equipment safety, standard operating procedures, biological safety, noise and vibration, ergonomics, psychological issues.

2.3. Safety Management Systems

Managing the risks associated with an organization’s operations has been a subject of increasing importance over recent years (Santos-Reyes and Beard 2002). Different OHSMS-based standards have been developed (HSE 1997; OHSAS 1999; AS/NZ4801 2001; ILO 2001; PN 2001; BSI 2004) within the public, and private sectors and many have been adopted by workplaces. The European Agency for Safety and Health at Work (2001) discussed the advantage of strong occupational health and safety management systems as being that bigger companies reduced their numbers of work accidents and, through that, the working time lost. HSE (1997) is of the opinion that safety should be integrated as part of sound management. Implementing a safety management system reduces accident rates and improves the company’s productivity and economic and financial performance (HSE 1997; Smallman and John 2001; Rechenthin 2004). However, very little work has been done in academic institutions to define what constitutes an effective Safety Management System. There are still no well defined and established criteria that could help to develop such SMS (Santos-Reyes and Beard 2002). There is also literature available on the application of the management system to a laboratory environment. Kapin (1999) points out that completion of a Laboratory Safety Plan will identify health and safety needs for that lab, provide appropriate documentation, and outline required activities and training.

2.4. Hazard Identification and Risk Assessment

Risk assessment is a vital process in making policy decisions for risk management. The identification of hazards and measures to control them provides the base for a safety program and effectively determines the extent, content and complexity of a successful occupational health and safety management system (Mearns and Flin 1995; Makin and Winder 2008). Hazards should be controlled on a regular basis in order to ensure that the risks associated to them do not increase above an acceptable level (Kuusisto 2000).

2.5. Safety Culture and Climate

Organizational culture is generally accepted to have an influence on an organization’s success or failure (Donnellan 2003). Many industries around the world are showing an increasing interest in the idea of ‘safety culture’ as a way of reducing the probability of major disasters, and accidents related to everyday tasks (Cooper 2000). Turner and Pidgeon (1997) said that the problem of safety culture was, what is it and “how do you become one?”, is perhaps the key issue in modern thinking about safety. The distinction should be made between safety culture and safety climate. The latter ought to be distinguished from safety culture, where the former is a symptom or ‘snapshot’ (Flin, Mearns et al. 2000) of the latter (Guldenmund 2000). The concept of safety climate was introduced by Zohar (1980). He defined the climate as ‘a summary of moral perceptions that employees share about their work environment’. During the last two decades renewed interest has emerged in the role of safety climate in accident and injury prevention. Guldenmund (2000) identified ten studies on safety climate that were published during the 1990s, in contrast to only two articles that appeared in the decade when Zohar (1980) published his article.

2.6. Safety Climate Assessment

In safety culture research a safety climate questionnaire has been the main measurement tool (Collins and Gadd 2002). In the past years significant effort has been put into the construction of a valid and reliable safety climate questionnaire and plenty articles were published on that topic (Zohar 1980; Davies, Spencer et al. 1999; Cox and Cheyne 2000; Flin, Mearns et al. 2000; Guldenmund 2000; DeJoy, Schaffer et al. 2004; HSE 2005; Guldenmund 2007; Tsung-Chih Wua 2007; Hahn and Murphy 2008). Workplace safety climate has been assessed in many different industrial sectors including construction (Matilla, Rantanen et al. 1994), manufacturing (Zohar, 1980), airport ground handling (Diaz and Cabrera 1997) and more recently in various health care settings (Gershon, Karkashian et al. 1999). Many different questionnaire designs have been used as well, ranging from very simple and short (Gillen, Baltz et al. 2002; Hahn and Murphy 2008) to multidimensional scales (Diaz and Cabrera 1997; Carroll 1998; Gershon, Karkashian et al. 1999). In this study the "Safety Climate Assessment Toolkit" (HSE 1999) was used. It was initially tested in one organisation involved in hydrocarbon production (Davies, Spencer et al. 1999; Cox and Cheyne 2000). Cox and Cheyne (2000) have extensively piloted the questionnaire. The initial analysis showed the tool to be reliable in terms of what it measures, and sufficiently sensitive to reveal differences between occupational groups. The feedback also suggested that the questionnaire is easy to administer and profile. Although the toolkit has been developed in association with the oil industry, specifically for use in offshore environments, in general the process could be applied in other industry sectors, subject to industry-specific modification (Davies, Spencer et al. 1999).

3. METHODOLOGY

3.1. Safety Climate Questionnaire

3.1.1. Population and Sample

There were about eighty employees directly involved in laboratory work within the College. Sixteen i.e. twenty percent, were technical staff and the remainder were researchers. Participation was entirely voluntary and anonymous. No monetary or other incentives were provided. Laboratory workers from all five departments were surveyed. Sixty questionnaires were personally distributed to employees who were available at the time. Respondents were given thirty minutes to complete the questionnaire. Fifty eight questionnaires were returned giving a response rate of ninety seven percent.

3.1.2. The Instrument

This research adopted the Safety Climate Questionnaire developed by HSE (1999) to collect the data. The questionnaire consisted of forty three questions. The scale was used to measure the employee's perception of safety climate in nine dimensions, including management commitment, communication, priority of safety, safety rules and procedures, supportive environment, employee's safety involvement, personal priorities and need for safety, personal appreciation of risk and work environment. Each question was a complete narrative statement. Based on their actual experience and feeling, respondents rated each of the questions using a five-point Likert scale (from 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree).

3.2. Safety Culture Interviews

A series of five informal interviews were conducted with members of technical officers and researchers. The interviewees were chosen randomly and their answers were recorded anonymously. The purpose of this task was to gather information about the views of the employees on the deficiencies in health and safety practices in the College's laboratories and their ideas on how to improve matters.

3.3. Development of a Laboratory Safety Management System

The aim of this paper was to develop elements of a Safety Management System for the College laboratories. From interviews conducted with technical officers it was apparent that ideally such a system should be practical and would not create much paperwork. For these reasons the main feature of the system developed is an electronic database. The database is contained in a single folder and consists of a number of spreadsheets. The first spreadsheet is for the management of equipment (inventory, risk assessment, maintenance, servicing, Portable Appliance Testing (PAT) testing schedules). The next contains an inventory of chemicals and waste management records. The third and fourth spreadsheets are for vaccination and training records respectively. Apart from the database there was a need for the development of the laboratory safety checklist, risk assessment procedure and standard operating procedure template. All the above are discussed in greater detail in the following paragraphs.

3.3.1. Development of the Laboratory Safety Checklist

The Laboratory Safety Checklist is an aid in the assessment of laboratory safety status at the beginning of the development of the Laboratory Safety Management System and later for periodic audits and updates. The laboratory safety checklist was tested in three laboratories. The aim of this exercise was to make sure that the checklist covers all the health and safety issues in laboratories where very different activities are performed. The key to the selection of laboratories was to try the checklist out in varying types of working environments.

3.3.2. Risk Assessment

The template for this task was adopted from the guidelines contained in *British Standard 8800:2004* (BSI 2004). The Risk assessment matrix and some elements included are shown in Figure 1.

<u>Elements contained in the Risk Assessment:-</u>

Example of Hierarchy of Controls required for a Milling machine

Engineering:

- Install an Interlocking Guard on the mill work area
- Fit an Emergency Stop

Administrative:

- Provide induction training about the machine
- Have Standard Operating Procedures for the use of the machine in place

PPE:

- Procedure includes the required PPE in Pictorial media.

The risk assessment matrix for Severity and Likelihood are:

Severity:
1= Slight Harm, 2= Moderate Harm, 3= Extreme Harm

Likelihood:
1= Very Unlikely/Yearly,
2= Unlikely/During a Semester,
3= Likely/Weekly,
4= Very Likely/Daily

	1	**2**	**3**
1			
2			
3		**X**	
4			

Figure 1. Risk assessment matrix and key elements (adopted from BS8800).

3.3.3. Standard Operating Procedures

The key to a practical and functional SOP is the way it provides the user with appropriate data. The information should be concise, easily understood and communicated in basic technical terms. Particular attention was given to making the SOP as short and easy to read as possible, as during interviews it was discovered that people don’t usually tend to read overly long instructions. The first part of the SOP (example shown on the Figure 2) is meant for the pictorial communication of hazards present for the particular task or piece of equipment, instructions for the use of PPE and Engineering Controls. The interviews with laboratory workers revealed that they find that it is easier and quicker for them to read information represented pictorially. The fact that the large group of researchers come from non-English speaking countries substantiates the use of pictograms.

Hazards			
Personal Protective Equipment Required			
Engineering Controls			

Figure 2. *Example of pictorial description of hazards, PPE and Engineering Controls for an SOP.*

The second part of the SOP contains information on document number, member of staff that prepared the SOP, date and the review due date. It also includes the outcome of the relevant risk assessment. The third and last part of the SOP is made up of ten paragraphs containing information on scope of the activity, reference documents, specific safety and environmental hazards, Personal Protective Equipment required, engineering controls, equipment needed to run a process, materials used to complete the task, lab procedure, waste products and maintenance requirements. The Standard Operating Procedure template was tested on two pieces of equipment and on two laboratory procedures. The template proved to be adequate for both procedures and pieces of equipment. All processes and laboratory procedures are to be documented.

3.3.4. Portable Appliance Testing

Portable Appliance Testing (PAT) is now required by Irish *Safety, Health and Welfare at Work (General Application) Regulations, (2007).* Depending on the usage and deterioration rate of a given piece of equipment, the frequency of testing will differ. PAT testing schedules should ideally be included in a database.

3.3.5. Equipment Maintenance and Servicing Schedule and Database

The regular maintenance and servicing of equipment is vital for its safe operation and also is required by the 2007 regulations. To ensure the timely and adequate maintenance and servicing, a database of all the equipment and schedules needs to be developed. Also the ‘tagging’ of equipment should be introduced. The database should contain information on name, asset number and location of equipment and also on all due dates of maintenance, service and PAT test. Also there should be appropriate reference to documents such as risk assessment, service or PAT testing certificates.

3.3.6. Vaccinations

According to the *Safety, Health and Welfare at Work (Biological Agents) Regulations, (1994)* where there is a risk of being infected by microorganisms at work, the employer must make vaccinations available to their personnel. Since potentially infectious organisms are handled in the environmental laboratory, staff and students working there need to get vaccinations. To keep track of vaccinations due dates, a database is needed.

3.3.7. Training

Provision of appropriate training is a legal duty of employers to their employees as required by the *Safety, Health and Welfare at Work Act 2005* and *General Application Regulations, 2007*. The safety training should cover at minimum the following areas: manual handling; safe use of chemicals; safe handling of biological agents; workshop safety; safe work with certain laboratory equipment (e.g. autoclaves or centrifuges); first aid essentials; Emergency procedures. Induction training should be introduced for new students or staff, covering the basics of safe laboratory work.

3.3.8. Chemical Purchasing and Inventory

Inventory should be kept up to date and one person should be in control of it to avoid purchasing excessive amounts of chemicals. It is also important to keep track of expiry dates of substances, especially those that are forming peroxides with time. The designated person shall also take care to store chemicals appropriately. For example flammable substances must be kept in special cabinets and only compatible chemicals may be stored together.

3.3.9. Hazardous Waste Management

Examples of hazardous waste include biologically contaminated waste (might also contain animal waste or human blood), radioactive waste, waste or expired chemicals, solders, used batteries, etc. The contractors for safe disposal of any of the above types of waste should be carefully chosen and all safe procedures for handling those types of waste should be assessed and followed cautiously.

4. RESULTS

4.1. Safety Climate Questionnaire

Fifty eight laboratory workers out of eighty (i.e. 72.5%) took part in the Safety Climate Questionnaire and the results of the assessment are presented on a radar plot graph where each of the dimensions represented on the radar plot was scored on a standardized scale (Figure 3). Overall, the assessment process didn't reveal any significantly weak areas in the perception of employees, as nearly all average results were higher than 6.0 on a scale of 0 to 10. There were some weaknesses in the areas of Management Commitment (with a standardized mean of 6.0) and Safety Rules and Procedures (with a standardized mean of 6.0) and they are most in need of improvement. The questionnaire survey also highlighted some Communication issues (with a standardised mean of 6.5), the Work Environment (with a standardised mean of 6.6) and Priority of Safety (with a standardised mean of 6.6). The interviews supported these findings.

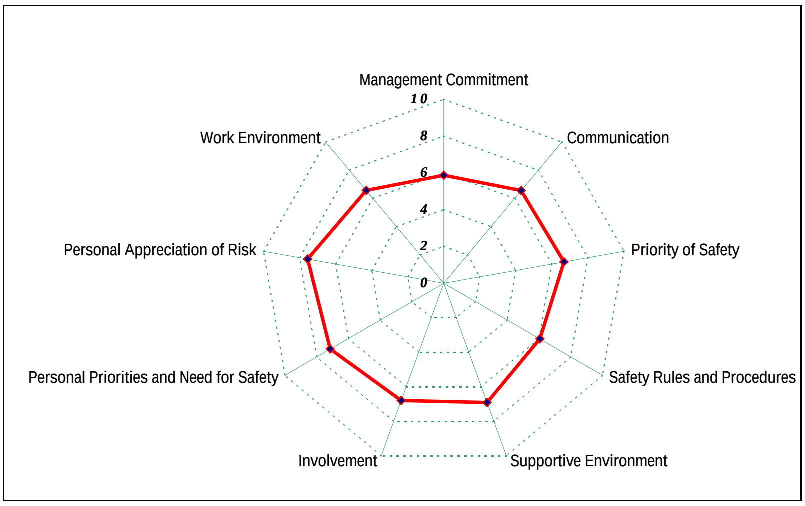

Figure 3. *Safety Climate Questionnaire results for the College.*

4.2. Safety Culture Interviews

Five informal interviews were conducted with members of both technical officers group and researchers group. The main findings of these sessions are as follows:

- Most people find the available safety training is not sufficient for the needs, especially for researchers and undergraduate students doing final year projects.
- The interviewees felt that there is lack of good communication and information sharing between personnel on safety topics.
- Some personnel thought there should be formal, written procedures in place for use of equipment, emergencies, chemicals purchasing and hazardous waste management and that they should be enforced.
- Generally people felt that the house keeping within the laboratories is inadequate and that this poses a health risk for the users.

4.3. The Laboratory Safety Checklist

The laboratory safety checklist was tested in three laboratories. The results at that time were as follows:

- Some work practices were not performed safely. For example the PPE was not used by all employees.
- There were no written procedures for emergency actions, experiments or waste disposal.
- There is no adequate training for new employees.
- Heavy objects were stored above head level in inappropriate locations.

- Standard Operating Procedures were not developed for use of hazardous chemicals, equipment or for experiments.
- Harmful chemicals were seen to be used outside of the fume hood.
- There are no decontamination procedure established and no autoclave performance checks completed monthly.
- The housekeeping appeared poor.
- There was no guarding on some machines.
- There was no record of regular maintenance or PAT testing of most of the equipment.

Since the move to the new engineering laboratories these issues have been and continue to be addressed.

4.4. Risk Assessments

In total there were ninety one pieces of equipment risk assessed. The results of the risk assessment show that the most often encountered hazards were the occurrence of flying particles or material, exposure to noise, burning or scalding, cuts and abrasions and entanglement. Also the inhalation of vapors or fumes was encountered in case of nearly twenty pieces of equipment. The most serious hazards, or in other words posing the gravest risk, were entanglement, crushing, cuts and entrapment of body parts. It was also noted again during this task that some pieces of equipment did not have suitable controls in place. In most instances a guard would be needed to alleviate the risk. Appropriate recommendations were given on these risk assessment sheets and where practicable all machines were fitted with guards. Some old machines were decommissioned as they could not be upgraded economically. Risk assessment must be carried out frequently to ensure that the required management actions are implemented and that any changes to process or procedure are incorporated in the risk assessments.

5. DISCUSSION OF RESULTS

5.1. Conclusions

5.1.1. Safety Climate Questionnaire and Safety Culture Interviews

A questionnaire proved to be a useful tool for the assessment of the safety climate. It was relatively easy to administer and profile and also to provide reliable results. The key findings of the survey were that generally the laboratory workers are quite comfortable with the safety climate in their workplace, however there is a strong feeling that there is too little commitment from the management to safety issues and that the safety rules and procedures are not fully adequate. Consequently these two areas are most in need of improvement. In comparing some key areas of this research with Cox and Cheyne's study is can be see that in their study performance differences were as follows: Management commitment was up 20%, Safety Rules and Procedures up 15%, Work Environment up 25% and Management style was up by 15%, whereas the college performed better in Supportive Environment by 15%, Involvement by 20%, and Personal Priorities by 5%. The areas of Communication and Appreciation of Risk were roughly the same in both studies. This comparison clearly shows the areas where improvement is required. Safety culture interviews were the tool that allowed elaborating more on the findings of the questionnaire. The main findings of the interviews were that the biggest deficiencies are in the areas of training, housekeeping, communication, and safety procedures. Some of these areas were addressed in the move to the new engineering building i.e. Work Environment, Safety Systems, Housekeeping, and Communications. Others are getting management attention now especially in the area of risk assessment and the development of SOP's. Machine guards have been fitted to several pieces of equipment and any equipment that was deemed to be at an unacceptable risk level has been removed from service until the required modification are made. The ongoing development of a culture shift is a matter for University management and can be addressed by training, communications, and by management commitment to safety.

5.1.2. The Laboratory Safety Checklist

The laboratory safety checklist proved to be a useful tool to assess health and safety matters in any kind of laboratory. The testing of the checklist in three laboratories uncovered many health and safety deficiencies. The most serious inadequacies were the lack of proper housekeeping, Standard Operating Procedures, and not using PPE as required as a result of improper information or wrong attitude towards safety, the lack of any noise survey records and no evidence of maintenance or service records for equipment.

5.1.3. Standard Operating Procedures

The SOP template was developed to aid users to work with laboratory equipment and procedures in a safe way. The SOP's also provide information on quality and environmental management requirements. Four Standard Procedures were developed for two pieces of equipment and two laboratory procedures that differed in the degree of complication and by the various hazards they represent. This task did not reveal any deficiencies in the template. Interviews with staff also confirmed the adequacy of the proposed SOP form. The integration of safety, quality, and environmental requirements into one simple procedure will lead to a more efficient management system with less paperwork and greater use of pictograms.

5.2. Recommendations

5.2.1. Safety Climate Questionnaire and Safety Culture Interviews

The recommendation for further study would be to survey the laboratory workers within other Colleges of the University and maybe even outreaching to other Universities. Obtaining such results would allow for the comparative studies between many different laboratories. It could also highlight other issues not discovered and explored in this research as despite a uniform legislative basis each University/Organisation operates in slightly different conditions and safety climate and culture depends on the specific environment developed over the years of management practice.

5.2.2. Final remarks

It was our intention to focus primarily on the practical documents that can be easily incorporated into health and safety practice and records of each of the laboratories. It is also suggested that this template of LSMS would be approved for use in all of NUI, Galway's laboratory facilities and should be maintained uniform, to present a consolidated approach to health and safety issues and to provide transparency and ease of monitoring as much as possible and practicable. This research has a character of a once-off, limited in scope report; however it points out the areas that should be developed further. It is also the authors' belief that once this approach to safety and environmental management is approved and adhered to, it will form a live action plan that will constantly monitor and improve safety climate, culture and attitude to advance the working environment in NUI, Galway's laboratories and effectively eliminate any dangerous occurrences. The integration of safety, environment and process related detail in one standard operating procedure will reduce the amount of paperwork and is easier to manage and keep up to date. Management commitment and communication is a critical part of maintaining the management system.

6. REFERENCES

(1994). Safety, Health and Welfare at Work (Biological Agents) Regulations. T. a. E. Minister of State at the Department of Enterprise.

(2007). Safety, Health and Welfare at Work (General Application) Regulations 2007. T. a. E. Minister of State at the Department of Enterprise.

AS/NZ4801 (2001). Occupational health and safety management systems – Specifications with guidance for use.

Broggy, S. F. and J. Gaffey (2008). Results of Initial Inspection Sheet in College of Engineering and Informatics Laboratories. Results of Initial Inspection Sheet, National University of Ireland, Galway.

BSI (2004). BS8800:2004. Occupational health and safety management systems — Guide., BSI.

Carroll, J. (1998). "Safety culture as an ongoing process: culture surveys as opportunities for enquiry and change." Work and Stress **12**: 272-284.

Collins, A. M. and S. Gadd (2002). "Safety culture: A Review of the Literature." Health and Safety Laboratory, Human Factors Group, Sheffield.

Committee on Prudent Practices for Handling Storage and Disposal of Chemicals in Laboratories, N. R. C. (1995). Prudent Practices in the Laboratory. Washington, DC, National Academy Press.

Connolly, N. (2004). Laboratory safety and ergonomics: a compartive study between industry and academia. MSc, National University of Ireland.

Cooper, M. D. (2000). "Towards a model of safety culture." Safety Science **36**: 111-136.

Cox, S. J. and A. J. T. Cheyne (2000). "Assessing safety culture in ofshore environments." Safety Science **34**: 111-129.

Davies, F., R. Spencer, et al. (1999). Summary guide to safety climate tools. Offshore Technology Report, Health and Safety Executive.

DeJoy, D. M., B. S. Schaffer, et al. (2004). "Creating safer workplaces: assessing the determinants and role of safety climate." Journal of Safety Research **35** 81– 90.

Diaz, R. I. and D. D. Cabrera (1997). "Safety climate and attitude as evaluation measures of organizational safety." Accident Analysis and Prevention **29(5)**: 643– 650.

Donnellan, P. (2003). Cultural and Organizational Aspects. Gower Handbook of Quality Management. M. Seaver, Gower Publishing**:** 452-462.
Doolittle, K., G. Esparsen, et al. (1995). NMSU Guide to Laboratory Safety, New Mexico State University.
European Agency for Safety and Health at Work (2001). The Use of Occupational Safety and Health Management Systems in the Member States of the European Union. Luxembourg, European Agency for Safety and Health at Work.
Fleming, D. O. (2000). Biological safety: principles and practices. Washington, DC, ASM Press.
Flin, R., K. Mearns, et al. (2000). "Measuring safety climate: identifying the common features." Safety Science **34**: 177–192.
Foster, B. L. (2003). "Principles of laboratory safety management in academia." Chemical Health & Safety: 13-16.
Furr, A. K., Ed. (1990). Handbook of Laboratory Safety, CRC Press.
Gershon, R. R. M., C. D. Karkashian, et al. (1999). "Compliance with universal precautions in correctional health care facilities." Journal of Occupational and Environmental Medicine **41(3)**: 181– 189.
Gillen, M., D. Baltz, et al. (2002). "Perceived safety climate, job demands, and coworker support among union and nonunion injured construction workers." Journal of Safety Research **33**: 33–51.
Guldenmund, F. W. (2000). "The nature of safety culture: A review of theory and research." Safety Science **34**: 215–257.
Guldenmund, F. W. (2007). "The use of questionnaires in safety culture research – an evaluation." Safety Science **45** 723–743.
Hahn, S. E. and L. R. Murphy (2008). "A short scale for measuring safety climate." Safety Science **46** 1047–1066.
HSE (1997). HSG 65. Successful health and safety management., HSE Books.
HSE. (1999). "Safety Climate Measurement User Guide and Toolkit." Retrieved 22/05/2008, from http://www.lboro.ac.uk/departments/bs/safety/document.pdf.
HSE (2005). A review of safety culture and safety climate literature for the development of the safety culture inspection toolkit., HSE.
ILO (2001). ILO Guidelines on Occupational Safety and Health Management Systems, ILO.
Kapin, J. M. (1999). "Beyond chemical safety - an integrated approach to laboratory safety management." Chemical Health & Safety(July/August): 20-22.
Kim, Y., R. Furr, et al. (2005). "Health and safety challenges in start-up of a multi-discipline/open lab research facility." Chemical Health & Safety: 24-29.
Kuusisto, A. (2000). Safety management systems. Audit tools and reliability of auditing. PhD, Tampere University of Technology.
Makin, A. M. and C. Winder (2008). "A new conceptual framework to improve the application of occupational health and safety management systems." Safety Science **46**: 935–948.
Matilla, M., E. Rantanen, et al. (1994). "The quality of work environment, supervision and safety in building construction." Safety Science **17**: 257– 268.
Mearns, K. and R. Flin (1995). "Risk perception and attitudes to safety by personnel in the offshore oil and gas industry: a review." Journal of Loss Prevention in the Process Industries **5**: 299–305.
OHSAS (1999). Occupational health and safety management systems. OCCUPATIONAL HEALTH AND SAFETY ASSESSMENT SERIES, BSI.
PN (2001). Systemy zarządzania bezpieczeństwem i higieną pracy. Wytyczne., PN.
Rechenthin, D. (2004). "Project safety as a sustainable competitive advantage." Journal of Safety Research **35**: 297–308.
Santos-Reyes, J. and A. N. Beard (2002). "Assessing safety management systems." Journal of Loss Prevention in the Process Industries(15): 77–95.
Smallman, C. J. and G. John (2001). "British directors perspectives on the impact of health and safety on corporate performance." Safety Science **38**: 227–239.
The Office of Environmental Health and Radiation Safety, E. (2008). "Chemical Hygiene Plan." Retrieved 30.05.2008, from http://www.ehrs.upenn.edu/programs/labsafety/chp/toc.html.
Tsung-Chih Wua, C.-W. L., Mu-Chen Lua (2007). "Safety climate in university and college laboratories: Impact of organizational and individual factors." Journal of Safety Research **38**: 91-102.
Turner, B. A. and N. F. Pidgeon (1997). Man-Made Disasters., Butterworth-Heinemann, Oxford.
Zohar, D. (1980). "Safety climate in industrial organizations: Theoretical and applied implications." Journal of Applied Psychology **65**: 96-101.

Psychological safety climate and professional drivers' wellbeing. The mediating role of time pressure

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Abstract

Professional drivers are at risk of poor health, thus, research on potential antecedents of health such as safety climate and time pressure has valuable practical implications. Professional drivers are remote/lone workers that lack face-to-face supervisory oversight and access to immediate support from others. In this context safety climate would act as a frame of reference. To date, research on the relationship between safety climate and employees' wellbeing is scarce and has been mainly conducted in traditional settings rather than remote-working situations. Time pressure also arises as a critical antecedent of drivers' wellbeing due to work intensification and "just-in-time" management. However, previous research has mainly focused on more general conceptualizations of stressors such as job demands or workload rather than time pressure. Finally, several theoretical frameworks suggest that organizational climate influences job design. Safety climate is a facet specific climate and time pressure a relevant job demand. Thus, safety climate may be accompanied of lower time pressure that, in turn, will mediate the relationship between safety climate and drivers' wellbeing. To date, research on this issue is scarce. Previous research has mostly focused on the relationship between safety climate and safety, and the intervening variables in this relationship.

This study examines the relationship between perceived safety climate and drivers' wellbeing (burnout and general health), and the mediating role of time pressure in this relationship. Sample was composed of 367 professional drivers and structural equation modeling was used to test two competing models: full and partial mediation. Findings showed that safety climate was beneficial for drivers' wellbeing whereas time pressure was detrimental. The association between perceived safety climate and drivers' general health and burnout was partially mediated by time pressure.

Findings extend previous research providing insights into the mechanisms underlying safety climate-employees wellbeing linkage, and supporting theoretical arguments on the influence of organizational climate on job design. In addition, it encourages future studies to address the single effect of specific job demands that are crucial for specific work environments.

Keywords: Safety climate, time pressure, general health, burnout, professional drivers

1. INTRODUCTION

Professional drivers are at risk of poor health. They are more likely to suffer work intensification, strain, and higher exposure to psychosocial risks (European Foundation for the Improvement of Living and Working Conditions –Eurofound-, 2014). A 32% of respondents from the transport sector reported feeling a negative effect of work on health; this proportion was higher than in the rest of sectors (Eurofound, 2014). Thus, research on how to prevent professional drivers' poor health has relevant practical implications for policymakers across Europe.

This study examines the relationship between safety climate and drivers' wellbeing (burnout and general health), and the mediating role of time pressure in this relationship. Previous research has mostly focused on the relationship between safety climate and safety-related outcomes, and the intervening variables in these relationships (e.g., Beus, Payne, Bergman, & Arthur, 2010; Christian, Bradley, Wallace, & Burke, 2009; Huang, Zohar, Robertson, Garabet, Lee, & Murphy, 2013a; Huang, Robertson, Lee, Rineer, Murphy, Garabet, & Dainoff, 2014; Mooren, Grzebieta, Williamson, Olivier & Friswell, 2014; Öz, Özkan, & Lajunen, 2013; Zohar, Huang, Lee, & Robertson, 2014). Although it is true that some studies address the safety climate-employees' wellbeing association (e. g., Clarke, 2010; Fogarty & Buikstra, 2008; Golubovich, Chang, & Eatough, 2014; Nahrgang, Morgeson, & Hofmann, 2011; Siu, Phillips, & Leung, 2004), in many cases, this relationship is not the main focus of the study (e. g., Clarke, 2010; Fogarty & Buikstra, 2008; Siu et al., 2004).

In addition, previous research on safety climate has been mainly conducted in traditional organizational settings rather than remote-working situations (Huang et al., 2014). Instead, this study has been conducted using professional drivers who are regarded as lone/remote workers;

they work alone and without in-person direct supervision and access to immediate support from others (Huang, et al., 2013a).

1.1. Psychological Safety Climate, Time Pressure, and Professional Drivers' Wellbeing

This study addresses the influence of psychological safety climate and time pressure on drivers' wellbeing (burnout and general health). Regarding psychological safety climate, it refers to individual perceptions (James & James, 1989) of policies, practices, and procedures focused on safety (Christian et al., 2009; Zohar, 2010); and their interrelationship with those related to other competing goals (e. g., safety vs. productivity or efficiency) that establish the relative priority of safety (Zohar, 2003). This study focuses on safety climate at the individual level of analyses in accordance with other studies based on lone workers (e.g., professional drivers, utility/electrical workers…) (Huang, Zohar, Robertson, Garabert, Murphy, & Lee, 2013b).

Psychological safety climate is expected to promote employees' wellbeing by means of showing concern for employees' health and safety, and providing advice and support. Safety climate has been associated with decreased burnout (Clarke, 2010; Nahrgang et al., 2011), psychological strain (Fogarty, 2005; Siu et al., 2004), frustration (Golubovich et al., 2014) and poor general health (Clarke, 2010; Fogarty & Buikstra, 2008; López-Araújo & Segovia, 2010). Based on these arguments, hypothesis 1 was formulated as follows:

Hypothesis 1: Psychological safety climate will be negatively related to burnout and poor general health

Time pressure refers to the lack of time to complete job related tasks (Kinicki & Vecchio, 1994), and it is a well-established job demand (e. g., Karasek, 1985; Kristensen, Bjorner, Christensen, & Borg, 2004). Job demands are defined as *"those physical, psychological, social, or organizational aspects of the job that require sustained physical and/or psychological (cognitive and emotional) effort or skills and are therefore associated with certain physiological and/or psychological costs"* (Bakker & Demerouti, 2007; pp. 302). Role ambiguity, role conflict, and workload are most important job demands (Bakker, Demerouti, & Sanz-Vergel, 2014; Alarcon, 2011). Time pressure is an indicator of quantitative workload (e.g., Sonnentag & Bayer, 2005; Spector & Jex, 1998) which has been regarded as crucial amongst professional drivers (Dorn, Stephen, Wåhlberg, & Gandolfi, 2010; Paillé, 2011).

Job demands-resources (JDR)' model (Bakker & Demerouti, 2007) establishes that prolonged exposure to high demands (such as time pressure) is detrimental for employees' health and increases burnout (Bakker et al., 2014; Alarcon, 2011). In contrast, job resources will counteract job demands, and stimulate personal growth, learning, and development. This study focuses on the job demands hypothesis. It is noteworthy that job demands are more strongly related to burnout than job resources do (e.g., Bakker et al., 2014).

To date, research on time pressure correlates is scarce and inconclusive (van den Tooren and de Jong, 2014). Its role has been mainly examined through composite measures of job demands (e.g., Consiglio, Borgogni, Alessandri, & Schaufeli, 2013; Demerouti, Bakker, Nachreiner, & Schaufeli, 2001) and workload (Bakker, Demerouti, & Euwema, 2005). Contrary to expectations, van den Tooren and de Jong (2014) found the relationship between time pressure and general health was non-significant. They argued that time pressure may act as an stimulating rather than as a energy-depleting demand. Nonetheless, empirical evidence supports the negative effect of job demands on employees' burnout (Alarcon, 2011; Consiglio et al., 2013) and its positive association with strain (Presseau, Johnston, Johnston, Elovainio, Hrisos, Steen et al., 2014). Seemingly, workload has been also positively associated with burnout (Alarcon, 2011; Bakker et al., 2005). Following Job demands-resources (JDR)' model (Bakker & Demerouti, 2007) and empirical evidence on job demands and workload hypothesis 2 was formulated as follows:

Hypothesis 2: Time pressure will be positively related to burnout and poor general health

1.2. Psychological Safety Climate and Professional Drivers' Wellbeing. The Mediating Role of Time Pressure

Previous research has mostly focused on the effect of psychological safety climate on safety (e.g., Beus et al., 2010) rather than its influence on employees' wellbeing and the intervening variables in this relationship. This study contributes to this research gap by means of testing the mediating role of time pressure in the relationship between psychological safety climate and employees' wellbeing.

Safety climate is expected to be negatively associated with time pressure for several reasons. First, it is defined as a specific facet of organizational climate which has been regarded as an antecedent of job demands (e.g., time pressure) (Hemingway & Smith, 1999; Morgeson, Dierdorff, & Hmurovic, 2010; Wilson, Dejoy, Vandenberg, Richardson, & Mcgrath, 2004). Morgeson et al. (2010) argues that *"… in an organization with a strong safety climate, incumbents may be more attuned to the physical features of the job (e.g., physical demands, equipment use)"* (p. 355). Thus, policies and practices will guide managers to value safety against other organizational goals such as production or time pressure, thus, they will attempt to make time pressure manageable.

Second, according to social information processing approach (Slancik, & Pfeffer, 1978) safety climate would make any information related to safety more salient and would set expectations of low time pressure at work: time pressure would be minimized because pressure toward cost-effectiveness may lead to safety degradation (Rasmussen, 1997; 2000).

As regards to the empirical evidence, whereas the influence of safety climate on job demands remains unexplored, the impact of other facet-specific aspects of organizational climate have been examined (e.g., Idris, Dollard, Coward, & Dormann, 2012). For instance, several authors (Dollard, Opie, Lenthall, Wakerman, Knight, Dunn, et al., 2012) provided longitudinal evidence on the cross level positive effect of climate for psychological wellbeing on workload (Dollard et al., 2012), work pressure (Dollard & Bakker, 2010), and emotional demands (Dollard & Bakker, 2010; Idris et al., 2014). In contrast, other studies found inconclusive results (Idris et al., 2012). This study showed partial support for the influence of team climate for psychological wellbeing on workload, psychological (e. g., work pace) and emotional demands. However, none of the other climate measures included in the study (team psychological climate and climate for physical safety) were associated with job demands. Seemingly, to date, the mediating role of time pressure in the relationship between psychological safety climate and employees' wellbeing remains unexplored. Thus, hypothesis 3 reads as follows:

Hypothesis 3: Time pressure will mediate the relationship between psychological safety climate and drivers' general health and burnout.

2. MATERIALS AND METHOD

2.1. Sample and Procedure

The sample consisted of 34 Spanish road transport organizations of a total of 107 companies contacted to participate in this study (response rate of 31.8%). Most organizations were small organizations (less than 25 employees) (41.4%) or medium organizations (less than 250 employees) (44.8%). Only 13.8% were large ones (more than 250 employees). Fifty-nine per cent of the organizations were dedicated to the transportation of goods and 41% to passenger transportation. Survey was administrated at 367 employees (drivers). In most of cases, the questionnaires were collected by means of group sessions during working time. In every group session, researchers explained the purpose of the research project and assured confidentiality. Nonetheless, in some organizations, surveys were sent by post together with stamped addressed envelopes. The survey was accompanied by an instruction letter detailing the purpose of the research project and the main researcher contact information. Eighty-seven per cent were male. Sixty per cent were between 35 and 55 years of age, 30% were less than 35 years old, and 10% were 55 years old or over. Regarding academic level, 16.3% did not hold any academic title, 51.7% had completed primary education, 30.5% secondary education, and 1.5% were university graduates. Most drivers had previous experience in the road sector (56.5%).

2.2. Measures

Time pressure. Drivers' shared perceptions on time pressure were measured using three items adapted from Semmer, Zapf, and Dunckel (1995; 1999). Drivers answered using a 5-point scale ("1. *Never*", "5. *Always*"). An example item was "Regarding your recent work, how often do you feel pressured due to the lack of time?". Cronbach's alpha was .87.

Psychological safety climate. Drivers' perceptions of safety climate in the organization were measured using a 3 items adapted from existing questionnaires (Cox, & Cheyne, 2000; Mearns, Whitaker, & Flin, 2003). Items were accompanied by a 5-point rating scale, ranging from 1 (*strongly disagree*) to 6 (*strongly agree*). Sample items include "In this company safety is first priority". Cronbach's alpha was .82.

Burnout. Burnout was measured using three items from the Spanish translation of the Maslach Burnout Inventory (MBI; Maslach & Jackson 1986). Each item corresponded to one burnout dimension: emotional exhaustion, depersonalization and personal accomplishment. Emotional exhaustion was measured with the item: *'I feel tired when I get up in the morning and have to face another day at work.".* Cynicism was measured with the item: *"I don't feel interest for my job".* Professional efficacy was measured with the item: "*I feel I work well at my job*". Responses to the last item was reverse-scored, so that high score indicated burnout. Respondents answered using a 5-point scale (1= never, 5= always). Cronbach's alpha was .70.
General health. One single item measure obtained from the Work Conditions Survey (CIS, 1997) was used to assess self-reported health (*"In general, I think my health is...*"). Self-reported health was assessed using a 5 point scale ranging from 1 (*Very bad*) to 5 (*Very good*).

2.3. Data Analysis

We performed structural equation modelling (SEM) techniques. First, we tested the measurement model, including psychological safety climate, individual perceptions of time pressure, and individual burnout items. Next, we tested several competing structural models in order to confirm the hypothesized model (see Figure 1). First, we tested a *partial mediation model* that posited that safety climate had both direct and indirect influences on both individual burnout and health. Then, we compared the fit of the partial mediation model with the fit of an alternative model, the full *mediation model,* that posited that safety climate did not have a direct influence on both individual burnout and health. The input for the analysis was covariance matrix, and the method of estimation used (maximum likelihood method) assumed multivariate normality. In all the causal models, drivers' age and organizational tenure were used as control variables (De Jonge, Janssen & Breukelen, 1996). Considering that the item distributions departed from normality, we computed the chi-square fit statistic corrected for non-normality. We also computed an absolute measure of fit, the Root Mean Square Error of Approximation (*RSMEA*), and a relative measure, the Comparative Fit Index (*CFI*).

3. RESULTS AND DISCUSSION

Means, standard deviations and bivariate zero order correlations are presented in Table 1.

Table 1. Descriptive Statistics and Correlations.

Variables	*M*	*SD*	*1*	*2*	*3*	*4*	*5*	*6*
Age	3.05	1.01	-					
Organizational tenure	4.55	1.58	.46**	-				
Safety climate	3.67	.91	-.02	-.12**	-			
Time pressure	2.72	1.05	-.09	.02	-.33**	-		
Perceived health	4.04	.67	-.15**	-.14**	.35**	-.25**	-	
Burnout	2.24	.91	.00	.15**	-.33**	.56**	-.42**	-

* p<.05; ** p<.01

To test our hypotheses, a partial mediation model was tested. The partial mediation model showed a good fit to the data (χ^2 = 79.454, *df* = 46, SRMR= .048; RMSEA = .049; CFI = .976). The fit of the partial model was compared to the fit of a full mediation model (see Table 2). The fit of the full model yielded worse fit indices than the partial mediation model (χ^2 = 90.454, *df* = 48, SRMR= .053; RMSEA = .054; CFI = .969), and its SRMR and RMSEA values were marginally above the reference values that indicate an acceptable fit. The chi-square difference test confirmed that the partial mediation model provided a better fit to the data than the full mediation model ($\Delta\chi^2$ = 11.000, Δdf = 2, p< .01).
Estimated parameters are displayed in Figure 1. As expected (Hypothesis 1) safety climate showed a positive relationship with general health (γ = 0.20, p < 0.01) and a negative relationship with drivers' burnout (γ = -0.15, p < 0.05). Both associations were statistically significant. These findings are congruent with previous theoretical arguments and empirical studies (Clarke, 2010; Fogarty & Buikstra, 2008; López-Araújo & Segovia, 2010; Nahrgang et al., 2011) that support the benefits of safety climate on employees' wellbeing.
As stated in hypothesis 2, time pressure was significant and negatively associated with general health (γ = -.31, p < 0.01), and significant and positively associated with burnout (γ = 0.70, p < 0.01). These findings provide insights into previous research on the single effect of time pressure on employees' wellbeing which is scarce and inconclusive (van den Tooren & de Jong, 2014). Results are congruent with Job demands-resources (JDR) model (Bakker & Demerouti,

2007), and previous empirical studies that have shown job demands (Alarcon, 2011; Consiglio et al., 2013; Presseau et al., 2014) and workload (Alarcon, 2011; Bakker et al., 2005) to be detrimental for employees' wellbeing.

Finally, the relationship between safety climate and drivers' health indicators was partially mediated by time pressure (Hypothesis 3). The estimation of the standardized indirect effect was .17 ($p < 0.01$) for general health, and -.39 ($p < 0.01$) for burnout. Safety climate showed a negative relationship with time pressure ($\gamma = -0.56$, $p < 0.01$). These results extend previous research in several ways. First, to our knowledge the mediating role of time pressure in the relationship between psychological safety climate and employees' wellbeing has not been previously explored. Second, results provide empirical evidence that supports Morgeson et al. (2010)'s postulates on the influence of organizational climate on job design. Results are also aligned with social information processing theory (Slancik & Pfeffer, 1978) that suggest that safety climate would make safety information more salient, and would set expectations of low time pressure at work because time pressure could be counterproductive for safety.

Table 2 - Goodness of fit indicators of the two competing models.

	χ^2	*df*	SRMR	RMSEA	90% CI for RMSEA	CFI
1. Partial mediation	79.454	46	.048	.049	.03 - .067	.976
2. Full mediation	90.454	48	.053	.054	.037 - .071	.969

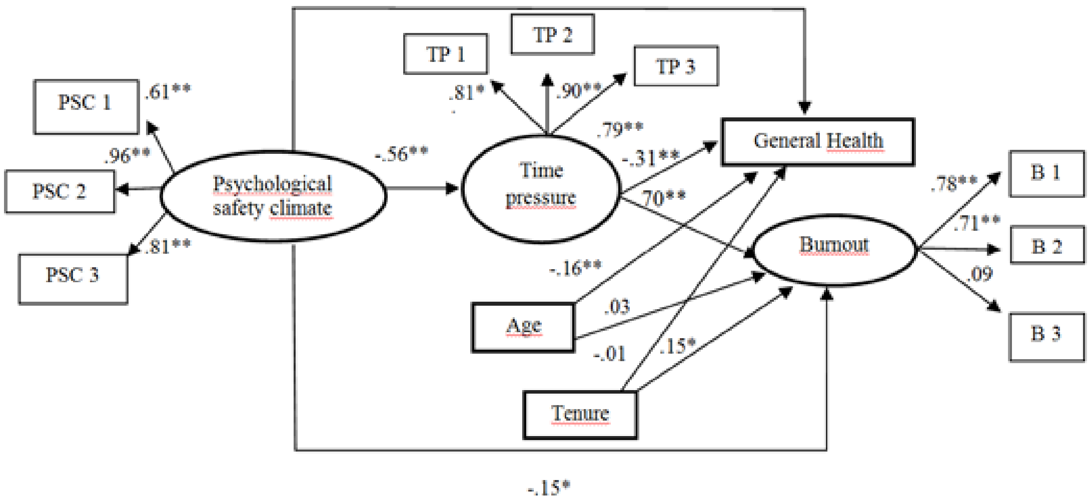

*Figure 1. Structural equation modeling results: Partial mediation model. * p<.05; ** p<.01.*

4. CONCLUSIONS

Findings support the postulated hypotheses; psychological safety climate (hypothesis 1) was negatively associated with poor drivers' general health and burnout, whereas time pressure (hypothesis 2) was positively associated. The psychological safety climate-employees' wellbeing relationship was mediated by time pressure.

These findings are congruent with previous research and have relevant theoretical implications. First, results evidenced time pressure is a relevant job demand amongst professional drivers; and encourage future studies to address the single effect of specific job demands that are prominent in the work environment under study. Second, this study support Morgeson et al. (2010) theoretical developments on the influence of organizational climate on job design. Findings encourage future studies to test these postulates in different types of facet-specific climates. Finally, the mediating role of time pressure in the relationship between psychological safety climate and employees' wellbeing sheds light into the mechanisms underlying this relationship. Previous research has mainly focused on the intervening variables in the relationship between safety climate and safety outcomes.

In addition, this study has relevant practical implications for policy makers within the transport industry. Notice that professional drivers are at higher risk of poor health, thus, research on its antecedents is crucial. This study suggests that organizational policies fostering safety climate may decrease time pressure and, subsequently, contribute to employees' wellbeing. Policies on safety climate are especially relevant in the transport sector. Compared to traditional work environments, professional drivers lack face-to-face supervisory oversight. In remote-working

situations psychological safety climate will become their frame of reference (Huang et al, 2013b).
Finally, this study has several limitations. This is a cross-sectional study based on self-reported data. In order to reduce common method bias, respondents' anonymity was assured and different scale formats were used (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003). In addition, burnout was measured using three items without distinguishing between its dimensions.

Table 2. Goodness of fit indicators of the two competing models.

	χ^2	*df*	SRMR	RMSEA	90% CI for RMSEA	CFI
1. Partial mediation	79.454	46	.048	.049	.03 - .067	.976
2. Full mediation	90.454	48	.053	.054	.037 - .071	.969

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6. REFERENCES

Alarcon, G. M. (2011). A meta-analysis of burnout with job demands, resources, and attitudes. *Journal of Vocational Behavior, 79* (2), 549–562. doi:10.1016/j.jvb.2011.03.007

Bakker, A. B., Demerouti, E., & Euwema, M. C. (2005). Job resources buffer the impact of job demands on burnout. *Journal of Occupational Health Psychology,* 10 (2), 170–180.

Bakker, A. B., Demerouti, E., & Sanz-Vergel, A. I. (2014). Burnout and Work Engagement: The JD–R Approach. *Annual Review of Organizational Psychology and Organizational Behavior,* 1 (1), 389–411.

Bakker, A. B.; Demerouti, E. (2007). The job demands-resources model: state of the art. *Journal of Managerial Psychology,* 22 (3), 309 – 328.

Beus, J. M., Payne, S. C., Bergman, M. E., & Arthur, W. (2010). Safety climate and injuries: an examination of theoretical and empirical relationships. *The Journal of Applied Psychology, 95* (4), 713–727.

Christian, M. S., Bradley, J. C., Wallace, J. C., & Burke, M. J. (2009). Workplace safety: a meta-analysis of the roles of person and situation factors. *The Journal of Applied Psychology*, 94 (5), 1103–1127.

CIS (Centro de Investigaciones Sociológicas) (1997). *Actitudes hacia el trabajo - Work Orientations (*Work Conditions Survey). www.cis.es/cis/opencms/ES/1_encuestas.

Clarke, S. (2010). An integrative model of safety climate: Linking psychological climate and work attitudes to individual safety outcomes using meta-analysis. *Journal of Occupational & Organizational Psychology*, 83, 553–578.

Consiglio, C., Borgogni, L., Alessandri, G., & Schaufeli, W. B. (2013). Does self-efficacy matter for burnout and sickness absenteeism? The mediating role of demands and resources at the individual and team levels*. Work & Stress*, 27 (1), 22–42.

Cox, S. J., & Cheyne, a J. T. (2000). Assessing safety culture in offshore environments. *Safety Science*, 34, 111–129.

Demerouti, E., Bakker, A. B., Nachreiner, F., & Schaufeli, W. B. (2001)., & Demerouti, E., Bakker, A. B., Nachreiner, F., Schaufeli, W. B. (2001). The job demands-resources model of burnout. *Journal of Applied Psychology*, 86 (3), 499–512.

Dollard, M. F., & Bakker, a B. (2010). Psychosocial safety climate as a precursor to conducive work environments, psychological health problems, and employee engagement. *Journal of Occupational and Organizational Psychology*, 83 (3), 579–599.

Dollard, M. F., Opie, T., Lenthall, S., Wakerman, J., Knight, S., Dunn, S., … MacLeod, M. (2012). Psychosocial safety climate as an antecedent of work characteristics and psychological strain: A multilevel model. *Work & Stress*, (March 2015), 1–20.

Dorn, L., Stephen, L., af Wåhlberg, A., & Gandolfi, J. (2010). Development and validation of a self-report measure of bus driver behaviour. *Ergonomics*, 53 (12), 1420-1433.

Eurofound (2014). *Working conditions and job quality: Comparing sectors in Europe.* European Foundation for the Improvement of Living and Working Conditions: Dublin.

Fogarty, G. J. (2005). Psychological strain mediates the impact of safety climate on maintenance errors. *International Journal of Applied Aviation Studies*, 5 (1), 53–63.

Golubovich, J., Chang, C. H., & Eatough, E. M. (2014). Safety climate, hardiness, and musculoskeletal complaints: A mediated moderation model. *Applied Ergonomics*, 45 (3), 757–766.

Hemingway, M. a., & Smith, C. S. (1999). Organizational climate and occupational stressors as predictors of withdrawal behaviours and injuries in nurses. *Journal of Occupational and Organizational Psychology*, 72 (3), 285–299.

Huang, Y. H., Zohar, D., Robertson, M. M., Garabet, A., Lee, J., & Murphy, L. a. (2013a). Development and validation of safety climate scales for lone workers using truck drivers as exemplar. *Transportation Research Part F: Traffic Psychology and Behaviour*, 17, 5–19. doi:10.1016/j.trf.2012.08.011

Huang, Y. H., Zohar, D., Robertson, M. M., Garabet, A., Murphy, L. a., & Lee, J. (2013b). Development and validation of safety climate scales for mobile remote workers using utility/electrical workers as exemplar. *Accident Analysis and Prevention*, 59, 76–86. doi:10.1016/j.aap.2013.04.030

Huang, Y., Robertson, M. M., Lee, J., Rineer, J., Murphy, L. a., Garabet, A., & Dainoff, M. J. (2014). Supervisory interpretation of safety climate versus employee safety climate perception: Association with safety behavior and outcomes for lone workers. *Transportation Research Part F: Traffic Psychology and Behaviour*, 26, 348–360.

Idris, M. A., Dollard, M. F., Coward, J., & Dormann, C. (2012). Psychosocial safety climate: Conceptual distinctiveness and effect on job demands and worker psychological health. *Safety Science*, 50 (1), 19–28.
James, L. A., & James, L. R. (1989). Integrating work environment perceptions: Explorations into the measurement of meaning. *Journal of Applied Psychology*, 74, 739–751.
Jonge, J. D., Janseen, P. P., & Van Breukelen, G. J. (1996). Testing the demand-control-support model among health-care professionals: A structural equation model. *Work & Stress*, 10 (3), 209-224.
Karasek, R. A. (1985). *Job content questionnaire and user's guide*. Lowell, MA: Department of Work Environment, University of Massachusetts.
Kinicki, A., & Vecchio, R. (1994). Influences on the quality of supervisor-subordinate relations: The role of time pressure, organizational commitment, and locus of control. *Journal of Organizational Behavior*, 15, 75–82.
Kristensen, T. S., Bjorner, J. B., Christensen, K. B., & Borg, V. (2004). The distinction between work pace and working hours in the measurement of quantitative demands at work. *Work and Stress*, 18, 305–322.
López-Araújo, B., & Segovia, A. O. (2010). Influencia de algunas variables organizacionales sobre la salud y la accidentabilidad laboral. *Anales de Psicologia*, 26 (1), 89–94.
Maslach, C. y Jackson, S. E. (1986). *Maslach Burnout Inventory* (2ª ed, 1981 1ª ed.). Palo Alto, California: Consulting Psychologists Press.
Mearns, K., Whitaker, S. M., & Flin, R. (2003). Safety climate, safety management practice and safety performance in offshore environments. *Safety Science*, 41 (8), 641–680.
Mooren, L., Grzebieta, R., Williamson, A., Olivier, J., & Friswell, R. (2014). Safety management for heavy vehicle transport: A review of the literature. Safety Science, 62 (August 2015), 79–89.
Morgeson, F. P.; Dierdorff, E. C., Hmurovic, J. L. (2010). Work design in situ: Understanding the role of occupational and organizational context. *Journal of Organizational Behavior, 31*, 351–860.
Nahrgang, J. D., Morgeson, F. P., & Hofmann, D. a. (2011). Safety at work: a meta-analytic investigation of the link between job demands, job resources, burnout, engagement, and safety outcomes. *The Journal of Applied Psychology*, 96 (1), 71–94.
Öz, B., Özkan, T., & Lajunen, T. (2013). An investigation of professional drivers: Organizational safety climate, driver behaviours and performance. *Transportation Research Part F: Traffic Psychology and Behaviour*, 16, 81–91.
Paillé , P. (2011). Perceived stressful work, citizenship behavior and intention to leave the organization in a high turnover environment: Examining the mediating role of job satisfaction. *Journal of Management Research*, 3, 1–16.
Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: a critical review of the literature and recommended remedies. *Journal of applied psychology*, *88* (5), 879.
Presseau, J., Johnston, M., Johnston, D. W., Elovainio, M., Hrisos, S., Steen, N., et al., (2014). Environmental and individual correlates of distress: Testing Karasek's Demand-Control model in 99 primary care clinical environments. British Journal of Health Psychology, 19(2), 292–310.
Rasmussen, J. (2000). Human factors in a dynamic information society: Where are we heading?. *Ergonomics,* 43 (7), 869-879.
Rassmusen, J. (1997). Risk management in a Dynamic Society: A modelling Problem. *Safety Science,* 27, 2, 183-213.
Salancik, G. R., & Pfeffer, J. (1978). A social information processing approach to job attitudes and task design. *Administration Science Quarterly*, 23, 224–253.
Semmer, N. K., Zapf, D., & Dunckel, H. (1995). Assessing stress at work: A framework and an instrument. In O. Svane & C. Johansen (Eds.), *Work and health—scientific basis of progress in the working environment* (pp. 105–113). Luxembourg: Office for Official Publications of the European Communities.
Semmer, N. K., Zapf, D., & Dunckel, H. (1999). Stress-oriented job analysis ISTA. In H. Dunckel (Ed.), *Handbook on job analysis*. Zurich, Switzerland: Verlag der Fachbuchvereine.
Siu, O. L., Phillips, D. R., & Leung, T. W. (2004). Safety climate and safety performance among construction workers in Hong Kong: The role of psychological strains as mediators. *Accident Analysis and Prevention*, 36 (3), 359–366.
Sonnentag, S., & Bayer, U.-V. (2005). Switching off mentally: Predictors and consequences of psychological detachment from work during off-job time. *Journal of Occupational Health psychology*, 4, 393–414.
Spector, P. E., & Jex, S. M. (1998). Development of four self-report measures of job stressors and strain: Interpersonal conflict at work scale, organizational constraints scale, quantitative workload inventory, and physical symptoms inventory. *Journal of Occupational Health Psychology*, 3, 356–367.
Tooren, M. Van Den, & Jong, J. De. (2014). Job demands-resources and employee health and well-being: The moderating role of contract type. Career Development International, 19 (1), 101–122.
Wilson, M. G., Dejoy, D. M., Vandenberg, R. J., Richardson, H. A. & Mcgrath, A. L. (2004). Work characteristics and employee health and well-being: Test of a model of healthy work organization. *Journal of Occupational and Organizational Psychology*, 77 (4), 565–588.
Zohar, D. (2003). Safety climate: Conceptual and measurement issues. In J. C. Quick & L. E. Tetrick (Eds.), *Handbook of occupational health psychology* (pp. 123–142). Washington, DC: American Psychological Association.
Zohar, D. (2010). *Thirty years of safety climate research: Reflections and future directions*. Accident Analysis and Prevention, 42(5), 1517–1522.
Zohar, D. (2014). Safety Climate: Conceptualization, Measurement, and Improvement. In B. Schneider , & K. Barbera (Eds.), The Oxford Handbook of Organizational Climate and Culture (317–334). United States of America: Oxford University Press.
Zohar, D., Huang, Y. H., Lee, J., & Robertson, M. (2014). A mediation model linking dispatcher leadership and work ownership with safety climate as predictors of truck driver safety performance. *Accident Analysis and Prevention*, 62, 17–25.

The importance of communication for the maintenance of health and safety in work operations in ports

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Abstract

Introduction: The work of transport and handling of goods at the port is collectively executed and so it requires good coordination among workers to deal with the usual and unexpected situations of daily work (Dejours, 1993). Communication is fundamental so that they can cope with the variability of work, that is, communication is a component of the activity (Silva, Brito and Athayde, 2004) and are used to plan, monitor, modify, coordinate, negotiate, discuss, evaluate the practical action thus serves to guide the useful knowledge for the actions (Navarro, 1993). The strong ties built in the work in ports have a very peculiar culture. Thus, the body language as well as the oral are important components of maintaining health and safety at work. In many situations, the workers point out the importance of communication for ensuring safety at work, which happens to be in their own hands, supported by bonding activities (Queiroz, Moreira and Dalbello-Araújo, 2012). There are collective construction reports and important partnerships for the implementation of activities, and several indicatives insinuate the necessary familiarity with the universe of the port for the effectiveness of the various activities in the sector (Queiroz, Moreira and Dalbello-Araújo, 2012). Objective: To analyze how communication take place between port workers and their importance for the preservation of health and safety for operators. Methodology: The research is the result of a case study conducted in a port located north of Portugal, where the movement of goods, representing 25% of Portuguese external trade by sea. This port is responsible for transporting various types of loads, such as wood chips, scrap, glass, wind parts, *verguinha*, metal rollers, stone, wheat flour, containers and vehicles. The research included dock workers of a private company, providing services in the container terminal and general cargo terminal. It involved systematic observations of work activity on the pier and boats, completed with semi-structured interviews and individual and collective refunds. Individual and collective refunds served to deepen some aspects identified during observations, fundamental to the knowledge of subjective experiences of these workers. Results and Discussion: During the investigation each port worker was observed not as an isolated individual but inserted into working relations with other port workers, who perform other functions, such as boarding, stevedores, inspectors, crane operators, among others. These interactions among workers take place through various forms of communication: gestures, movements, looks, facial expressions, verbal or printed information, operative codes. In the observations was possible to register some forms of communication that does not necessarily passed through oral communication between team members (whether by the distance between the elements, either by noise of the machines working on the docks and in the cellars). Thus, there was the use of horn, in the examples of situations: 1) the port worker uses horn to inform traffic workers (ground) when there are locked containers preventing the landing. These, in turn, point to the crew (on board) through gestures and shouts, which immediately unlock the said container. 2) in bulk flour landing, crane operator uses a crane to transfer the ship's cargo to a huge funnel, in soil, where it is deposited in trucks. The traffic worker regulates the load to be placed in each truck using a horn to inform the driver of the truck when it has to move forward or when he has to leave if the load is already complete. However, if the horn is broken he hits a piece of iron to make himself understood. The use of gestures with upper limbs and hands (every gesture has a meaning) in the examples: 1) the gangway, when performing its function, for example the transport of *verguinha*, uses radio communication, but also gestures and movements to inform the crane operator to tell where to deposit the load or when interrupting the operation (fist arms or bent arms forming a cross) respecting the planning of the ship's officer and the safety of colleagues in the hold of the vessel, as stevedores. 2) in the transport of containers, the gangway, working on the ground or boarding the ship, according to the need and gestures tells the portico of the workers when they need to pick up or deposit any local load that does not allow its view, so gangway acts as the eyes of the crane operator. In this case, boarding gestures might include: fist up and down means container with merchandise; flat hand up and down is indicative of empty container. The use of oral communication, in the example of the situation: 1) to move enormous wind machine parts in the basement of the vessel the coordinator does not see the stevedore (the other side) and has to rely on verbal information provided by the same, during the placement of braces which will then be hauled back out of the vessel by the crane worker. Conclusions: performing work activity involves the introduction of different ways to communicate and it is essential to rely on the information that is received and that is sent out. The impact of these communications is visible at several levels: the possibility of meeting deadlines; the quality of their work; and also for the safety of all those involved in work situations. There are variations in communication according to the type of load to be carried, but also according to the function of each team member. Communication related to security issues are closely related to working communication, no safety behaviors may be considered distinct from work behaviors.

Keywords: health, safety, port worker, communication;

1. INTRODUCTION

The loading and unloading work in merchant ships dates to the Antiguity for the water transport was the first to be used commercially by humanity (Medeiros, Silveira and Dantas, 2000). In the huge context of port operations and complex logistic system with its variety in operations, in port layout, in meteorologist, labor conditions, the biomechanics factors and the operational ways of workers (D´Elia and Silva, 2014), the port worker performs his duties in a dangerous environment and, many times unhealthy, and the risks increase in relation to the load being around, exposing workers health to permanent danger. (Soares *et al*, 2008).

Even the dock workers emphasize the need for team effort to conduct an activity recognized as of collective work , which presupposes confidence in partners as teammates and security as the technical ability of each one in the activity performed (Machin , Couto and Rossi , 2009) . The main form of social interaction in this collective activity is by cooperation, a consensual adjustment of the organization as directed. For this, those who strive to work together as a team need to reorganize the division of labor and human resources by creating practical rules , accepted and respected by all (Dejours, 2013) .

On the other hand, regulations and controls established to prevent the free interpersonal communication is a hinder perceived as a major limitation to freedom in the workplace (Seligmann -Silva, 1994).

Dalbello-Araujo (2001) in a study with port workers found that the forms of gestural communication and mutual aid were essential to prevent many accidents from occurring while performing the work. Queiroz, Moreira and Dalbello-Araújo (2012) report that both the body language and oral are important components of maintaining health and safety at work .

2. METHODOLOGY

The study is characterized as a case study and ran from January to September 2014. The empirical research was conducted in a public port located north of Portugal, which moves 16 million tons of goods per year, representing 25% of Portuguese Foreign Trade by sea. The main types of cargo transported, which could be observed during the research included: wood chips, scrap glass bran, wind pieces *verguinha*, metal rollers, stone, wheat flour, containers and vehicles.

There was consent to the research by the private company responsible for the management of labor of the designated port workers, which provides services to the container terminal and general load terminal.

Participated effective port workers, contractors and temporary workers, who performed the following duties: engineer, lecturer, stevedore , gantry worker / crane operator, ground worker, gangway. Almost every workday, they are designated to perform different jobs, so they can be considered multifunctional workers. Work teams are variable with respect to the number of workers (between 8-11 members) and there may be several teams working simultaneously, depending on the amount of ship holds and loads to be moved.

There were systematic observations of collective work and the different forms of communication in the pier area and boats. It was complemented with semi-structured interviews (made immediately after the observation period) and four individual and two collective returns (one for the direction of the company and the union and another for workers).

3. RESULTS AND DISCUSSION

The process and the organization of the port operations raise interactions between the subjects in everyday working relationships, where the various forms of communication founded the collective and are important to account for the variability of work in the port. This form of the port worker context of the organization has relations of this subject-worker with the world around and creates ways of thinking, acting, living in a constant process of transformation of oneself and the world of work.

Although teams can have a varying number of members and each of the workers can be expected to perform a different function, these port workers work fixed for one of the companies providing services at the port: general load terminal and container terminal.

This form of work organization can establish itself as a facilitator for the preservation of health and safety because they know the different elements that can make their team as well as the different functions that are performed. Moreover, according to Queiroz, Moreira and Dalbello-Araújo (2012) it is the ability to stay longer together around the same activity that allows the building of trust and solidarity in the port.

Thus, knowing their pairs and familiarity with port operations lead to forms of very subtle and diversified communications, integrated closely in the activity, may be shown as looks, gestures, movements, facial expressions, verbal information or operational codes.

The strong bonds built between port workers in different forms of communications are so important ingredients for the maintenance of health and safety.

One of the non-oral communication strategies refers to the horn of port machinery, as will be illustrated in the following examples: 1) the horn is used by the port worker to inform traffic workers (ground) when there are containers locked preventing the landing. The reaction of the worker on the ground is immediate: signals with gestures and shouts to the crew who are on board the need to unlock the said container. Only, thus, will it be possible to continue the unloading of load, in compliance with deadlines. But the horn could also be used by these professionals for the sake of security, because when moving the gantry, the noise signal acts as a warning to port workers in soil, seeking thereby to avoid accidents. 2) The horn is also used by traffic worker in bulk flour unloading, resource that belongs to the control booth of that operator. The product of the ship is carried by the crane operator depositing it into a huge funnel on the ground. Subsequently, the flour is transferred to trucks, which will lead to the storage area. The traffic worker regulates the load to be placed on each truck using the horn to tell the truck driver when he has to move forward or when the load is complete and can break. However, when the horn does not work, the traffic worker beats with a piece of iron in the cabin window to signal to drivers. Thus, this communication tool is to ensure continuity of production.

Another form of communication of the port work refers to performing gestures with their arms and hands: 1) In the transport of *verguinha* (thin metal structure used for construction) the gangway figure, performs his duty on deck or in the hold of the ship, being away from the crane operator that must guide. For this orientation usually uses the radio communication, but also adds gestures and movements to tell the crane operator where you can /must deposit the load or when you must stop the operation (fist in the air or crossed arms in the form of a cross). It is noticed that there is on the part of a trader a concern to meet the request by the officer of the ship, but also to maintaining the security of colleagues on board, for example, to signal the location of dockers to prevent the load being placed over his fellows. Communication via radio is well complemented with gestures, to strengthen guidance and to confirm what was stated verbally. 2) In container shipping, the gangway, on the ground or on board the ship, gestures to inform the port workers, when they need to pick up or deposit load in any place you cannot see entirely or in part. The gangway works in such cases as the "eyes" of the crane operator. The gangway of gestures may include: fist up and down which means container with goods; flat hand up and down is indicative of empty container. But gestures can also be used to indicate other important information for crane operator like; whether it should go further to the left / right, up / down, you have someone around if the pins were removed / placed in containers. In this sense, the gangway plays an important role not only for the quality of services provided on schedule, but also to preserve the health and safety of other staff members who operate and move in the same workspace.

In addition to the use of tools like the horn and use of gestures for communication at a distance, oral language remains a need to achieve the team goals: 1) to move huge wind parts, imported from Germany, the coordinator works with the stevedore in the hold of the vessel. However, to put the straps on parts, to be hoisted, working at heights and the engineer cannot see the stevedore, who is in the opposite side of the part and has to rely on verbal information provided by him, to then inform the crane operator when it is time to carry t/he part.

4. CONCLUSIONS

In conducting the port activities there are different forms of communication, known, understood and used by all members of the work team. Such communications may vary according to the type of load to be carried and according to the function that each staff member is performing at that time. It is vital that there are trust bonds between the elements that make up this teamwork, not only for the preservation of health and safety but also in the quality of services, in compliance with deadlines. Communications related security issues are closely related to work communications, with no safety behaviors that can be considered distinct from work behaviors.

5. REFERENCES

Dejours, C. (1993). Travail, usure mentale: de la psychopathologie a la psychodynamique du travail. Paris: Bayard.

Silva, E. F., Brito, J., Athayde, M. (2004). Trabalho de merendeiras: relações entre atividade de trabalho nas escolas e produção de saúde/doença. In: A. Araujo, M. F. Alberto, M.Y. Neves e M. Athayde (Orgs.), Cenários do trabalho: subjetividade, movimento e enigma. Rio de Janeiro: DP&A.

Navarro, C. (1993). L'étude des activités collectives de travail: aspects fondamentaux et méthodologiques. In: Lês aspects colletifs du travail. Coordenateurs: Francis Six; Xénophon Vaxevanoglou. *Actes du XXVII Congrès de la Société d'Érgonomie de Langue Française*. Editions: Octares.

Queiroz, M.F.F., Moreira, M.I.B., Dalbello-Araújo, M. (2012). O processo de modernização portuária e a produção de sujetividade: o caso do porto de Santos. *Cadernos de Psicologia Social do Trabalho*, 15 (2), 205-218.

Medeiros, A.P., Silveira, S.R.B., Dantas, R.C. (2000). Operações de embarque de açúcar em sacarias – riscos operacionais. *Anais do I Congresso Nacional de Segurança e Saúde no Trabalho Portuário e Aquaviário.* Vitoria-ES: FUNDACENTRO.

D`Elia, M.I., Silva, R.M. (2014). Análise ergonômica da atividade do operador de portêiner. *Anais do III Congresso Nacional de Segurança e Saúde no Trabalho Portuário e Aquaviário.* Itajaí- SC: FUNDACENTRO.

Soares, J.F.S.; Vaz, M.R.A.M., Sassi, R.A.M., Almeida, T.L., Baisch, A.L.M., Soares, M.C.F.; Costa, V.Z. (2008). Percepção dos trabalhadores avulsos sobre os riscos ocupacionais no porto do Rio Grande, Rio Grande do Sul, Brasil. *Caderno de Saúde Pública*, 6 (24),1251-1259.

Machin, R., Couto, M.T., Rossi, C.C.S. (2009). Representações de trabalhadores portuários de Santos – SP sobre a relação trabalho-saúde. *Saúde Soc*. São Paulo, 18 (4), 639-651.

Dejours, C. (2013). A sublimação, entre sofrimento e prazer no trabalho. *Revista Portuguesa de Psicanálise*, 33 (2), 9-29.

Seligmann-Silva, E. (1994). Desgaste mental no trabalho dominado. Rio de Janeiro: Editora UFRJ; Cortez Editora.

Dalbello-Araujo, M. (2001). Psicologia social, trabalho e contemporaneidade: o trabalho portuário e suas vicissitudes. In: H. Novo, L. Souza & A. Andrade (Orgs.), Ética, cidadania e participação: debates no campo da psicologia. Vitória: Edufes.

Environmental stressors on sea cargo work: How can safety shout instead of whisper when money talks?

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Abstract
Earlier research has shown that safety resources are scarce on cargo vessels with low public attention, low price rates and flags with limited regulation. This study sheds light on how working conditions are affected by environmental stressors through qualitative data from 15 Norwegian-owned coastal cargo vessels in three sectors. Bulk, general cargo and live fish vessels operate in markets with different degrees of attention, rates and regulation. In this paper their varying working conditions are presented. The analysis elaborate on and modify earlier research: high rates, attention and regulation lead to both more and less safe working conditions, because immaterial conditions (like time and competence making discretionary space) influence more than emphasized in the literature. The crews' descriptions of their working conditions also indicate that a high level of regulation moderates negative environmental stressors; when money talks, regulation can make safety noticeable. However, market and regulation are not easily separated, as companies that do not afford their regulatory demands can register their vessels in states with lower demands. Under these circumstances, this study suggests that improvement of immaterial working conditions can be an affordable safety measure. Also, the international society or nations include more vessels in quality regulation or make sure customers have joint responsibility to ensure safe working conditions on sea cargo vessels.

Keywords: maritime industry; working conditions; environmental stressors; market; regulation.

1. INTRODUCTION

Money talks in maritime transport. When I know which coach I want, I buy it as cheap as possible, so without knowing I probably choose the manufacturer with the lowest transport expenses. The transport market is fierce, and maritime transport most be cheapest to be chosen, even though it is safer than road transport (Haram, Hovi, & Caspersen, 2015). Safety means to control working conditions "to avoid accidental side effects causing harm to people, environment, or investment," which is often complicated by conflicting priorities from the organization and environmental stressors (Rasmussen, 1997, p. 184). Research shows that safety resources are scarce on cargo vessels with low public attention (Lindøe, Engen, & Olsen, 2011), low rates (Soma, 2004) and flags with limited regulation (DeSombre, 2008; Størkersen, Bye, & Røyrvik, 2011). This indicates that public, financial or regulatory pressures are drivers for safe conditions on the vessels, and if so that environmental stressors could be as important as organizational differences.

In this paper I want to explore examples of how working conditions are affected by environmental stressors in Norwegian coastal cargo vessels. The goal is to advise policy makers and managers how safety can be afforded. The mean is to compare descriptions from crew on 15 Norwegian-owned coastal cargo vessels from different Norwegian sectors: bulk, general cargo and live fish vessels. Live fish carriers transport living salmon to and from fish farms, are locally registered and receive a certain amount of attention and income. Other cargo vessels, such as bulk or general cargo, operate with nearly no attention or profit, and, although Norwegian owned, many are registered in low regulation states. When transferring the introduced research to Norwegian-owned coastal cargo vessels, we get the assumptions that (1) environmental stressors such as *high* rates, regulation and attention (at live fish carriers) turns into safety resources and, thereby, safe working conditions, while (2) *low* rates, regulation and attention leads to few safety resources and unsafe conditions (for bulk and general cargo vessels). These assumptions are evaluated in this paper.

To find examples on how environmental stressors influence working conditions, I present descriptions of Norwegian coastal cargo in Section 2; the study in Section 3; the cargo crews' stories in Section 4; and then compare the working conditions, assumptions and environmental stressors in Section 5. This study is the first to delve so deeply into coastal cargo work.

In contrast to the assumed explanations, the comparison shows that high level of attention, rates and regulation have both positive and negative influences on these vessels, as immaterial resources leading to discretionary space are more important than emphasized in the literature. Further, this study indicates that regulation – where it is present – can hinder economical stressors to rule. Crew' descriptions show that when money talks, regulation is especially important.

2. CARGO ON THE NORWEGIAN COAST

Maritime transport is a substantial part of Norwegian trade. In 2013, 1,344 maritime cargo enterprises were registered in Norway with 16,127 employees and a turnover of 18,441 billion USD (Statistics Norway, 2015c). This paper is concerned with coastal cargo between Norwegian ports, which is not easily accounted for since much activity is in private ports, and many vessels and crews are registered in foreign countries. Even though Norwegian registered vessels are highly regulated, the industry is fragmented and mostly market-driven. Every actor hiring sea transport services is called a charterer. The charterer directly contacts the relevant maritime transport companies, which normally are Norwegian controlled and have one to ten vessels of different sizes and flag/registration.

It is common to divide cargo vessels into types such as general cargo and bulk vessels (Statistics Norway, 2015a). The vessel types operate in different markets with contracts of different lengths and criteria. *General cargo* vessels are pallet, container, roro vessels, vehicle carriers, etc. *Bulk* vessels include gas and oil tankers, chemical, food, cement, sand, etc. Some bulk and general cargo vessels operate a steady route over decades, for oil companies, governmental constructors, public cargo handlers or manufacturers. However, *live fish carriers* are atypical bulk vessels, as they often are new, Norwegian-registered and operate between private fish farms with sophisticated technology to keep the fish safe and alive. Live fish carriers are often built by a fish farmer who charters it for years. Vessels of all kinds have spot contracts commissioned for one voyage. For information about the life on the coastal cargo vessels, see Section 5.

In Norwegian governmental ports there were 36,722 port calls in 2014 by Norwegian owned vessels, of which 18,040 port calls were by cargo vessels (Statistics Norway, 2015b); see Figure 1. Of those, 77 % were general cargo vessels. Live fish carriers and bulk vessels mostly go between company owned remote quays or fish farms.

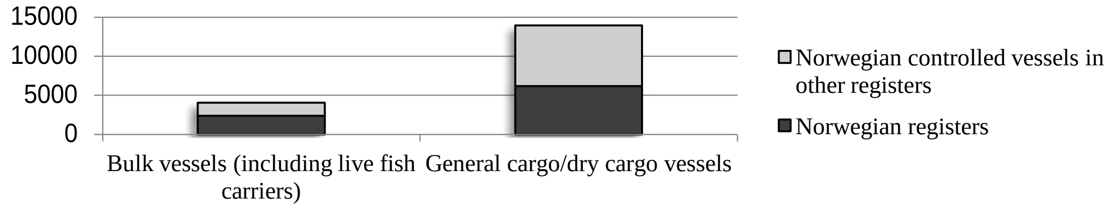

Figure 1: Number of port calls in Norwegian ports by Norwegian registered or controlled cargo vessels (Statistics Norway, 2015b).

Although accidents in maritime transportation are fewer and with less consequences than those in other transport forms (Statistics Norway, 2009), the annual number of ship accidents has increased. Therefore measures for safe working conditions are important for everyone involved. Ship accidents are accidents involving a vessel, such as groundings, collisions or engine breakdowns (not personnel injuries). As Figure 2 shows, in 2000−2014 general cargo vessels were involved in 453 accidents, bulk vessels had 195 accidents and live fish carriers had 80 accidents (Maritime Authority, 2015). Normalization has proven problematic as it is difficult to calculate the vessels' activities and whereabouts (Størkersen et al., 2011). We know that 77.3% of the Norwegian cargo port calls in 2014 were by general cargo vessels, but we also know that many bulk vessels and almost all live fish carriers operate in private areas where "port calls" are not counted. It seems impossible to use the port and accident statistics as an indication of which cargo vessel type is most accident prone, but general cargo vessels had 69.9% of the bulk and general cargo accidents in 2000−2014.

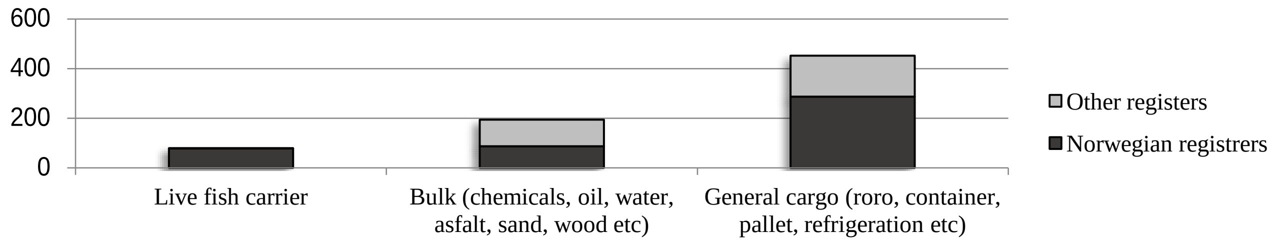

Figure 2: Number of ship accidents on cargo vessels in Norwegian waters 2000−2014 (Maritime Authority, 2015).

All vessels operating in Norway can be inspected by the Norwegian Maritime Authority. Vessels of Norwegian registration (NOR) must comply with Norwegian regulations. Norway ratifies international conventions, so these are included in Norwegian regulations (see Table 1 for examples of rules). Foreign vessels in Norwegian ports might get port state inspections that control whether they comply with international minimum regulation. Regulations similar to those mentioned in Table 1 should apply here since international regulation involves technical, managerial and organizational factors (ILO, 2013; IMO, 2015; Paris MOU, 2015), but in practice the port state inspections primarily cover technical working environment (Størkersen, 2015).

Table 1: Norwegian regulation for work hours, resting periods, manning, professional competence and safety management.

Work hours	Regular work hours on board should be 8 hours/day. (§ 23, Norwegian Ship Safety Act). Exemptions are normal.
Resting period	The resting period of a day can be split in two, where one period has to be at least six hours. (§ 23, Norwegian Ship Safety Act) Monthly resting period forms are handed to the Maritime Authority.
Manning	A ship must be «manned in a safe manner» (§ 15, Norwegian Ship Safety Act). The company and master are to consider the need for additional manning (§12, Regulation of manning of Norwegian vessels)
Professional competence	The «ship master is to make sure the navigation and handling of the ship is done in accordance with good seamanship». (Norwegian law on navigation § 132)
Safety management	Every vessel must have a safety management system that is adapted to its activities. Shipmaster and crew must contribute to the content and function of the safety management system. (§ 7, Norwegian Ship Safety Act, from the International Maritime Organization's International Safety Management Code)

3. LITERATURE: ENVIRONMENTAL STRESSORS, SAFETY AND DISCRETIONARY SPACE

How an actor can perform tasks depends on surrounding actors. We know from Rasmussen (1997) that work is a part of a socio-technical system with organizational levels affected by environmental stressors (see in particular Figure 3). The working conditions for operational staff are influenced by resources provided from the management, company, etc., and directly and indirectly, by environmental stressors. Environmental stressors are, for example, political climate, public awareness, market conditions and financial pressure. Rosness, Blakstad, Forseth, Dahle, and Wiig (2012) introduce the understanding that an actor during work "receives" (faces) conditions that are intentionally or unintentionally "sent" (created) by other levels of the organization, in other organizations, markets, etc. In the current study, the cargo crews are receivers of safety resources, manning, schedules, etc., from the management and regulators, and of environmental stressors such as customer demands, prices, regulations from the market and politicians. These are conditions that indirectly affect how safely work can be done, through influence on discretionary space, cooperation, incentives, power, communication and decision-making on all levels (Rosness, 2009; Rosness et al., 2012). Thus, environmental stressors influence how risks of accidents can be controlled (Rasmussen, 1997; Rosness et al., 2012).

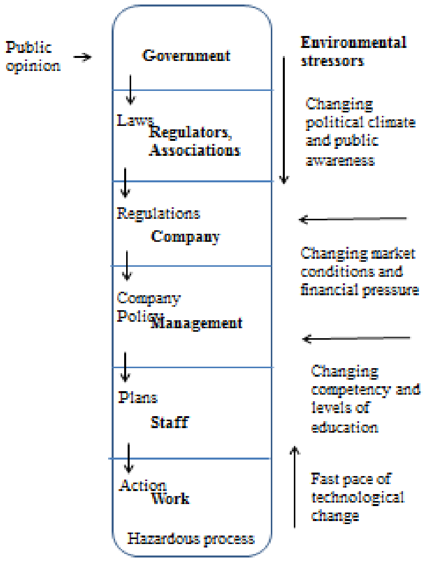

Figure 3: Levels and stressors involved in risk management (Rasmussen, 1997).

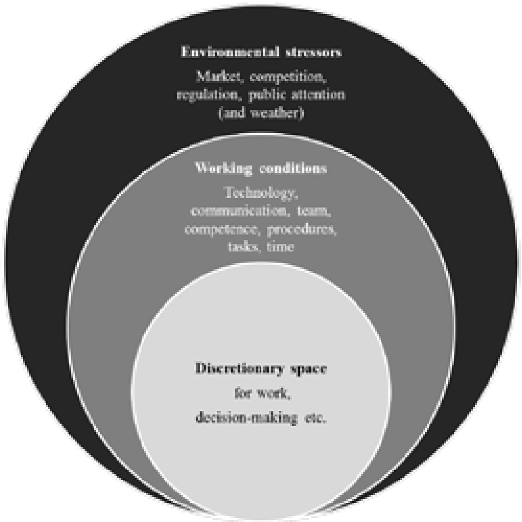

Figure 4: Environmental stressors and working conditions constitute the personnels' discretionary space.

In order to perform tasks, personnel receive resources from their upper levels. Yet, conditions related to the market often lead both managers and crews to prioritize production instead of safety and protection in daily work or business decisions (Hollnagel, 2009; Reason, 1997; Størkersen, 2012; Vaughan, 1997). Safety is sometimes left to market forces, also among maritime policy-makers, who leave safety regulation development paralyzed because of global competition, costumers' and industry's propensity to profit, and the political fear of out-flagging (Størkersen, 2015). In two surveys on Norwegian-owned cargo vessels, crewmembers describe various working conditions, frequent violations of procedures, and hazardous work due to efficiency demands (Fagerholt, Kongsvik, & Størkersen, 2014; Størkersen et al., 2011). Especially when it comes to the opportunity to rest, there are large differences between registration states: 61.5% of the crews on vessels with flags of convenience report to be so tired during work hours that it conflicts with safety, and only 4.1% of the Norwegian crewmembers agree (Størkersen et al., 2011).

To actually be able to work safely, the personnel not only need material resources from the upper levels, but also space or agency to make decisions after their own values and competence. Rasmussen (1997 and earlier works) calls it a space of possibilities where the actors have degrees of freedom to perform the tasks after subjective preferences. Dekker (2012, p. 81) calls it a discretionary space that can be "filled with ambiguity, uncertainty, and moral choices." A certain space is necessary to be able to anticipate and understand what can prevent accidents and how to handle the unforeseen (Hollnagel, Woods, & Leveson, 2006; Reason, 1997). As Rasmussen and Svedung (2000, p. 5) put it: “Due to human flexibility and creative intellectual powers, a human organization presents a particular potential for such an adaptive control, given the right conditions—people are a very important safety resource, not only an error source.” An organization should be clear about the frames or borders for the discretionary space for each level, group or individual since responsibility without the space and authority to make decisions creates unfair double binds (Dekker, 2012). Sufficient resources and discretionary space can lead to safe working conditions. However, a combination of too few degrees of freedom and inadequate resources is common, for instance, a complex set of procedures or strict leadership. Too many rules and minimal freedom can lead to fear of sanctions and limited trust, and certainly not safer, thought-through actions [e.g., Almklov, Rosness, and Størkersen (2014); Bieder and Bourrier (2013); Dekker (2014); Kongsvik, Antonsen, and Størkersen (in review); Vandeskog (2015); Walters and Bailey (2013)]. Safe actions are not created by employees afraid of sanctions if they do not handle their discretionary space correctly, but by empowered employees involved in discussions about their own discretionary space (Dekker, 2012, p. 81). Therefore, the upper echelons must find a way to decide on the right type of resources that can lead to safe operations if paired with the right degrees of freedom (Grote, 2012).

In sum, the literature shows that environmental stressors, internal resources and discretionary space together constitute the working conditions in which actors can make more or less safe decisions (see Figure 4).

4. MATERIAL AND METHOD

This study examines working conditions on 15 vessels that mainly sail in Norwegian coastal waters between Norwegian ports (see Table 2). All the vessels have Norwegian owners. Ten of the vessels are flagged in Norway. The other five vessels are registered in Malta, Faroe Islands, Togo and St. Vincent Grenadines; countries that are listed on the International Transport Workers' Federation's list of Flags of Convenience, which implies that they are minimally regulated with the option to employ cheap global and non-union labor (ISF, 2015).

Table 2: The data material.

Vessels	Vessel age	Vessel size (BT/DWT)	Crew members interviewed	Vessels	*NOR registration*	*Other registr.*
Bulk (tank, self-dischargers)	1967-2007	522/800-3859/4447	17	3	*2*	*1*
General cargo (incl. fodder)	1971-2008	1560/1278-4636/4380	36	6	*2*	*4*
Live fish carriers	1997-2013	458/700-3893/5500	17	6	*6*	
Total			70	15	*10*	*5*

Initially, there was no intention to compare the vessel types or registration, so the selection was not made as a balanced comparison base, only to get perspectives from crews sailing on the Norwegian coast at the time of data collection.

Data was collected as observation and interviews of 70 crewmembers in 2010 and 2013. In the fall of 2010, one researcher was on voyages of one to three days on ten of the vessels, where we participated in operations and the life on board. On board each of the ten vessels we also had two to four interviews with one individual or groups of the crews. The crewmembers of the last five vessels were interviewed at the ship-owners' company offices in 2013. All interviews were semi-structured research interviews with a prepared interview guide about conditions in the transport industry. The quotes in Section 5 are from the interviews.

This study is abductive, comparative and exploratory in combination. Interview transcripts and field diaries were manually analyzed to find patterns of similarities and differences of working conditions and environmental stressors. The findings from 2010 and 2013 are similar, suggesting only small changes in the Norwegian cargo industry the last years. There were many similarities between the groups, so the results are categorized in types of working conditions with subsections about differences in vessel types or regulation (Section 5). The discussion includes a descriptive section (6.1), an assumption evaluation (a light form of hypothesis testing) (6.2), and further exploration of the nested environmental stressors (6.3). In this paper officers and ratings together are called *sailors* or *crewmembers*.

Since this study is limited, the results cannot be generalized. Yet, they give examples of working conditions and environmental stressors on cargo vessels in Norway and illuminate how some of them affect work safety.

5. EMPIRICAL RESULTS

This paper investigates how working conditions on coastal cargo vessels are affected by environmental stressors. Each subsection starts with a description of the working conditions, then group comparisons (before discussing in Section 6 how the conditions are affected by environmental stressors). The analysis in this section is summarized in Table 3.

Table 3: Summary over working condition similarities and differences between the vessel types and regulation

	Shared descriptions 15 vessels (70 crewmembers)	Fish carriers Higher rates and public attention 6 NOR vessels	General cargo Low rates and public attention 2 NOR + 4 other	Bulk Low rates and public attention 2 NOR +1 other	All vessels with minimal regulation 5 vessels
Basic conditions (watch, resting and schedules)	Little rest for personnel with tasks under sailing and ports. Want more manning or less work.	Both short and long voyages.	Short and frequent port calls, short passages, exhausted crews.	Some relaxed days; sometimes longer voyages and time to rest.	Working periods are markedly longer. One company has system so navigators get more rest.
Conditions for sailing (navigation, engine, maintenance, reports)	Difficult to plan and perform navigation with professional competence (seamanship) with many disturbances.	Much disturbance from interested parties.	Much disturbance from interested parties.	More calm sailings due to few and silent charterers.	The three watch company has no bridge paperwork. Still, many are too tired to concentrate.
Conditions for ports (loading/ discharging, maintenance, reports)	Poor ports conditions, so crews perform operations under dangerous circumstances.	Practicalities are prioritized before safety to keep the schedule.	Practicalities are prioritized before safety to keep the schedule.	Few and longer port calls gives time for safe work in many situations.	Practicalities are prioritized before safety to keep the schedule, and not questioned.
Overall		Not best conditions of the vessel types (in contrast to ass. 1).	Maybe worst conditions of the vessel types (like assumption 2).	Not worst working conditions (in contrast to assumption 2).	Worst working conditions in the data selection (like assumption 2).

5.1 Basic working conditions

The crews' opportunity to divide their days and nights into rest and work depends largely on basic working conditions: manning, frequency of port calls, amounts of maintenance, and the crew members' shared competence and experience. Data material about this is presented in this section. On larger ships, the crews are manned so that two persons share a position during night and day, but on the coastal cargo vessels this is considered an unaffordable luxury. Usually, the officers in charge (navigators) plan work and rest for the crew when they get information about the next port calls. Some personnel are supposed to work under port operations and other personnel during voyages, and they rest when they do not work. Important under sailing are the navigators on navigating watch, engineers, and ratings on lookout watch. Important under loading and discharging are ratings, stewards, engineers or navigators working as machine-operators. All vessels in the study have one engineer or part time engine man on board. He or she often monitors the running engine and is the only one to do all maintenance and repairing of the engine and technical equipment. Only when they are sure that no one listen, some engineers talk about their situation:

> *Normally I work 8 to 17 hours, but I'm on standby all the time, also standby at nighttime. Sometimes 16 or 24 hours when it's necessary. I'm alone here, and sometimes it's very difficult. (Engineer, general cargo, minimal regulation)*

Also, navigators have to work in port, either with loading or administration (more about paperwork in Section 5.2 Working conditions during sailing).

> *It's not always I'm able to sleep. I've to send and report all kinds of things; it cuts into the resting period. I can't do those things under watch-keeping. And I'm the only person able to send it. (Navigator, general cargo, Norwegian regulation)*

Most sailors want the company to reduce administrative tasks on board or to add a crew member. Yet, most understand that the companies are not in a position to utilize such resources.

> *Of course we'd want to be six men, with our sailing frequency. When everything's okay, it's okay, but some days are very hectic and things do happen. We have a continuous operation and things arise. (Navigator, live fish carrier, Norwegian regulation)*

5.1.1 Basic differences between regulation types

While most Norwegian-registered vessels have working periods of four weeks, most vessels with other flags have working periods of four months or more. Especially the crews on the limited-regulated vessels in this study have much unpaid overtime, stress and noncompliance with resting periods. They describe accumulated sleep deficiency. One master at a limited-regulated vessel says:

> *Every month you get more tired. The first month each crewmember is 10 % tired. The second month you're 25 % tired, the third month you're 45 % tired and the fourth month you're 60 % tired. That gives a lot of risk. I'm nervous about the human factor. We need to know more. (Navigator, general cargo, minimal regulation)*

These crews seldom complain about the long working periods and fatigue since it is normal and many have short working contracts that they want to get renewed.

Many minimal regulated vessels have low food fares since they are expected to take in supplies in low-cost areas, so foodstuff can be scarce some periods. Most of the vessels are old and have outdated technology and equipment. They are often in need of repairs, but have low maintenance budgets. However, note that most bulk and general cargo vessels – regardless of regulation – are old, with minimal rates mostly covering fuel and regular expenses.

5.1.2 Basic differences between vessel types

Another difference is that the vessel types have substantially different voyage lengths. The bulk vessels in this study (one tank ship and two self-dischargers) have few port calls per day, some over-night stays and relatively long sailings in between. They usually can rest several times during the day, although the resting periods can be short here too.

> *We usually have six hours or more continuous resting period, but it can be three or four. (Crewmember, bulk vessel, Norwegian regulation)*

On the other end of the scale is general cargo, with several port calls per day and primarily short sailings in between. This often results in much stress and administration, brief resting periods and too little sleep with the accumulated sleep deficiency described last section. Live fish carriers also have short sailings and much stress in periods.

5.2 Working conditions during sailing

In the interviews, the crews report that most important under sailing is professional competence and opportunities to plan and work without disturbances, and this is what this section is about.

During sailing, the navigator needs discretionary space, but many of the navigators do not appear to have the time or the freedom to navigate according to their professional criteria because of numerous administrative tasks and disturbances. All navigators in our study say they have to answer phones and email, and do much administrative work while on watch-keeping duty, but the amount of time under navigation is different between the vessel types, as we will see in next subsection. Generally, a small part of the administration is valued positively (for example electronic reporting of rest period forms), but paper work is most considered negative. Administrative tasks are seen as indifferent for the operations, only distorting the real work, without a natural position on board.

> *The problem is that no one sees the use [of paperwork]. And that reflects on the motivation. It's meaningless, only filling out forms. (Navigator, general cargo, Norwegian regulation)*

The "useless" administrative tasks lead to a division between professional competence – seamanship – and paperwork. The administration makes the sailors unable to fulfill what they view as their core tasks.

> *My job's to take care of the cargo and the vessels, but I'm a safety officer and fire chief, loading and discharging man, and partly purchasing manager and flushing out that Al Qaida. Oh, yes, and I'm to steer the boat. (Navigator, bulk vessel, Norwegian regulation)*

As mentioned, navigators often have to choose between doing paperwork during resting periods or during voyages. Most navigators oppose doing it under navigation, especially in coastal waters, since it is easy to lose track of the navigation. Some say in interviews that they sometimes discover that they have done reporting for a long time without looking out or paying attention to the sailing. This is viewed as bad seamanship and considered very risky. Several navigators report that they would rather use their entire resting period once a week to fulfill administrative duties.

> *About documentation, I often must take a free watch to do it. It might be because of my structure, but it lets me work in peace. I can sit with my back against the view. (Navigator, general cargo***,** *Norwegian regulation)*

5.2.1 Differences between regulation types during sailing

The low regulated vessels with three watch system for their navigators are also special when it comes to administration; when they have three navigators on each vessel, paperwork can be done by an officer on administrative watch. This ship-owner deliberately does not have office stations on its vessels' bridges.

Still, the majority of the crews on these and other vessels with limited regulation emphasize that they are too sleepy to concentrate properly some weeks into their working period.

5.2.1 Differences between vessel types during sailing

We know that more frequent port calls and shorter sailings mean more paperwork and less time to do it. Some of the masters in this study describe a minimum of two hours administrative work per port call. Our three bulk vessels have fewer port calls and longer voyages than the general cargo and live fish carriers, so the bulk vessel navigators complain less about administration.

The bridge is a communication hub in the chain of logistics, and especially general cargo vessel crews describe their bridge as a joint hotel reception and a staff recruitment agency, in addition to a place for safe navigation. As we have seen, the navigator's concentration is often interrupted during sailing. A large part of the work load for navigators on live fish and general cargo vessels consists of dialogue with charterers, ship-company, pilot, government and other sailors, about cargo and personnel logistics.

> *We have to deal with someone above us. The client has a tendency to call here, and if the information flow is slow it's easy to make a slip, to promise more than we can keep. We can do that, and the company also can do that. It goes both ways. But we're aware over where we're in the system, and we do what we can to get to everything we're ordered to. Of course, we often would want more time to prepare it all, but that's not how it is. (Navigator, live fish carrier)*

Interviewees explain that the number of actors involved fragments their responsibility and complicates their planning.

In a situation during our field study, four alternative voyage plans were discussed and negotiated between three charterers, the ship-owner and the ship master. To reach a conclusion on the voyage plan, these actors' preferences were important, in addition to regulations and keeping the time schedule. The master sighed and explained:

> *You say that the master is responsible of the ship, but it's not as easy as that. (Navigator, live fish carrier)*

In significant contrast to the live fish carriers and general cargo vessels, the bulk vessel navigators report that their charterers and costumers seldom "bother" them during navigation and planning. Although the bulk vessel navigators get some phone calls and do have their share of administrative tasks, they report that a manageable number of charterers and management personnel want to get ahold of them.

5.3 Working conditions in port operations

This section deals with the need for resources such as equipment and manning, and the crew members' improvisation when the environmental stressors are not adequate.

Many Norwegian ports are improved to satisfy *security* regulations, but still are without light, moorings or personnel. When they are also exposed to rough weather, it becomes difficult to set fast the vessel, not to mention to load or discharge safely. Similar conditions can be expected on fish-farm rafts or netcages, but they mostly have lights and sometimes manning. If a vessel operate large ports they get to throw the moorings to terminal operators that set the vessel fast, but a large part of the cargo vessels' port calls happens without help on poorly equipped quays.

> *Many places the quay doesn't fit our size. The boats have gotten larger and larger, but the ports are not changed. (Crewmember, general cargo, Norwegian regulation)*

The sailors in this study put in much effort to keep the schedule. Practically all the interviewed crewmembers reveal that they do short cuts to keep the schedule, especially when they come alongside unmanned quays or fish-farm rafts. If no one is at the quay, they have to jump from the vessel to be able to do the mooring. Crewmembers who are conscious about the procedures say they are not supposed to leave the vessel before it is made fast, but this is sometimes impossible. They underline that accidents seldom happen, but one sailor says he has fallen in the water between the quay and the vessel. When asked if the procedures say anything about entering unmanned quays, he says:

> *Yes, I guess they do, but we still have to do what we have to do. (Crewmember, bulk vessel, Norwegian regulation)*

Often the crewmembers also go through with loading and discharging even though they experience the operations as unsafe due to stress, sleepiness, scarce manning or worn-out equipment. Most of the sailors describe situations where they wished to stop, but did not to keep the schedule and not create economical loss for the company. They comprehend their companies' weak financial situation and choose to compromise with their own feelings of safety to keep the schedule and the business going.

> *It's about the equipment you have to help yourself with and that the margins are so small before something happens. So you go further than you should, yes, you do. (Navigator, live fish carrier, Norwegian regulation)*

A few sailors say that they have stopped operations because of harsh weather:

> *If [our charterer] doesn't get fodder [our company] gets fines. So you almost feel it's your fault if you don't try to approach. We say no in the end, but we have in our minds that we must try so they don't run empty. (Crewmember, general cargo, Norwegian regulation)*

Interest from the charterer about working conditions and reporting systems to learn between the vessels is not described on any vessel, even though the hard working conditions generate injuries and sick leave. As two coworkers describe:

> *[Our charterer] is not very engaged in the things that happen onboard the boats, but it would've been nice to have something like that [reporting and learning about accidents] on the boats, if something is similar across the boats, for example. (Crewmember, general cargo, Norwegian regulation)*
>
> *For example, could we have seen the reason for all the sick leaves on the boats, maybe opened the eyes and seen that something has to be done. (Crewmember, general cargo, Norwegian regulation)*

5.3.1 Differences between regulation types in port operations

The unsafe working conditions associated with port operations are emphasized on vessels from all the branches and with all types of regulation in this study.

However, *awareness* about safety and possible risk prevention varies. The feeling that safety is degraded is most substantial on vessels with minimal regulation, but here the efficiency demands and possible measures are seldom questioned. The notion that practicalities are prioritized before safety and that this could have been avoided is stronger on Norwegian regulated vessels.

> *It's clear that it's many assignments we've taken, that we, from my point of view, obviously should've said no to. It can be because of the conditions, too bad weather so*

the margin you have if something happens … [When we have taken the assignment …] no matter the conditions, it's expected that we do it. (Navigator, live fish carrier, Norwegian regulation)

Crews with long contracts and strict regulation are used to being a part of their organizations' decision making, and they want to be able to give their opinion to charterers too, although this co-decision-making between organizations is not common in coastal cargo.

Much of the small accidents could've been avoided if we could participate in the decisions. With 100 meter longer tubes we could've saved many operations. Cooperation between [the costumer] and the supplier would've been for the best. (Crewmember, general cargo with some fodder in bulk, Norwegian regulation)

6. DISCUSSION

In light of the foregoing descriptions, I will now discuss how environmental stressors affect the working conditions on these coastal cargo vessels, and how safety resources can be increased.
Generally, with the terminology of Rasmussen (1997) and Rosness et al. (2012), the crews express how they face conditions that are primarily created or shaped by the upper levels of the safety management chain, such as their management, owners and regulators, but that they also get input directly from charterers and the public – and preserve their conditions themselves through their work and acceptance of the situations. The empirical data further suggests that the upper levels receive strong influence from each other and the environmental stressors of market and financial pressure, which they translate and send further to the sharp end of the organization as their working conditions. This is consistent with earlier research of maritime regulators and company management that also show how they are heavily influenced by economics, in addition to politics and the public (Almklov et al., 2014; Lindøe et al., 2011; Soma, 2004; Størkersen, 2015).

6.1 Similarities in the working conditions

The studied crews express how they need immaterial and material resources to have safe working condition. For example, to safely make sailing plans the navigators need material resources such as functional technology, but as important are immaterial resources such as competence, procedures, information and time. Another example is when the crewmembers need to jump from the moving vessel to the quay, they could have needed material resources such as terminal personnel or equipment, but a safe alternative could include immaterial alternatives such as time and possibility to follow regulations and rather abort the operation. Both material and especial immaterial resources are important to have discretionary space to make safe decisions. Often all types of resources are scarce, which is a common phenomenon (Reason, 1997; Vaughan, 1997) that Dekker (2012) describes as unfair double binds.
Most of the interviewed crewmembers have some kind of respect of their companies' resource saving instead of spending on safety measures. The crews ambiguously report of time pressure and a wish to increase the company's profit by performing operations fast without delays – either they are on a vessel in a sector with little or much attention, high or low prices, or less or more regulation. This is in line with survey results from some of the same crews, where a third of the crewmembers say they experience situations where they put themselves in danger to get the job done, and 40 and 36.5% admit to often violate procedures to get the job done, especially because of efficiency demands (Størkersen et al., 2011). In this sense, the personnel safety is given a lower priority than the economical investments in daily situations; the crews are efficient instead of making safe decisions to thoroughly avoid all side effects (Hollnagel, 2009; Rasmussen, 1997, p. 184). All the crews interviewed in this current study say they often choose production before protection (as it is put by Reason, 1997), although earlier research of live fish carrier loading operations show that it is easier to stop operations with reference to their live product, which also protects the personnel (Størkersen, 2012).

6.2 Differences in working conditions – evaluating the assumptions

Even if the crews on the different vessels emphasize similar aspects of the working conditions, the groups are affected if different degree (see Table 3 at the start of Section 5 for a summary). Most important for basic and port conditions are contracts and port frequency, while sailing conditions vary after disturbances. In Section 1 two assumptions about vessels working conditions are presented based on earlier research: (1) the live fish carriers might have relatively safe working conditions, and (2) the bulk and general cargo vessels of Norwegian or other registration might have more unsafe working conditions.

As supposed in the first assumption, the empirical analyses in Section 5 display that the vessels with high rates, regulation and/or attention often have better material working conditions than the others. The live fish carriers have better equipment and are newer than most bulk and general cargo vessels since they are made by a rich industry. However, better material conditions do not automatically result in safer working conditions. The live fish carriers also have charterers and managements with high demands of efficiency and high expectations of communication with the navigators during navigation. In addition, Norwegian-regulated vessels are certified with safety management systems, that often leads to much administration on the vessels [more about this in, for example, Almklov et al. (2014); Kongsvik et al. (in review)]. It is difficult to use ones competence to plan and perform navigation with many disturbances, so immaterial conditions are inadequate on live fish carriers. A simplified overview is made as an illustration in Figure 5.

The same conclusion goes for the second assumption (that low regulation, attention and rates lead to worse conditions): It seems to be correct with regard to accessibility of *material* resources and wrong because *immaterial* aspects are at least as important for the working conditions. The studied bulk and general cargo vessels are often old with outdated technology, low maintenance budgets, low food fares and few or non-existing support personnel on shore. However, on the low paid bulk vessels, the disadvantages also go hand-in-hand with benefits not accounted for in the assumptions; longer voyages and port calls and less interruptive customers give freedom for the crews to concentrate on tasks, and to rest. Such discretionary space is important to make safe decisions, that potentially also comply with procedures (Dekker, 2012; Rosness, 2009, etc.).

There also are large differences between the vessels affected by the second assumption. Compared to the crews on Norwegian-regulated vessels, the sailors on the vessels with low regulation say they are more tired and have more stressful days. (This difference is established through statistical analysis as well (Størkersen et al., 2011).) On the interviewed Norwegian-registered vessels, the crews tell they have long contracts with employers and more often demand safety resources from the managements, alert the management of unsafe conditions, or abort unsafe operations. Both the current qualitative and the earlier quantitative data therefore indicate that the crews on the low regulation vessels operate within worse structures in terms of too much work and too little rest for long working periods. The regulation differences seem to be general across the sectors of bulk and general cargo vessels, and the variance is even larger compared to the all Norwegian-regulated live fish carriers. All in all, the differences in working conditions might be larger between regulation than between vessel types/industry branch, or with regulation in combination with low cargo rates and minimal attention.

This evaluation shows that both assumptions are partly wrong because immaterial aspects, such as number of port calls and length of voyages, seem to be more significant than previously assumed. In contrast to the assumptions, the data comparison suggests that poor economy and low attention can be both positive and negative for safe working conditions, but that minimal regulation is basically negative: Regulation seems to be an important environmental stressor for safety. This gives a foundation to discuss the relationship between the environmental stressors important for the studied vessels.

6.3 Nested environmental stressors

In the small selection of this study (see Table 2), the safety resource level in general are higher on the vessels with Norwegian registration than on the vessels registered in other states. Some differences seem to be results of different regulation of those vessels. Regulation can be viewed as an environmental stressor because it is mainly made by politicians and the industry (Størkersen, 2015). The safety regulation and inspection regime is stricter for the Norwegian-registered vessels. Other studies have shown that comprehensive regulation serves to heighten some safety resource levels (Knapp & Franses, 2009; Kongsvik et al., in review) and make the gap even larger to low regulation states that implement international conventions minimally or not at all (DeSombre, 2008; Knudsen & Hassler, 2011). On the other side, regulation can be associated with less safe conditions if it is not adapted to the work context (Grote, 2012) and rather leads to proceduralization that reduces the crews' discretionary space to act according to competence (for example Almklov et al., 2014; Bieder & Bourrier, 2013; Dekker, 2014; Kongsvik et al., in review). This study's data material does not include the ship-owners' reasons for choosing minimal regulation, but it is not surprising if it is related to low rates and little public attention. Nevertheless, it is difficult to say how important regulation is as long as companies have the option of choosing registration states, and thereby regulation type. One *can* say, though, that in spite of extreme market forces in the maritime industry – and that regulation and market stressors are nested – regulation plays an important role for sure.

Market is the most directly mentioned environmental stressor in the cargo crew descriptions. Market-related industrial differences can be another reason for the unequal working conditions on the vessels in this study. Market aspects might be a reason for the ship-owners' out-flagging, and industrial conditions also can directly reduce the managements' financial potential to implement safety measures. For example, the bulk vessel crews recognize that their rates do not leave room for more than their fuel and regular expenses. Even if ship owners moved their vessels to Norwegian registers, they might not have the option of raising the rates and earn enough to heighten the safety level. We also know that the regulation is severely influenced by industry and market forces (Størkersen, 2015), so the borderlines are blurry, and it is difficult to say if it is really regulation or market stressors that most influence the working conditions on cargo vessels in Norway. Some of this complex relationship is illustrated in Figure 5. Therefore, this investigation can only state that market and regulation affect the working conditions severely, not whether regulation trumps market stressors with its safety demands or if Norwegian regulated vessels just operate where market stressors allow for safe working conditions.

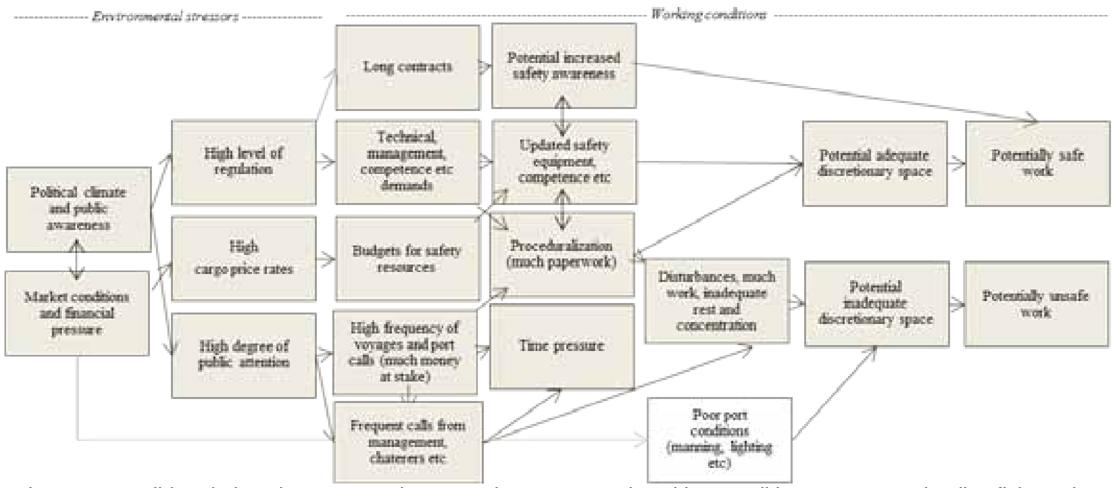

Figure 5. Possible relations between environmental stressors and working conditions on Norwegian live fish carriers.

7. MONEY TALKS, BUT SAFETY COULD SHOUT

In this paper I have explored the influence of environmental stressors on working conditions in Norwegian coastal cargo and found that market forces affect safe working conditions both positively and negatively, but that regulation – where it is present – can hinder economical stressors to rule. This study is the first to delve so deeply into the details of the Norwegian coastal cargo work. The text began with assumptions based on earlier research results (Lindøe et al., 2011; Soma, 2004; Størkersen et al., 2011): that cargo vessels in sectors of high attention, price rate and regulation (live fish carriers) might have safe working conditions, while vessels in sectors of low attention, rate and/or regulation (bulk and general cargo vessels) might have less safe working conditions. An analysis of the crews' working conditions shows that the assumptions were partly wrong because immaterial resources that give the crews discretionary space (such as time and concentration) are more important for the working conditions on these vessels than is emphasized in the literature. As the studied vessels with less regulation are more exposed to the market stressors of low rates, minimal resources, fast pace and accompanying lack of discretionary space, they have the worst working conditions.

The results can be used as examples of how environmental stressors can influence maritime working conditions and how important it is to allow for crews' discretionary space. Not least, the results can empower actors that struggle to make maritime safety a priority. Managers now know that discretionary space is an important safety measure that they can provide for the crews without going bankrupt: Time to rest, calm and competency to make safe decisions are not free, but possible to consciously accumulate over time without large financial investments.

Policy makers and customers – the public – are in charge of the conditions most important for the crews' work safety: Regulation, rates, and attention. Customers can show willingness to pay for cargo services provided by companies that implement safety measures. When I buy a coach, I can demand to know how it is transported, and thereby create a pressure for social responsible corporations to invest in safe transportation. Since regulation can heighten the safety resources, regulators and policy makers can work for transport companies to be able to choose – or be forced to use – high-quality regulation. As long as it is possible to register a vessel in a state where it is not operating, policy makers can implement joint responsibility so transport costumers and charterers are made responsible for the crews' conditions. The traditional power struggle is turned; the people are costumers, voters and pressure groups. We can raise safety levels and make safety unneglectable.

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9. REFERENCES

Almklov, P. G., Rosness, R., & Størkersen, K. (2014). When safety science meets the practitioners: Does safety science contribute to marginalization of practical knowledge? *Safety science, 67*, 25-36.

Bieder, C., & Bourrier, M. (2013). *Trapping safety into rules: how desirable or avoidable is proceduralization?* England: Ashgate.

Dekker, S. (2012). *Just culture: balancing safety and accountability*. Aldershot, Hampshire, England: Ashgate.

Dekker, S. (2014). The bureaucratization of safety. *Safety science, 70*, 348-357.

DeSombre, E. R. (2008). Globalization, competition, and convergence: shipping and the race to the middle. *Global Governance: A Review of Multilateralism and International Organizations, 14*(2), 179-198.

Fagerholt, R. A., Kongsvik, T., & Størkersen, K. V. (2014). *Sikkerhet i fraktefarten. En spørreundersøkelse*. Retrieved from Trondheim, Norway:

Grote, G. (2012). Safety management in different high-risk domains–All the same? *Safety science, 50*(10), 1983-1992.

Haram, H. K., Hovi, I. B., & Caspersen, E. (2015). *Potensiale og virkemidler for overføring av gods fra veg- til sjøtransport*. Oslo: TØI.

Hollnagel, E. (2009). The ETTO principle: efficiency-thoroughness trade-off : why things that go right sometimes go wrong (pp. vii, 150 s. : ill). Burlington, Vt.: Ashgate.

Hollnagel, E., Woods, D. D., & Leveson, N. (2006). *Resilience engineering: concepts and precepts*. Aldershot: Ashgate.

MLC - Maritime Labour Convention, 2006 (MLC, 2006). (Entry into force: 20 Aug 2013), (2013).

IMO. (2015). History of SOLAS. Retrieved from http://www.imo.org/KnowledgeCentre/ReferencesAndArchives/HistoryofSOLAS/Pages/default.aspx

ISF. (2015). Flags of convenience. Retrieved from http://www.itfglobal.org/en/transport-sectors/seafarers/in-focus/flags-of-convenience-campaign/

Knapp, S., & Franses, P. H. (2009). Does ratification matter and do major conventions improve safety and decrease pollution in shipping? *Marine Policy, 33*(5), 826-846.

Knudsen, O. F., & Hassler, B. (2011). IMO legislation and its implementation: Accident risk, vessel deficiencies and national administrative practices. *Marine Policy, 35*(2), 201-207.

Kongsvik, T., Antonsen, S., & Størkersen, K. V. (in review). Safety management regulation's effects on efforts to prevent personal injury and ship accidents. *Journal of Risk Research*.

Lindøe, P. H., Engen, O. A., & Olsen, O. E. (2011). Responses to accidents in different industrial sectors. *Safety science, 49*(1), 90-97.

Maritime Authority. (2015). *Datauttrekk. Skipsulykker 1981-2014 (pr 12042015)*. Retrieved from: http://www.sjofartsdir.no/ulykker-sikkerhet/ulykkesstatistikk/datauttrekk/

Paris MOU. (2015). Port State Control: Adjusting Course. Addendum: detailed MLC figures.

Rasmussen, J. (1997). Risk management in a dynamic society: a modelling problem. *Safety science, 27*(2), 183-213.

Rasmussen, J., & Svedung, I. (2000). *Proactive Risk Management in a Dynamic Society*. Karlstad, Sweden: Swedish Rescue Services Agency.

Reason, J. (1997). *Managing the risks of organizational accidents*. Aldershot: Ashgate.

Rosness, R. (2009). A Contingency model of decision-making involving risk of accidental loss. *Safety science, 47*(6), 807-812.

Rosness, R., Blakstad, H. C., Forseth, U., Dahle, I. B., & Wiig, S. (2012). Environmental conditions for safety work–theoretical foundations. *Safety science, 50*(10), 1967-1976.

Soma, T. (2004). *Commercial Accidents-an assessment of four leading tanker companies.* Paper presented at the Probabilistic Safety Assessment and Management.

Statistics Norway. (2009). *Transport i Norge (Transport in Norway)*. Retrieved from Oslo, Kongsvinger, Norway:

Statistics Norway. (2015a). Arrivals of vessels at Norwegian and foreign ports, 2014. About the data. Retrieved from https://www.ssb.no/en/transport-og-reiseliv/statistikker/skipanut/aar/2015-04-15?fane=om#content

Statistics Norway. (2015b). Arrivals of vessels at Norwegian and foreign ports, 2014. Port calls by register and vessel types. Retrieved from https://www.ssb.no/en/transport-og-reiseliv/statistikker/skipanut/aar/2015-04-15?fane=tabell&sort=nummer&tabell=223925

Statistics Norway. (2015c). Table: 07437: Transportation and storage. Principal figures, by industry group (SIC2007). Preliminary figures 2013. Retrieved from https://www.ssb.no/statistikkbanken/selectvarval/saveselections.asp

Størkersen, K. V. (2012). Fish first: Sharp end decision-making at Norwegian fish farms. *Safety science, 50*(10), 2028-2034.

Størkersen, K. V. (2015). Survival versus safety at sea. Regulators' portrayal of paralysis in safety regulation development. *Safety science, 75*, 90-99.

Størkersen, K. V., Bye, R. J., & Røyrvik, J. O. D. (2011). *Sikkerhet i fraktefarten: analyse av drifts- og arbeidsmessige forhold på fraktefartøy*. Trondheim: Studio Apertura, NTNU Samfunnsforskning.

Vandeskog, B. (2015). The Legitimacy of Safety Management Systems in the Minds of Norwegian Seafarers. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, 9*(1), 101-106. Retrieved from http://www.transnav.eu/Article_The_Legitimacy_of_Safety_Management_,33,561.html

Vaughan, D. (1997). *The Challenger launch decision: Risky technology, culture, and deviance at NASA*: University of Chicago Press.

Walters, D., & Bailey, N. (2013). *Lives in peril: profit or safety in the global maritime industry?* Basingstoke: Palgrave Macmillan.

A basic occupational health and safety awareness training subject for engineering degree students

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Abstract

International institutions, as the European Commission, have enhanced the importance of the inclusion of occupational health and safety awareness in the academic programs at University. In this sense, member states of the European Union have developed occupational health and safety strategies that include educational issues at the university level. In the case of Spain, the integration of occupational risk prevention contents in the academic programs at university titles was included in the national occupational health and safety strategy for the period 2010-2012.

This work has the aim to include a basic knowledge of occupational health and safety in the academic curriculum of the students of the High Technical Engineering School of the University of Seville (ETSI). The inclusion of occupational health and safety contents in the engineering degrees allows to promote an occupational risk prevention culture in the future for both employees and employers. To do this, the Chair of Occupational Risk Prevention of the University of Seville offers a new optative subject titled Analysis and Prevention of Occupational Risk to the students.

The subject consists of a training program that meets the requirements set out in the RD 39/1997 Spanish regulation. It consists of five modules: (I) basic concepts of occupational health and safety; (II) general risks, description and prevention; (III) specific risks, description and prevention in the industrial sector, (IV) basic tools for risks prevention management and (V) first aid. After passing the course, the students get an official title on basic occupational risk prevention. This title will allow the students to assume some rules in occupational risk prevention. E.g. they will assume, both as worker or employer, the risk managements in a small company.

The teaching process was design under a practice paradigm. The theoretical knowledge and the tools presented are employed in practical lessons. Teachers have a high qualification in Industrial Safety, Hygiene, and Human Factors. The subject program includes seminaries with external professional experts and technical visits to industrial plants. Students have to pass several partial tests throughout the course. Also, to get the official title, they have to attend 80% of classes at least.

The subject was offered to the students of four different degrees of the ETSI (Industrial Technology Degree, Civil Engineering Degree, Chemical Engineering Degree and Aerospace Engineering Degree), at the 2013-2014 course, and 58 students chose it. At the 2014-2015 course, the subject was included in the programme of three degrees more (Energy Engineering Degree, Management Engineering Degree and Telecommunication Engineering Degree) and 129 students chose it. A pass ratio of 99% was observed at both academic courses. Regarding the first four degrees in which the subject was offered, an enhancement of 72.4 % is observed in the number of students. Attending this results, it can be concluded that the basic occupational health and safety awareness training subject is being successfully implemented in the different engineering degrees of the ETSI.

Key words: Risks prevention culture, basic risks prevention knowledge, engineering degree

1. INTRODUCTION

In the last years, occupational accidents have been reduced in the countries members of the European Union as consequence of the improvement in both production process and the occupational risk prevention management. Figure 1 show the Incidence Index by productive sectors in Spain in 2007 and 2013 [GS, 2007, GS, 2013]. It can be see a significate reduction of the accident in all the productive sectors but the agricultural. But also is shown that accidents still happen in all of them.

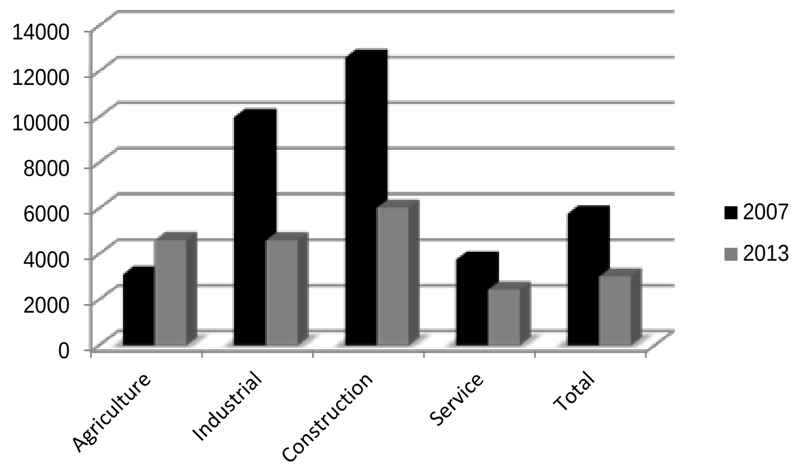


Figure – 1. Incidence Index by productive sectors in Spain in 2007 and 2013.

In order to reduce the accidents, two different approaches have been used by companies and administrations. The technical improvement of both the process and the safety tools have involved a big reduction of the number of occupational accidents. But this approach need to be complemented with the promotion of an occupational risk prevention culture in all levels of the company [ISSA, 2015; Iberdrola, 2015; UPC, 2014; FIOH, 2013; DGUV, 2012; EASHW, 2011].

In [Reason, 1997] four characteristics are described for a positive safety culture of an organization:

1. A reporting and informed culture. People readily report problems, errors and near misses.
2. A just culture. Justice and reliable information generates credibility and confidence. Everybody knows what is acceptable or unacceptable behavior.
3. A flexible culture. The culture have to allow adaptation to changing conditions or new requirements.
4. A learning culture. People want to improve the occupational health and safety, and have the capacity to reflect on their own behavior and that of others.

It is clear that, to reach each of these characteristics, a minimum knowledge about occupational health and safety is required for all the member of the organization. The intensity of this knowledge will depend on the responsibilities in this area.

With the aim to reach a 25 % reduction in the total incidence rate of accidents at work by 2012, the European Commission published in 2007 the Community strategy 2007-2012 on health and safety at work [EC, 2007]. The integration of health and safety into education and training programmes was included in this strategy as a tool for promoting changes in behaviour. According to this strategy, a risk prevention culture should be developed in training programmes at all levels of education, including at university.

In the case of Spain, the integration of occupational risk prevention contents in the academic programs at university titles was included in the national occupational health and safety strategy for the period 2010-2012 [GS, 2010]. But in this strategy, only the specific titles directly related with the occupational health and safety are included. In the region of Andalusia, the necessity of general improvement of the occupational health and safety training at University was included in the occupational health and safety strategy for the period 2010-2014 [GA, 2010].

In this framework, the Chair of Occupational Risk Prevention of the University of Seville was created in 2010 with the support of the Government of Andalusia. One of the main objectives of the Chair is to introduce a risk prevention culture in the young students. This is done with the aim that these students will promote in the future, as employees or employer, good practices and behaviours in their companies or work places, spreading the preventive culture. With this object, the chair promotes teaching, research and dissemination activities in the field of occupational health and safety.

On other hand, the skills and formation required for the exercise of preventive functions, is regulated in Spain in the RD 39/1997 [GS, 1997]. The preventive capacities and the required formation for theses are divided in three level: basic (50 hours training), intermedium (300 hours training at least) and superior (60 hours at least).

In order to promote an occupational risk prevention culture in the university students, this work is focus on the inclusion of a basic occupational health and safety awareness training for engineering degree students. To do this, the Chair of Occupational Risk Prevention of the University of Seville offers to the students of the Haigh Technical Engineering School (ETSI) a new optative subject titled Analysis and Prevention of Occupational Risk. Passing the course, the students get the Basic Level Accreditation in Occupational Risk Prevention. Holding this title, these future employees and employers will have the competencies listed below [GS, 1997]:

a) Promotion of: safe behaviours, correct use of both occupational and protective equipment
b) Promotion, monitoring and control of the basis risk prevention strategies as: order, cleanliness, signage and general maintenance
c) Collaboration in the Occupational Risk Assessment of the Company by visiting the occupational places, addressing complaints and suggestions, data registration and others activities.
d) Management of the firsts actions in emergency case and first aid
e) Cooperation with the Occupational Health and Safety Services
f) In this work, the academic program for the new subject offered is described. Also the teaching methodology and the evaluation system. Finally, the results obtained in number of student that selected de subject and the pass ratio were analysed for the first two courses in which the subject was offered.

2. MATERIALS AND METHODS

The subject was designed from a practice point of view and including all the topics required in the Spanish legislation for the Basic Level accreditation in occupational risk prevention: (1) basic concepts of occupational health and safety; (2) general risks, description and prevention; (3) specific risks, description and prevention in the industrial sector, (4) basic tools for risks prevention management and (5) First aid [GS, 1997]. After pass the course, the students get an official title on Basic Occupational Risk Prevention. This tithe will allow the students to assume some rules in occupational risk prevention. E.g. they will can assume, both as worker or employer, the risk managements in a small company.

Initially, the subject was offered to students of four different engineering degrees of the ETSI in the course 2013-2014: Industrial Technology Degree, Civil Engineering Degree, Chemical Engineering Degree and AED Aerospace Engineering Degree. In the course 2014-2015, the subject was included in the programme of three engineering degrees more: Energy Engineering Degree, Management Engineering Degree and Telecommunication Engineering Degree.

The teacher team consists of University teachers and external professionals. Teachers for topics related to Safety, Hygiene and Human Factors have high qualification in both engineering and occupational health and safety. For topics related to Occupational Medicine and First aid, teachers are experienced medicine professionals.

To pass the subject, the students have to assist to the 80 % of the classes at least. Also they have to pass the partial exams with a score of 5 over 10 at least. These exams consist of two sections. First one, focused on the theoretical knowledge about the topic, based on both multiple election and short question. In the second one, the students have to solve a practical case. To solve the case, they have to do a basic risk assessment, including the necessary preventive actions.

The subject consist of 50 hours distributed in five theoretical modules, practice classes and one technical visit. The content of the course is showed below.

- **Module I. Basic concepts of occupational health and safety (6 hours classroom)**

This module consists of a description of the normative framework and legislation in the matter of occupational health and safety. Both basic concepts and definitions included in the Spanish legislation are introduced to the students. Also a brief description of the focus of the different disciplines involved in occupational health and safety are included. These disciplines are: Safety, Hygiene, Human factor and Ergonomics, and Occupational medicine. The module consists of two themes:

o Theme 1: Basic normative framework in the matter of prevention of risks at work. Rights and obligations

o Theme 2: Introduction to occupational health and safety

• 2.1. Health and work. Basic concepts

• 2.2. Damages relates to work

§ 2.2.1. Occupational accidents. Safety

§ 2.2.2. Occupational diseases. Hygiene

• **Module II. General risks and their prevention (17 hours classroom)**

In this module, both the most typical risks and some tools for the prevention and control of them are introduced to the students. Risks are identified according to their origin. Depending on the factor that promotes the risk, each risk is studied under one of the different four disciplines cited before. For example: same level fall, fall from eight and electrical risk in safety; chemical, physical and biological risks in hygiene; burnt out stress and occupational fatigue in human factors; musculoskeletal disorders in ergonomics. Some tools for risk prevention and control are included. At the end of the module, the occupational medicine is showed by an external professional in this matter. The module consists of next six themes:

o Theme 3: Risks related to safety

• 3.1. General risks

• 3.2. Relevant risks (electrical, machine related, fall from height, etc.)

o Theme 4: Occupational environmental risks

• 4.1. Chemical risks (I)

• 4.2. Chemical risks (II)

• 4.3. Physical risks

• 4.4. Biological risks

o Theme 5: Risk related to psychosocial and ergonomic factors

• 5.1. Ergonomic risks

• 5.2. Psychosocial risks

o Theme 6: Risk control systems. Collective and personal protection

o Theme 7: Emergency and evacuation plan

o Theme 8: Workers health control

• **Module III. Specific risks management in Industry (6 hours classroom)**

This module consist of five sessions. Each session is focused in the specific risks of one different industrial sector. The sessions are conducted by experimented professionals and include cases of real companies. The industrial sectors have been selected taking into consideration the different degrees of the students.

o Session 1. Specific risks management in the aeronautic sector

o Session 2. Specific risks management in the civil work sector

o Session 3. Specific risks management in the electrical sector

o Session 4. Specific risks management in the mechanical sector

o Session 5. Specific risks management in the chemical sector

• **Module IV. Basic knowledge on occupational risk management (3 hours classroom)**

This module is mainly focused on the requirements for the management systems included in the Spanish normative. The occupational risk management system proposed in OHSAS 18001 is described. Also national and international institutions related to the occupational health and safety are presented. The module consists of two themes:

o Theme 9: Institutions and Organizations related to occupational health and safety

o Theme 10: Occupational risk prevention management systems and their auditory

• **Module V. First aid workshop (6 hours)**

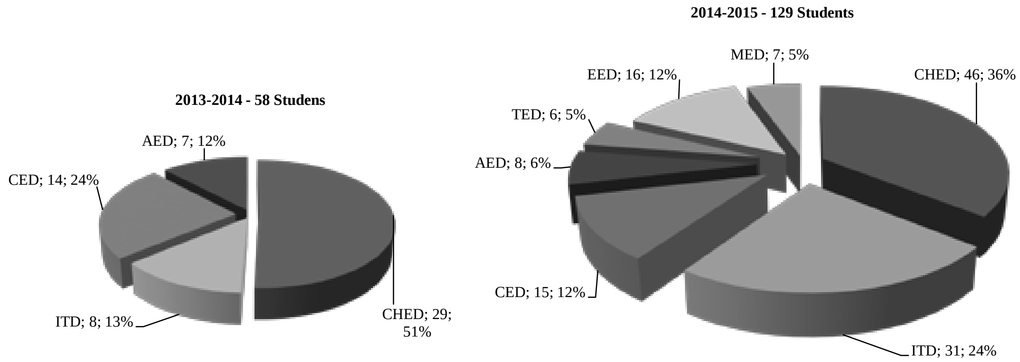
This module covers first aid basics such as choking, bleeding and CPR. Teachers are expert professional of heath and first aid. The workshop includes theoretical and practical training.

• **Practical classes (6 hours classroom)**
Consists of four 1.5 hours classroom sessions. A different practical case must be solved in each session. The students have to do a basic risk assessment. It has to include the risk control strategies in order to reduce the more important risks to acceptable values.

• **Oil refinery visit (6 hours)**
Students are brought to a real oil Refiner. There, an Occupational Health and Safety manager shows them most interesting aspect about risk prevention and control in this kind of industrial facility. In this way, students can be see a real use of the acquired knowledge before along the course.

4. RESULTS AND DISCUSSION

Figure 1 shows the number of students by degree for the two courses that the subject has been offered. The total number of students increased from 58 in the course 2013-2014 to 129 in the course 2014-2015. This represents an increase of 122 %. Regarding on the first four degrees in which the subject was offered, an increase of 72.4 % is observed in the number of students. This increase is mainly due to the high increase of the number of student of the Industrial Technology Degree that chose the subject. The number of student of the Industrial Technology Degree is approximately four times the number of student of the rest of degrees in the ETSI, so the capacity of increase respect to the first year was higher for this degree. No significant changes can be observed in el number of students of the other three degrees in which the subject was offered firstly.



ITD (Industrial Technology Degree), CED (Civil Engineering Degree), CHED (Chemical Engineering Degree), AED (Aerospace Engineering Degree), EED (Energy Engineering Degree), MED Management Engineering Degree, TED (Telecommunication Engineering Degree.

Figure 2 - Evolution of the number of students by academic course and by degree.

Figure 2 shows the scores obtained by the students in the courses 2013-2014 (left) and 2014-2015 (right). The pass rate in both courses was of 99 % and 88 % respectively. It represents a decrease of 11 % in the pass rate. But regarding to the students that followed the subject until the end, by suppressing the 11 % that correspond to not taken, the pass rate for the course 2014-2015 was of 99 % again. Also it can be observed the high quality of the scores, most of them higher than C in both courses.

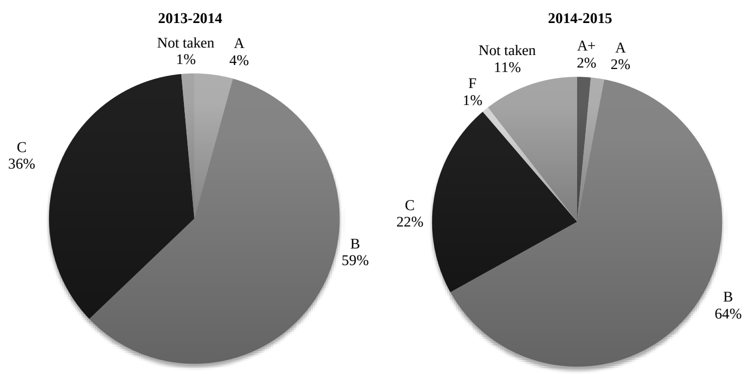


Figure 3 - Scores obtained by the students in the courses 2013-2014 and 2014-2015.

4. CONCLUSIONS

Attending the exposed results, it can be concluded that the basic occupational health and safety awareness training subject is being successfully implemented in the different engineering degrees of the ETSI. The engineering students of the ETSI have shown a great interest for the subject, getting high scores.

It is expected that the promotion of the preventive culture in the engineering students, by offering of the subject described in this job, will help to create a general culture that values health and risk prevention.

5. ACKNOWLEDGMENTS

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6. REFERENCES

EC. European Commission (2007). Improving quality and productivity at work: Community strategy 2007-2012 on health and safety at work. Communication from the Commission to the European parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Brussels, 21.2.2007. COM(2007) 62 final.

GA, Government of Andalusia (2012). Dirección General de Seguridad y Salud Laboral, Consejería de Empleo. Estrategia Andaluza de Seguridad y Salud en el Trabajo: 2010-2014.

GS, Government of Spain (1997). REAL DECRETO 39/1997, de 17 de enero, por el que se aprueba el Reglamento de los Servicios de Prevención. BOE nº 27 31-01-1997.

GS, Government of Spain. Ministerio de Trabajo e Inmigración (2007). Anuario de Estadísticas Laborales y Asuntos Sociales 2007.

GS, Government of Spain. Ministerio de Empleo y Seguridad Social (2013). Estadística de Accidentes de Trabajo y Enfermedades Profesionales. Datos anuales 2013.

GS, Government of Spain. Instituto Nacional de Seguridad e Higiene en el Trabajo. Ministerio de Trabajo e Inmigración (2010). Estrategia Española de Seguridad y Salud en el trabajo 2007-2012. 3er Plan de Acción-Periodo junio 2010-junio 2012.

UPC, Univeritat Politecnica de Cataunya. Servei de Prevnencio de Riscos Laborals (2014). Occupational Health and Safety Plan.

Iberdrola S.A. (2015). Occupational risk prevention policy.

EASHW, European Agency for Safety and Health at Work (2011). Occupational Safety and Health Culture Assessment-A review of main approaches and selected tools. Ed. Terence N. Taylor (EU-OSHA). ISSN 1831-9351. DOI 10.2802/53184.

FIOH, Finnish Institute of Occupational Health (2013). International Symposium on Cultture of Prevention-Future Approach. Helsinki, Finland. Book of Abstracts.

DGUV, Deutsche Gesetzliche Unfallversicherung e.V. (2012). Prevention yearrbook 2012-2013. Making prevention Sustainable.

ISSA, International Social Security Association (2015). A three-dimensional approach to safety and health at work.

Reason, J.T., (1997). Managing the Risks of Organisational Accidents. Ed. Aldershot. ISBN 978-1-84014-104-7

Exploring commitment to a zero accident vision in organisations in seven countries

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Abstract

This study explores commitment to a Zero Accident Vision (ZAV) in 27 companies, located in seven countries. We used a questionnaire to asses both how people perceive the commitment of the organisation, and how they are committed to ZAV themselves. In addition, the survey referred to safety climate, learning and communication.

Results show that two groups of companies could be distinguished with different levels of ZAV commitment, based on the scores on individual and organisational commitment. The group scoring highest on commitment scored significantly higher on all other safety dimensions in comparison to companies in the other group. These findings could indicate the importance of ZAV commitment on workplace safety and also suggest their impact on safety dimensions such as learning, communication and culture.

This study is a first attempt at measuring ZAV, and to measure it in relation to safety dimensions of culture, learning and communication. Although the findings raise many additional questions, this study lays a foundation for research into ZAV, by exploring not only ZAV in combination with other safety aspects, but also by exploring it in such a wide range of companies and countries. Moreover, the combination of approaches used in this study proved useful in studying ZAV, and may be used in future studies

Keywords: accident prevention; culture, safety learning, safety communication, safety climate

1. INTRODUCTION

Accident prevention and identification of effective measures for accident prevention have been major topics of interest for many years. Both researchers and practitioners from industry are continuously trying to minimise the number of accidents and to minimize the consequences. Important aspects in improving safety and thus in preventing accidents are a culture of openness and trust (Guldenmund 2000; Reason 1997), learning (Akselsson et al. 2012; Drupsteen and Guldenmund, 2014; Kletz 2001) and commitment (Michael et al. 2005, Petersen 1998). A specific commitment strategy that is gaining increasing attention is the Zero Accident Vision (ZAV) (Rasmussen 2013, Young 2014, Zwetsloot et al. 2013). ZAV is a vision that originates from industrial practices (MacCormack 1997; Liska, Goodlow and Sen 1993), in which the basic assumption is that all (serious) accidents are preventable, and that companies should do as much as possible in preventing accidents.

So far, only a few studies have explored the effects of ZAV commitment. These studies did demonstrate that the commitment to Zero Accidents results in better safety (Aaltonen 2007; Hinze 2002). Yet, an exact understanding of the mechanisms and success factors behind ZAV still lacks. This paper aims to shed further light on the underlying mechanisms of the relationship between ZAV commitment and improved safety by exploring several companies committed to ZAV. Specifically, the study investigates the levels of self-reported personal commitment to ZAV and the perception of organizational commitment through a survey, and relates this to measures of safety climate, safety learning, and safety communication.

Aim and research questions
The overall aim of this project – as part of a larger research project on ZAV - is to gain an increased understanding of ZAV committed companies. To do so we aim to answer the following research question: Are scores on safety dimensions different for companies with higher commitment to ZAV?

2. METHODS

Overall research design
The overall research project into ZAV is carried out in joint collaboration with seven European research institutes, with a total of 27 participating companies. The research project used three main approaches to study ZAV within organisations:

1. A brief questionnaire that gives information on company size, development of accident frequencies over the past years and on ZAV implementation and goals on a company level. These questions were completed by a single company representative such as the HSE manager.
2. A questionnaire study that builds on existing questionnaires, and measures the aspects: ZAV commitment, learning, safety climate and safety communication on an organisational and individual level.
3. Interviews with key actors for each of the participating companies, to provide context for the quantitative results.

In addition to these measures a focus group was organized in each country with representatives from the participating companies. These focus groups had a twofold aim: for the companies to share their experiences and good practices, and for the researchers to identify common factors that characterize ZAV companies. In the given investigation we mainly focus on the findings from the second questionnaire.

Participants
The project was carried out by research task partners from seven countries: Belgium, Denmark, Finland, Germany, The Netherlands, Poland and the United Kingdom. Each task partner recruited companies in their own country for this project. In the Netherlands and Finland, companies were recruited from the zero accident networks in those countries. In the other countries, such a network did not exist at the time of data collection and companies were recruited through the networks of the task partner. Altogether, the task partners recruited 27 companies that had adopted a ZAV-type approach in recent years.

Individual ZAV Questionnaire
The questionnaire was developed as part of the overall research project, primarily using items from already established measures:

- Nordic Safety Climate Questionnaire NOSACQ (Kines et al. 2011)
- learning from incidents survey (Drupsteen, Groeneweg and Zwetsloot, 2013)
- questionnaire on learning conditions (Jerez-Gómez, Céspedes-Lorente, Valle-Cabrera 2005).

The resulting survey consisted of 72 items in eleven dimensions, covering questions about organisational and individual commitment to ZAV, safety learning (learning actions and safety learning in general), safety culture/climate (consisting of empowerment, priority, justice and a group level measure) , safety communication (by managers and on individual level), and resilience. The resilience dimension is not used in this specific part of the overall research project, thus 10 dimensions are included in the analyses. Cronbach alpha's were calculated to verify the validity of the eleven dimensions. Generally Cronbach alpha is considered acceptable above .67 and good above .7. All scales had a Cronbach alpha higher than .7 (ranging from .71 to .92), except for one dimension. This scale originally had a Cronbach alpha of .57, but this was raised to .705 by dropping one item.
Commitment to ZAV was explored in the questionnaire through two dimensions: individual commitment to ZAV (5 items), and organizational commitment to ZAV (2 items). Statements that were used to assess the individual commitment were e.g.: 'I think that all accidents (injury-people & damage-objects) can be prevented'; 'I am personally committed to a zero accidents vision (preventing all accidents - injury to people and damage to objects)' and 'I think that safety performance can always be improved'. To assess organizational commitment to ZAV, we asked each participant to respond to the statements: 'Our workplace is committed to a zero accidents vision (preventing all accidents - injury to people and damage to objects)' and 'The

Management in our company is truly committed to a zero accident vision (preventing all accidents - injury to people and damage to objects)'.

There were four answering categories for each of the items in the questionnaire ranging from (1) 'strongly disagree', (2) 'disagree', (3) 'agree' to (4) 'strongly agree'. For some items in some of the other 9 scales a 'don't know' option was provided. The survey, in English, was translated into the native language of each country, and filled in either electronically or in a paper format. We asked the companies to have the questionnaires completed by a representative sample of their company, with a minimum of 40 completed questionnaires, of which 75% or more should be completed by operating personnel. A total of 8819 questionnaires were returned. After deleting the respondents that completed less than 50% of the questions, 7972 respondents remained for analysis. Table 2 shows the number of respondents used in the analysis for each country. Participants in the surveys and the interviews were identified dependent on selection from and by the companies, and the process varied between the 27 companies. In some cases all members of staff were invited to participate in the survey, whereas in other cases convenience sampling was used until reaching the minimum limit of 40 respondents. Therefore, it is not possible to calculate the participation rate for all 27 companies.

Table 1: Zero Accident vision in 27 companies: overview of respondents by country

Country (Number of companies)	**Respondents in analysis**
Belgium (3)	251
Denmark (3)	982
Finland (4)	487
Germany (3)	1448
Netherlands (4)	3169
Poland (5)	470
United Kingdom (5)	1165
Total	**7972**

Analysis

To answer the research questions scale scores were calculated for ten dimensions, by taking the average of the item scores. However, we only calculated the scale score if the respondent had filled in at least half the scale and no less than 3 items (with an exception for the dimensions *ZAV_organisation* that had only two items).

In addition, the companies were categorised into two groups, based on the response on the two dimensions for ZAV commitment *–ZAV_Organisation* and *ZAV_Individual.* For both dimensions, scores are categorized in three categories: low commitment (indicated by a score between 1 and 2.5; see answering categories 1 to 4 above), strong commitment (indicated by a score between 2.5 and 3.5), and very strong commitment (indicated by a score between 3.5 and 4). Since in all companies ZAV has already been introduced for some time, we expected that most organisations would have high scores on commitment. This expectation was confirmed as indeed few respondents fell in the low commitment category (10% or less of the respondents per company). Therefore we differentiated only between companies with a strong or very strong commitment. As cut-off it was decided that if on average 50% or more of the respondents fell in the upper category for both dimensions (meaning 3.5 or more on both dimensions), the company was categorised as being very strongly committed to ZAV, otherwise it was categorised as being strongly committed. As a consequence 14 companies (*N* = 3472 respondents) were categorised as being strongly committed to ZAV, and 13 companies (*N* = 4313) as being very strongly committed to ZAV.

3. RESULTS

Overall, respondents indicated that both themselves and their organisations were strongly committed to ZAV ($M_{ZAV\_Individual}$ = 3.46, SD =.55, and $M_{ZAV\_Organisation}$ = 3.39, SD = .41, respectively on a scale of 1 to 4). Furthermore, the reported individual commitment to ZAV had a strong correlation with the reported commitment to ZAV of the organisation ($r = .379$, $p < .001$). In other words, respondents who reported a high personal commitment to ZAV likely also experienced a high commitment to ZAV from their organisation and vice versa.

To explore the relationship of the concept of ZAV commitment with other safety dimensions, these were analysed with regard to groups of companies that were strongly committed and very strongly committed. These groups were based on a combination of organisational and individual commitment, as explained in the methodology section of this paper. Table 2 shows that companies who had a very strong commitment to ZAV scored consistently higher on every dimension related to safety dimensions.

Table 2. Comparison on safety dimensions between companies with a strong or a very strong commitment to a Zero Accident Vision. (M=mean on scale of 1-4)

	ZAV Commitment category	*N*	*M*	*SD*	*F*	*DF*	*P*
Communication							
Communication - Management	Strong	3573	3.02	0.48	247.35	(1. 7883)	.000
	Very strong	4311	3.19	0.49			
Communication - Individual	Strong	3614	2.87	0.45	207.89	(1. 7929)	.000
	Very strong	4316	3.02	0.47			
Safety Culture and Climate							
Climate priority	Strong	3546	2.99	0.47	293.04	(1. 7863)	.000
	Very strong	4318	3.17	0.47			
Climate justice	Strong	3258	2.88	0.42	284.93	(1. 7233)	.000
	Very strong	3976	3.07	0.52			
Safety empowerment	Strong	3517	2.92	0.49	380.79	(1. 7730)	.000
	Very strong	4215	3.14	0.50			
Safetyclimate - group level	Strong	3441	3.03	0.40	104.29	(1. 7599)	.000
	Very strong	4159	3.13	0.39			
Learning							
Learning - actions	Strong	3376	2.29	1.19	131.76	(1. 7426)	.000
	Very strong	4051	2.59	1.08			
Safety learning	Strong	3562	3.06	0.44	189.61	(1. 7872)	.000
	Very strong	4311	3.20	0.45			

Additionally, we explored whether respondents from seven countries differed significantly on the commitment dimensions. The mean values for organisational and individual commitment by country are summarised in Figure 1. Figure 1 illustrates that in Danish, Dutch, Polish and UK companies, there was a significant difference between organisational and individual commitment ($p<.05$). This means that respondents in the companies in those countries perceived the commitment of the organisation to be higher than their own individual commitment to ZAV.

We compared scale scores between countries for both organisational commitment and individual commitment. One-way ANOVA analyses showed significant group differences between countries on both dimensions. *(Organisational commitment:* $F(6, 7957) = 74.54$, $p < .001$, $\eta p2 = .05$; *individual commitment:* $F(6, 7374) = 34.34$, $p < .001$, $\eta p2 = .03$). The most prominent difference coming forth from the Bonferroni Post-hoc analysis was the fact that respondents from the UK companies reported significantly higher commitment to ZAV on both the individual ($M = 3.60$, $SD = .39$) and organisational ($M = 3.64$, $SD = .52$) level, compared to the other countries (means between 3.27 to 3.42 and 3.35 to 3.52 respectively).

For organisational commitment other significant differences exist between Danish companies and the rest: the Danish companies perceive organisational commitment to be significantly

higher as do the companies in other countries (except UK). Organisational commitment in Dutch companies was also significantly higher than in Belgian and German companies, but not significantly higher than in Finnish and Polish companies.
For individual commitment, the differences were less clear. As listed before, scores are significantly higher in the UK companies than in companies in all other countries. However, scores in Belgian, Danish and Finnish companies did not differ significantly from each other, but were all higher as in German and Polish companies. Scores in Danish and Finnish companies were also significantly higher than in Dutch companies, but differences between Belgian and Dutch companies were not. The companies in Poland had the lowest scores on individual commitment, which were significantly lower than in companies in all other countries except Germany.

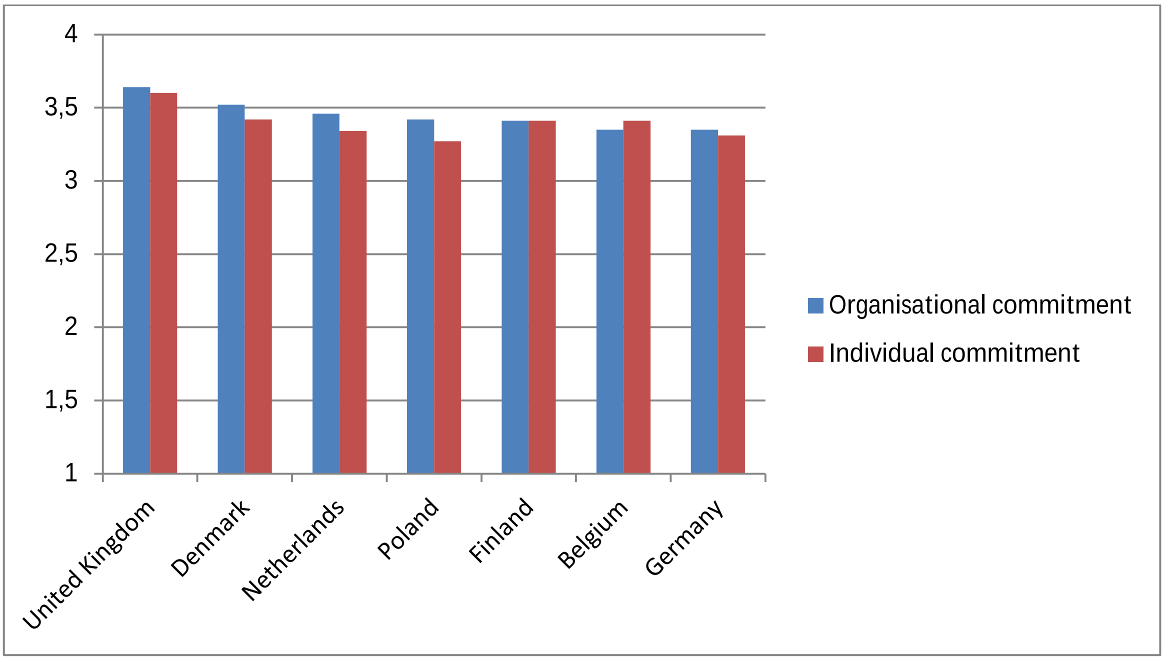

Figure 1: Zero Accident Vision - mean values for individual and organisational commitment by country (Scale 1 to 4).

4. DISCUSSION

This research explored ZAV commitment across 27 companies from 7 different European countries and revealed that companies with a very strong ZAV commitment as compared to lighter committed companies also yielded higher scores on safety dimensions such as communication, climate and learning.
The investigation presented was part of a broader research project on ZAV success factors that addressed samples of all members of staff by questionnaires , interviews and focus groups. The questionnaires from nearly 8.000 participants revealed that ZAV dimensions such as organisational and individual commitment to ZAV were correlated. This suggests that a concept like ZAV commitment requires both organisational anchoring and support as well as individual comprehension, conviction and implementation. Unfortunately, based on the questionnaires, it has not been possible to further investigate interdependencies between organisational and individual commitment. Interview data is required to further clarify these findings.
Results also show that, based on a combination of scores on individual and organisational commitment, two groups of companies could be distinguished with different levels of ZAV commitment. The group scoring highest on commitment scored significantly higher on all other safety dimensions – safety learning, climate and communication - in comparison to the other companies. Overall, also in the companies showing lighter commitment, scores on these safety dimensions were high. These findings appear to support the notion that commitment to ZAV contributes to better safety dimensions in the organisation. However, it remains difficult to attribute the safety successes to ZAV, since this study lacks a comparison group of companies that are not committed to ZAV. Also, whereas this study emphasises the possible effect of ZAV on the safety dimensions, ZAV commitment could also be considered as an outcome, where ZAV commitment is strengthened by the above described activities. A future study that compares ZAV committed companies to other companies, preferably companies that are safety

oriented (proactive) and companies that are not (reactive), would be necessary to differentiate the effect of ZAV commitment from general safety commitment. In addition, such a study could further investigate the differences between the now identified two groups, and aim to clarify the main distinction between strong and very strongly commitment means in practice. Possibly the difference between the two groups could be explained by their ability to translate ZAV into effective safety measures. Another possible hypothesis is that companies that have a longer commitment to ZAV fall into the highest category, whereas companies that recently committed to ZAV fall into the other category.

5. CONCLUSIONS

The main aims of this study were to explore levels of ZAV commitment and to explore the relationship to safety communication, climate, and learning. This study was performed in ZAV committed companies in seven European countries, as part of a broader research project on ZAV success factors. Having discussed the findings and limitations of this study, it can be concluded that although many questions remain, the findings support the importance of ZAV commitment for workplace safety. Since the group of companies with a very strong ZAV commitment - as compared to the group of companies that showed lighter commitment- yielded higher scores on safety dimensions such as communication, climate and learning, the study also seems to indicate that some of the differences in safety dimensions could possibly be explained by the level of ZAV commitment. Taken together, this study highlights possible directions for research into ZAV and lays a foundation for such research by exploring ZAV in combination with other safety aspects, in a wide range of companies and countries. Moreover, the questionnaire used in this study proved useful in studying ZAV, and may be used in future studies.

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7. REFERENCES

Aaltonen, M (2007). The zero effect model. In: The Quality of Working Life: Challenges for the Future. Liber Amicorum for the 10th Anniversary of Prevent. Prevent. Brussels, pp. 166–170.

Akselsson, R., Jacobsson, A., Börjesson, M., Ek A., and Enander A. (2012). Efficient and effective learning for safety from incidents. Work: A Journal of Prevention, Assessment and Rehabilitation, 41, 3216–3222.

Drupsteen L., Groeneweg J., Zwetsloot G.I.J.M. (2013), Identifying critical steps in learning from incidents, Journal of Occupational Safety and Ergonomics 19 (1) 63-77.

Drupsteen L. and Guldenmund F.W. (2014). What is Learning? A Review of Safety Literature on Learning from Incidents. Journal of Contingencies and Crisis Management, 22 (2), pp. 81 - 96.

Guldenmund, F.W. (2000). The nature of safety culture: a review of theory and research. Safety Science, 34, 1–3, 215-257.

Hinze, J., (2002). Safety Plus: Making Zero Accidents A Reality. CII Research Report 160–11. March 2002, University of Texas at Austin, Austin, Texas. Gainesville, pp. 110.

Jerez-Gómez, P., Céspedes-Lorente, J. and Valle-Cabrera, R. (2005). Organisational learning and compensation strategies: evidence from the Spanish chemical industry, Human Resource Management, 44(3), 279–299.

Kines P., Lappalainen J., Mikkelsen K.L. , Olsen E., Pousette A., Tharaldsen J., Tómasson K., Törner M. (2011). Nordic Safety Climate Questionnaire (NOSACQ-50): a new tool for measuring occupational safety climate. International Journal of Industrial Ergonomics, 41, 634-646.

Kletz T. (2001), *Learning from accidents*. Oxford, Butterworth-Heinemann.

Levitt R.E. & Samelson N.M. (1993). *Construction safety management.* New York: Wiley.

Liska R., Goodlow D.W., Sen R. (1993). *Zero Accident Techniques*. Construction Industry Institute, U of Texas in Austin.

MacCormack G., 1997. Zeroing In on Safety Excellence - It's Good Business!DuPont Executive Safety News. Vol.1.

Michael J.H., Evans D.D., Jansen K.J., Haight J.M. (2005). Management commitment to safety as organizational support: Relationships with non-safety outcomes in wood manufacturing employees. Journal of Safety Research, 36, 171-179.

Moran D.J. (2013). *Building Safety Commitment.* Joliet: Valued Living Books.

Petersen, D., Safety Policy, Leadership and Culture, In: Saari, J. (ed), Safety Policy and Leadership, ILO Encyclopedia of Occupational Health and Safety (4th edition, volume 2), 1998, pp 59.2-59.7.

Rasmussen H.B. (2013). Towards zero vision. The possibilities and challenges for accident prevention in the Danish oil and gas industry. Archives des Maladies Professionnelles et de l'Environnement, Volume 74, Issue 5, 554

Reason, J.T. (1997). *Managing the risks of organisational accidents*. Ashgate Publishing.

Young S. (2014) From zero to hero. A case study of industrial injury reduction: New Zealand Aluminium Smelters Limited. Safety Science, 61, 99-108.

Zwetsloot G., Aaltonen M., Wybo J.L., Saari J., Kines P., and Op De Beeck R. (2013), The case for research into the zero accident vision, Safety Science 58, 41-48.

Zwetsloot G., Drupsteen L., Kines P., Ruotsala R. (unpublished) Research into Zero accident vision: Success stories from 27 EU companies Paper for Working on Safety conference, 23-25 September 2015, Porto, Portugal.

Health and safety in small construction sites: A comparative analysis between brazil and Portugal

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Topics:
Research into practice
Understanding the knowledge base of OSH practice

Abstract
The Construction Industry is traditionally considered an industry that develops hazardous activities, in view of the high incidence of accidents and especially those fatal ones. Given this scenario, Portugal and Brazil have legislated on the various aspects of health and safety in this atypical industrial sector. The current study presents a literature review and empirical research from semi-structured interviews with various players from this area in Portugal and Brazil. The central objective of this research was to compare the laws of both countries on health conditions and occupational safety in small construction sites, in order to identify possible future contributions to improve the analysed sites. The results demonstrate that, in practice, much remains to be investigated for safety requirements and occupational health in small construction sites to be covered. It was concluded that either countries have a consistent legislative corpus, which one can withdraw contributions both to Portugal and to Brazil.

Keywords: Construction industry, Small construction sites, Legislation, Portugal, Brazil.

1. INTRODUCTION

The Construction industry is a sector that presents specificities within the productive universe of economy, whether in Portugal or Brazil, playing a key role in the development of both countries.
Currently, in Portugal, the number of jobs in the Construction industry increased by 3% from the 3rd to the last quarter of 2013, from 288.9 to 298.1 thousand workers. The contribution of public works in construction industry for the Portuguese Gross Domestic Product (GDP) was 0.9% in 2013 (INCI, 2014). In Brazil, this sector has already represented about 10% of its GDP in the early 2000s (Araújo and Meira, 2001), and more recently, in 2013, it accounted by itself for 5.4% of Brazil's GDP, with more than 3.5 million workers among the formal employment with a signed labor card (Apeop, 2015).
However, the construction sector - in both countries - also stands out for presenting high levels of work-related accidents. In Portugal, according to the Authority for Working Conditions (ACT), in 2014 there were 308 serious accidents in work activities and of these, 88 were in the Construction Industry, as well as from the 135 fatal accidents, construction held 41 cases, remaining in the 1st position among all other activities in the last three years. Data from the Superior Labor Court (TST, 2015) show that, in Brazil, in 2010, there were 54,664 accidents in construction, making this sector the second in number of accidents and, according to the Social Welfare, in 2013, as the second activity in accidents with fatalities.
Towards this context, Brazil and Portugal have revised and/or created laws in order to change these statistics and, above all, ensure safety and health for all involved workers. In Brazil, the pertinent legislation comprises a set of Regulatory Norms (NRs), while in Portugal these are through Decrees.
To characterize the small construction sites in Portugal and Brazil - the focus of this present work, legislations were analyzed, observing all conditions led to characterize and define the concept of small construction site. The present paper aims to compare the legislation on occupational health and safety in the small construction sites in Portugal and Brazil, in order to identify possible future contributions.

This comparative analysis may result in concrete indications of how a country can benefit from the positive experience from the other..

2. THE BRAZILIAN PANORAMA

2.1. Data From the Sector

According to the Brazilian Chamber of Construction Industry (CBIC, 2015), in August 2014, the average cost of construction increased by 0.26% in the country, being Southeast (where the largest cities are concentrated: São Paulo and Rio de Janeiro), and the Central West the regions registered as the highest increases. If in 2010 the GDP of the construction sector in Brazil had grown by 13.1%, in 2014 this percentage was negative, with a 2.6% decrease. These are the reference data of construction for the Brazilian economy and, more specifically, the construction industry has still a strong presence, both in the number of companies and workforce.

However, it is important to stress that, in the field of construction, recruitment is generally made by subcontractors and, as pointed out by Lima Júnior (2005), has specific characteristics, such as high turnover, combined with a low-skilled professional, as well as nomadism and short duration of the works

In this regard, even the construction sector thus offering fewer jobs in 2014, according to official data, it is essential to remember that these data do not include the majority of employees from small construction sites. Since, many of these contractors do not work with a formal contract and, therefore, do not make part of the formal employment universe, do not contribute to Social Welfare and, therefore, do not make part of the formally "employed personnel" universe of the construction sector.

2.2. Current Legislation

The labor legislation in Brazil was firmed with the Consolidation of Labor Laws (CLT), in the government of Vargas, in 1940 (Decree Law n$^{o.}$ 5452, from May 1, 1943). Chapter V of Title II of CLT refers to the safety principles and occupational health, topics that have been improved in 1967.

Since then, the protection instruments of workforce were improved but, when it comes specifically to the construction industry, the legislation was only consolidated in the 1970s, with the publication of the Regulatory Norms (NRs).

The NR-18 refers to the construction industry, and regulates the construction, demolition and repair works: establishes administrative and organizational guidelines, focusing on the implementation of control measurement and preventive safety systems in processes, conditions and working environment of the construction industry. According to Cruz (1998), NR-18 brought innovations in its formulation and in how it was consolidated, sticking to the requirements of the International Labor Organization. Since them this normative has been through 21 amendments in its text, in order to improve the safety regulation and occupational health in Construction, being the first change in 1992 and the latest in May 2015.

Most NRs are somehow interrelated, i.e., directly or indirectly, with NR-18. It is worth mentioning the NRs that are explicitly mentioned in the NR-18 are the NR number 03, 05, 06, 09, 17 and 35.

Specifying, the NR-5 relates to the Internal Commission of Accident Prevention (CIPA), which aims to make the workforce more participative in the category accident prevention and health damage (whose last update was in 2011). As for NR-6, it is important for dealing with Personal Protective Equipment (EPI) (updated April 2015). With regard to NR-7 (updated in 2013) and NR-9 (changed in 2014), regards to the Program for Medical Control of Occupational Health (PCMSO) and the Program for Environmental Risk Prevention (PPRA), respectively. The NR-8, the NR-10 and up to NR-16 norms, regard more specific aspects of the work process. The NR-17 addresses ergonomics, which refers to the debate on the problems in work environment and processes that will depend on how the activity is structured, and the NR-35 addresses working at heights (created in 2012 and amended in 2014), it considers, for purposes of its own application, the activity performed above 2 meters. Thus, it is clear that the Regulatory Norms are well elaborated and specific to the safety and working conditions within the construction site.

2.3. Characterization of the Small Construction Work

It is a difficult task to characterize the small construction work, exactly because of its nomad, invisible and temporary characteristic, according to Lima (2008). This type of construction work is related to renovations, demolition, painting, cleaning and maintenance, creating work relationships that, in turn, are also temporary and precarious.

Importantly, the NR-18 establishes, through its Article 18.3, the Conditions and Working Environment in the Construction Industry Program (PCMAT) (last updated in 2011). However, this program is only required in establishments with 20 or more workers. It can be concluded, therefore, that if the knowledge of NR-18 and its compliance is compulsory for all construction work. This regulation, by stating that companies with up to 19 employees must follow the PCMAT, is actually leaving a serious gap regarding safety and health precepts on small construction sites, which sometimes have few people working, or even a single individual. Thus, these sites are subject to the law by not having a practice and simplified guidance of minimally acceptable conditions of work in construction, established by the NR-18.

Formally, the small construction works are those in which the number of employees in the establishment, regardless of the work stage, is up to 19 workers. The most common type of this small construction works are those of residential, construction or renovation and are linked to the NR-18, however without the aforementioned requirement for a PCMAT (Gomes, 2011).

In Brazil, due to these characteristics, the employment relationship takes place, as a rule, with no formal contract and, for the most part, only with an agreement between the parties. It is in this precariousness work relationships that worker safety conditions are weakened, leading often to error, failure and accident and therefore the lack of workers' health in small construction sites.

In this sense, the Brazilian legislation, although advanced and detailed, still lacks a simplified tool for the small work sites, even with its characteristics of nomadism and temporality, to become visible, either by the contractor, either by the labor inspection and especially, by an increasing dissemination of basic safety principles in construction. This notion has been outlined, albeit isolated and independently, in Brazil, with the development of state and local laws, in order to formalize players who are working in small construction sites and their responsibilities towards these small works to ensure the labor safety and worker's health.

3.THE PORTUGUESE PANORAMA

3.1. Data from the Sector

In recent years, there has been a sharp activity contraction in construction sector in Portugal, either in public or private works. The central, regional and local administration levels have seen their budgets constrained, which limited the opening of more public construction works. Due to the general decline in housing demand in the country, the construction works of residential buildings was greatly affected and the construction activity was greatly reduced in this sector too. Also, due to the widespread crisis that has developed in the country, investment in non-residential buildings, including trade and services, was also very low.

According to FEPICOP, although the Portuguese GDP has registered in 2014 the first growth of the past three years, the downfall of construction sector has not stopped yet, even though it softened. The GVA of construction sector in 2014 fell by 4%, while in 2013 it had reduced from 13.1% and in 2012 from 14.7%.

The level of oriented demand for the sector has been declining. In public works, when comparing the first two months of 2015 with the same period in 2014, falls of 56% are observed in the value of public tenders and 37% in signed contracts. In residential buildings, in January 2015 there was an increased of 8.2% of new construction permits and a decline of 17.6% in rehabilitation work permits, if compared to January 2014. As for housing loans granted in January 2015, an increase of 39.3% was observed compared to January 2014, yet the volume of credit granted is still at historically low levels. In non-residential buildings, in January 2015 there were breakages in permits for new construction by 15.7% and breaks in the licenses of rehabilitation works by 27%, in relation to January 2014.

3.2 Legislation of Labor Safety and Health in Portugal

In Portugal there is enough legislation on occupational safety and health, much of this legislation results from transposition of European Directives. Following, the structuring Portuguese law, regarding safety and labor health in construction:

a) The Law 102/2009 of September 10th, amended by Law 3/2014 from January 28th, is often called the Framework Law, since it is the basis of all legislation on safety, hygiene and health at work, which it followed. Defines the general principles and the prevention system of occupational risks, the general obligations of the employer and workforce, the requirement for consultation, information and training of workers, and the mandatory election of representatives of workforce for safety. It requires the genetic heritage protection, defines the prohibited or conditioned activities in general,

for pregnant or breastfeeding workers, as well as for minors. It defines the organization and the functioning of labor health and safety services.
b) Decree Law 273/2003 from October 29th, establishes general rules of planning, organization and coordination to promote safety, hygiene and health at construction sites and transposes into national law Directive 92/57/CEE, of the Council, from June 24th, concerning the minimum safety and health requirements for work which apply for temporary or mobile construction sites.
There are however some legislation on labor safety and health of construction that did not result from the transposition of European Directives, including:
c) Decree 41821 from August 11th, 1958, that publishes "safety regulation in the work of construction", establishing a minimum level of safety procedures for the implementation of several high-risk activities.
d) Decree 46427 from July 10th, 1965, that publishes "regulation of temporary facilities for staff employed in the works" establishing minimum requirements for health and comfort for workers, which should be considered in the work site planning and during the execution of the construction work.
e) Law 98/2009 from September 4th, which regulates the repair regime of occupational accidents and occupational diseases, including rehabilitation and reintegration of professionals.
f) Law 42/2012 from August 28th, establishes the regime of access and the performance of occupational safety senior technician and occupational safety technician, the issuance of the respective professional qualifications and professional training of these technicians.

3.3. Characterization of Small Dimension Work Site

Although, in the Portuguese legislation there is no clear definition of what a small construction work site is. However, taking into account Article n^{o} 5 and 15 of Decree-Law 273/2003, it may be understood as a construction work site whose size and other characteristics does not require the preparation of a "health and safety plan", neither the "prior notice of the site opening".
In paragraph 4 of article n^{o} 5, states:
"The safety and health plan is obligatory in construction works subject to project and which involves activities implying special risks referred in Article 7 or the prior notice of the site opening.
In paragraph 1 of article n^{o} 15 of DL 273/2003, states:
"1 - The work site owner must give advance notice of the site opening to the General Labor Inspectorate when it is foreseen that the execution of work involves one of the following situations:
a) A total deadline superior to 30 days and, at any time, the simultaneous use of more than 20 workers;
b) A total of 500 working days, corresponding to the sum of work days from each worker."

4. METHODOLOGY

Methodologically, the study consists of two aspects. One of literature review and the other was a survey of aspects of occupational health and safety in both countries. Another aspect is an empirical research based on semi-structured interviews with professionals from various fields of training and performance in the construction industry in Portugal, in order to analyze their understanding about the political and health legislation on small work sites.
For the empirical work, a qualitative research was chosen, in order to hear the different voices of those who work in the construction industry in Portugal. Given that the directives of the European Community brought a cohesive legislative body for all countries, from the developed to those with less economic and/or financial conditions, these regulatory norms have served to suit all participant nations that Community, standardizing the minimum necessary for promoting health and safety at work in the construction industry. Thus, when electing the Portuguese case as better than the Brazilian one, it was assumed that the present qualitative research would bring important elements that could be also applied in Brazil. Accordingly, in line with Minayo (2004), the development of this small sample framework of what the workforce feel about the small construction work in Portugal, it was intended to analyze and understand how the health and safety policies work in these small work sites. Being this a qualitative analysis, sought to content analysis, to find the units of meaning in the speech of the respondents.
The research was conducted in three cities (or municipilaties) of Portugal: Porto with nearly 240,000 inhabitants; Braga, with 177,000 inhabitants; and Guimarães, with 162,000 inhabitants (INE, 2010). This diversity has allowed a more comprehensive view of the small construction work in medium and small cities of the country – which, although experiencing a fall in execution of construction works due to the crisis that now is perceived across the EU, we can see a higher concentration of small construction work - focus of research. In addition, due to the knowledge of

the authors with construction works and the persons associated with them. It was intended to diversify at most the interviewed categories specifically to obtain the widest possible universe of perspectives on construction sites and on the occupational health of construction workers.

In general, it is very difficult to get the confidence from lowest grade workers, so that they can express what they think of their labor reality – there is a great fear that those critiques could jeopardize their employment or work. However, it was also important to interview people who direct and guide the construction works, to make possible, after all, to form a bigger picture of the group of people involved in a construction work, once the goal of this study was precisely to find the flaws that lead to the precariousness of occupational health and work injuries in construction. Therefore, it was opted for semi-structured interviews with various professional categories, following a guiding script that to understand the perception of the subjects on the characteristics of a small work site. This script was previously elaborated and has been through certain adjustments after a survey with some respondents. The interviews were not recorded and all respondents were informed of the survey content, being explained that they would not be identified.

The central focus was to verify how these respondents saw the differences between large and small work sites, with emphasis on knowledge of the Regulatory Norms (NRs)and legislation; in the protection practices; in the most common failures; in the differences of protection, inspection and surveillance according to the size of the construction works; in the perception regarding the protection equipment; in the understanding of the causality of the most frequent accidents on construction sites and in the practices of prevention as well as the State's role in the supervision of working and safety conditions in the workplace.

Persons responsible for supervision, professionals from different categories that operate in the sector or are directly involved in the small work sites processes, as well as workers were interviewed. In all, there were twelve people, distributed as follows: three labor inspectors, two civil engineers from small construction work; two architects from small construction work; a work safety technician; two people in charge of small work projects; a union in connection with employees; a member of employers' association linked to the area players. The interviews were carried out at the construction sites or in their offices, as in the case of labor inspectors.

The current study considered that the sample of 12 respondents is broad enough to include different professionals, directly or indirectly involved in the construction industry; and that the responses found would permit outlying a research overview in which "the assessment of theoretical saturation from a sample is made by a continuous process of data analysis, begun in the early collection process" (Fontanella, 2008). A comprehensive reading of the entire field material was performed and, from there, the most significant contents were sought within the records, which were analyzed as relevant issues.

5. RESULTS

For the respondents, as a rule, the Portuguese construction work still requires a more specific look, although it is recognized that the legislation covers the fundamental aspects. Besides, it was clear that, for medium and large companies, there is no doubt left as to what needs to be done in terms of worker health and safety in small construction yards. However, when it comes to a small construction site, not only in Brazil, but also in Portugal communication is precarious, the inspection struggles to track these small construction yards, often invisible and temporary, so that today an employee may be doing a little repair in a residence and tomorrow will be in another, either through a small business or by their own, as an autonomous - and therein lies the difficulty of applying regulatory norms, as analyzed by the authors and respondents.

<u>Different conceptions of small work site</u>

For a civil engineer, a small construction work site "has up to 50 employees". By the understanding of the person in charge of the small work site, "around 30 employees." The safety technician affirmed that "a small work site has up to 100 employees", while the union representative believes that the small construction work site "has between 100 and 200 workers."

This divergence among respondents reveals an absence of specific parameter based on some classification criteria in the literature, in addition to express unawareness of the rules.

<u>Occupational health and safety in small work sites</u>

Respondents had also different understandings regarding safety in small work sites, which leads to the fragility of occupational health. Formally, most of respondents expressed their understanding through comparisons with the large scale work and ended up giving more emphasis to the use of Personal Protective Equipment, ignoring other forms of work safety. Explicitly or implicitly, referred that in small work sites there is no safety policy, attributing this deficiency to various reasons.

<u>Occupational accident and its causality</u>

There are still few studies available in academic literature on the percentage of the construction workers suffering some kind of occupational accident (considering that the official data refer only to those formal contract employees, as general rule, in larger construction work sites and almost never in small work sites).
Thus, it may be affirmed, it is the task content - the pace, the production of the work - that cause accidents, according to some respondents. Both the employee in charge and the architect declare "the pace of work is different when it comes to small or large construction work and therefore the logic is another".
State's role
It was found that, with respect to public policy, all respondents pointed out that the state has worked to minimize the failures in supervision. For labor inspectors, the state has been contributing with information campaigns in order to facilitate access to safety procedures in any activities that generate risks to workers.

6. DISCUSSION

6.1. Small construction work site - Brazil versus Portugal

For Brazil, the main regulatory norm is NR-18, which should be known by all and must be followed regardless of the size or temporality of the work being performed. However, the PCMAT must only be applied in work sites with more than 20 workers, and those with fewer shall be exempted to present a program regarding labor conditions. It is noteworthy that, in Brazil, it is considered workplaces with fewer than 20 employees. It also characterizes what is meant by small construction work site.
In Brazil, until recently (before 2013), nothing required the owner (contractor) of a small work site, with one or few temporary workers, to report to anybody the future realization of a construction work in an office, a store, or in a residence. Strictly speaking, a small construction work site. Just recently, laws and decrees at the state and municipal levels are being developed (with no coverage throughout the country), in order to regulate small construction sites. In the state of Rio de Janeiro, the State Law n^{o} 6,400/2013, which determines the inspection of both internal and external (facades) work sites, the Complementary Law 126/2013, which requires inspections of buildings every five years, and the municipal Decree n^{o} 37,426/2013, which establishes the technical inspection in constructions of the city of Rio de Janeiro. The creation of similar laws and decrees in other Brazilian states and cities are under study.Rio de Janeiro (both state and city), for its large number of infrastructure projects, has also a large number of smaller, residential or private construction works that were not under any NR, precisely for being small work sites and of few workers.
In Portugal, if to perform a work it is not necessary to establish the "safety plan and health", neither the "prior notice of the site opening", one shall consider to be a small construction work. However, questions arise in the interpretation of legislation, including:
The analysis of paragraph 4 of Article 5 from DL 273/2003, it is necessary to know when the construction works are "subject to project," but this is not clear in the Portuguese legislation, nor is it public works, or particular works.
The analysis of a) and b) of paragraph 1 of article 15 from DL 273/2003, in order to assess whether a particular work may or may not be considered as a "small work", there needs to be a detailed schedule of its execution, once without it one might not know the deadline, nor the daily load of workforce, or the total amount of work required to perform the work.
From it arouses two new questions:
- Do businesses make a sufficiently detailed planning of the work execution, supplying the necessary information to be able to assess the need to do or not to "prior notice of the site opening"?
- Does the Portuguese legislation requires such detailed planning of the works?
Regarding the first question, it is considered important to analyze two scenarios. First, if the small work is done by a medium or large company, once these have a significant technical and administrative structure, it is very likely that a detailed planning of the works to be performed will arise. Second, if the small work is made by a minor company, as its structure is based almost exclusively on production, it is less likely that a detailed planning of the works will arise. For the same reasons, it is even less likely than in microenterprises a detailed planning of the works will arise.
Regarding the second question, it is considered that in public works a detailed schedule of execution is necessary, however in private works that's no longer the case. The Legal system of

Urbanization and Building regulates private works and, in paragraph 1 of Article 11, Decree 232/2008, reports the elements necessary to the licensing applications for construction works. The only required element concerning deadlines for project execution, workforce load, or the work required to carry out the works is in its paragraph i), in which is only required one "timing of the work implementation;". In practice, it leads to any agenda to be accepted by the majority of municipalities, although with no technical basis, or the necessity to inform or not “prior notice of the site opening”.
In Portugal, in accordance with DL 273/2003, even a small work, for which it is not necessary to establish the "safety and health plan", if the activities present special risks referred in Article 7, is an obligation to keep records of safety procedures, in accordance with Article 14ºl in order to avoid accidents.
Finally, if in Portugal the requirement lies in the temporality of work, in Brazil, characterizing the small work does not refer to any deadline for its implementation. It remains as standard equality, that in both countries a small work is the one that has less than twenty employees, a criterion that does not contribute to promoting the necessary health and safety measures for the small work sites.

6.2. Health and Safety Legislation - Brazil versus Portugal

In Brazil, as described above, there is only one Regulatory Norm (NR 18) that although referring to other standards is simply the main document that aims to detail all the procedures necessary for the health and safety processes and in the workplace. This makes it a too prescriptive and detailed norm for its correct applicability, especially in small work sites.
In Portugal, however, there is a number of decrees and laws that, for being more diverse and punctual, allow a better understanding of safety procedures. Regarding that, it is noteworthy what is described in DL 273/2003 on the characterization and definition of roles of the main players responsible for the aspects of safety and health at construction sites, such as safety coordinators; the developer; director the work site; subcontractors; etc .. aspects whose are not made explicit in the Brazilian standard.
It still must be considered that Portugal, a member of the EU, by outlining policies common to all countries in the bloc benefits from this exchange of information among the other countries. This fact allows to closely monitor how each country, from the 28 EU members, has adapted these guidelines to its national law and what has reached to minimize accidents in their own construction sites.

7. FINAL CONSIDERATIONS

From these results, it is possible to verify that, in Brazil, the inspection in small works is still often ineffective - either by the size of the country and the great number of limited work sites to homes, offices and facades, where the nomadic nature makes it difficult for the health and safety aspects to be observed - and that, in Portugal, inspection appears to be more frequent and possibly more effective.
This study had an investigative character, in which it sought to recognize what legislation and the health and safety practices of the construction industry might contribute to this issue, when it comes to small works. It is urgently needed to elect committees that will seek solutions to ensure that small works will be communicated, authorized to open their sites, and inspected, especially in Brazil, which can learn from Portugal some guidelines from their legislation, which in practice can work in order to have greater safety, even in small works, and more health to workers.
It is believed that technical cooperation between engineers, lawyers, administrative staff of workers safety and health area can bring some light to this subject. However despite seeking solutions for the worker from small work site, is still insufficient. Especially by the volatility of this work carried out in private homes, shops, or offices, for the speed with which they are done - making it difficult to supervise - and for dealing in these situations with workers outside health and safety precepts at work.

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9. REFERENCES

Araújo, João Miguel Santos Melo de. **A gestão do conhecimento nas empresas de construção**. Organização de estaleiros e fase de arranque de obras como ponto de partida. Dissertação de Mestrado em Engenharia Civil. Porto: Universidade do Porto, 2011.

Araújo, Nelma Mirian Chagas de e Meira, Gibson Rocha. **Legislação sobre segurança e saúde no trabalho no setor da construção: um estudo comparativo entre as normas brasileiras e as diretivas da CEE**. In: 21 Encontro Nacional de Engenharia de Produção e 7 Congresso Internacional de Engenharia Industrial, 2001, Salvador. Anais do 21 Encontro Nacional de Engenharia de Produção e 7 Congresso Internacional de Engenharia Industrial, 2001.

Associação Paulista de Empresários de Obras Públicas – Apeop. **Boletim**. 2015. Disponível em: http://www.apeop.org.br/apeop/. Acesso em 07 fev. 2015.

Baganha, Maria Ioannis, Marques, José Carlos e Góis, Pedro. **O sector da construção civil e obras públicas em Portugal: 1990-2000**. Pemint, Relatório 1-P European Commission, 5th Framework Programme Improving Human Potential and Socio-Economic Knowledge Base Key Action for Socio-Economic Research (Contract No. HP-CT – 2001 – 00059). [2001]

Banco de Portugal. **Análise do setor da construção**. Estudos da Central de Balanços. Jan./2014.

Brasil. Ministério do Trabalho e Emprego (2014). **Norma Regulamentadora 18**. Disponível em: www.mte.gov.br. Acesso em 15 maio 2015.

Cabrito, Arlindo José Ribeiro Mendes. **A segurança e saúde no trabalho da construção e a aplicação dos princípios gerais de prevenção na fase de projecto**. Dissertação de Mestrado. Minho: Universidade do Minho, 2002. Disponível em: http://hdl.handle.net/1822/833. Acesso em 10 maio 2015.

Câmara Brasileira da Indústria da Construção – CBIC. **Banco de dados**. Disponível em: http://www.cbicdados.com.br/home/. Acesso em 25 maio 2015.

Cruz, Sybele Marla Segala da. **Gestão de segurança e saúde ocupacional nas empresas de construção civil. Florianópolis**.Universidade Federal de Santa Catarina. Programa de Pós-graduação em Engenharia de Produção. Dissertação, 1998.

Fontanella, B. J. B. et al. Amostragem por saturação em pesquisas qualitativas em Saúde. Cad. Saúde Pública, Rio de Janeiro, 24 (1): 17-27, jan. 2008.

Fundação Getúlio Vargas – FGV. **Número de empregados na construção encolheu**. In: Revista Exame. 02 fev. 2015. Disponível em: http://exame.abril.com.br/economia/noticias/numero-de-empregados-na-construcao-encolheu-em-2014-diz-a-fgv. Acesso em 10 maio 2015.

Gomes, Haroldo Pereira. **Construção civil e saúde do trabalhador: um olhar sobre as pequenas obras**. 2011. 23f. Tese (Doutorado em Saúde Pública) – Escola Nacional de Saúde Pública Sergio Arouca, Rio de Janeiro.

Instituto Brasileiro de Geografia e Estatística. **Pesquisa Anual da Indústria da Construção – PAIC**. Rio de Janeiro, Vol. 22. 2014.

Instituto da Construção e do Imobiliário - INCI. **Relatório Anual do Sector da Construção em Portugal**. Lisboa: INCI, 2014.

Instituto Nacional de Estatistica-Portugal .Estimativa de população residente dezembro/2010

Lima Júnior, Jófilo Moreira. **Segurança e saúde no trabalho da construção: experiência brasileira e panorama internacional**. In: Lima Júnior, Jófilo Moreira, López-Varcárcel, Alberto, Dias, Luis Alves. ______ . Brasília: OIT – Secretaria Internacional do Trabalho, 2005. Série Documentos de Trabajo, 200.

Lima, Raildo de Oliveira. **Verificação da qualidade na construção civil em um pequeno canteiro de obra de Foz do Iguaçu, uma mudança de paradigma**. Foz do Iguaçu: União Dinâmica das Faculdades Cataratas. Curso de Engenharia Civil, 2008.

Organização Internacional do Trabalho – OIT. In: DIAS, Luiz Alves. **Segurança e Saúde no Trabalho da Construção na União Europeia**. 2004. Disponível em: www.oit.org.pe/WDMS/bib/publ/doctrab/dt_200_port.pdf. Acesso em 15 fev. 2015.

Tribunal Superior do Trabalho – TST. **Dados dos acidentes do trabalho de 2011**. Disponível em: http://www.tst.jus.br/web/trabalhoseguro/dados-nacionais. Acesso em 07 fev. 2015.

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Impact of R&D technology and economic growth on companies' occupational safety and health strategies

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Abstract

Introduction: In the skill-biased technological change (SBTC) literature labour endowments influence the direction of technological knowledge, which, in turn, drives the wages of skilled and unskilled labour. The SBTC literature has been interpreting the rise in the skill premium as a result of the market-size effect. We analyse the direction of technological knowledge in a dynamic setting where, in line with the literature on scale effects, the scale effects are removed. Moreover, we follow reports of the Organisation for Economic Co-operation and Development, which point out that the capability to innovate and to bring innovation successfully to market will be a crucial determinant of the global competitiveness of nations over the coming decade. Indeed, there is growing awareness among policymakers that innovative activity is the main driver of economic progress and well-being as well as a potential factor in meeting global challenges in domains such as the environment and health. It is reported in literature that the influence of R&D intensity on firms' growth is an issue of great interest and complexity. R&D investment increases absorptive capacity, i.e. the capacity to absorb knowledge created from the relationships formed with agents outside the firm, as well as the capacity to use that knowledge to increase firm performance. In consequence, firms have to adjust their priorities regarding the investments namely in the Occupational Safety and Health (OSH).

Objective: This paper proposes a lab-equipment vertical R&D endogenous growth model to explain, for innovative countries, the co-movement of the respective R&D intensity, economic growth and the firm-size growth, by exploring the short-medium-run and the long-run growth effects.

Methodology: Bearing in mind some recent literature, it is possible to improve the R&D technology by considering that R&D is more labour intensive through time as complexity increases. It also possible to do that by introducing risk assessment, that the diffusion of designs is affected by coordination, organizational and transportation costs, and that a potential entrant will come up with the right idea is reduced because of the presence of a larger number of entrants. **Results and Discussion**: We show that when the economy is not initially on steady state, it can take a saddle path towards the unique and locally saddle-path stable interior steady state. The transitional dynamics and the steady state behaviour of our model are then consistent with, respectively, the time-series and the cross-sectional evidence.

Conclusions: Instead of the market-size channel emphasised by the SBTC, we propose another explanation for skill-biased technological knowledge. By removing the scale effects, we propose a new mechanism by which the pool of labour increases the rate of technological-knowledge progress and thus determines the technological-knowledge bias. Indeed, through the price channel, the technological-knowledge bias increases but at a decreasing rate until it reaches its new higher steady state. Concerning wage inequality, we find that an increase in skilled labour causes an immediate steep drop in the skilled premium since its relative supply decreases its relative wage. This immediate effect is reverted in the transitional dynamics towards the constant steady-state skilled premium, due to the stimulus to the demand for skilled labour resulting from the technological-knowledge bias. Moreover, we note also that with a sufficiently strong technological-knowledge-absorption effect, the steady-state high-skilled premium is greater than the previous one.

Keywords: R&D technology, Economic growth, Occupational Safety and Health.

1. INTRODUCTION

According to the European Commission (2010) Europe's average growth rate has been structurally lower than that of our main economic partners, largely due to a productivity gap that has widened over the last decade. Much of this is due to differences in business structures combined with lower levels of investment in R&D and innovation, insufficient use of information

and communications technologies, reluctance in some parts of our societies to embrace innovation, barriers to market access and a less dynamic business environment.
As new technologies and globalisation reduce the importance of economies of scale in many activities, and larger firms downsize and outsource more functions, the weight of Small and Medium-Sized Enterprises (SMEs) in the economy is increasing. The potential of small enterprises has been recognised and it is appreciated that employment and economic growth to a large extent depend on these enterprises. Both political and scientific interests in OSH in small enterprises have grown considerably during the last decade. In terms of OSH, small businesses present a challenge: they are difficult to regulate, as they are heterogeneous, geographically scattered, lack cohesive representation and have a short life cycle. The need to focus OSH research on small businesses is now recognised, but effective mechanisms to reach, assist and impact these companies continue to be a challenge. To date, most OSH research and interventions have been primarily focused on large companies (EU-OSHA, 2014).
For reasons of simplicity, we reflect in R&D technology all these concerns, by making use of the concept risk assessment, which represents an entry cost. In particular, we consider that the difficulty in conducting R&D is proportional to the size of the market measured by the stock of labour, which results in a 'permanent-effects-on-growth' specification (see, e.g., Dinopoulos and Segerstrom, 1999) because the technological-knowledge progress and economic growth are endogenous. In this case, however, the chain of effects is induced by the price channel, by which there are stronger incentives to improve technologies when the goods that they produce command higher prices, i.e., technologies that use the scarcer labour are favoured.
In order to understand the mechanism, we model a standard (in endogenous R&D-growth theory) economic structure. The production of perfectly competitive final goods uses labour together with quality-adjusted intermediate goods, which in turn use innovative designs under monopolistic competition. In particular, each final good can be produced by one of two technologies: one uses high-skilled labour together with a continuum set of high-specific intermediate goods; the other brings together low-skilled labour and a continuum set of low-specific intermediate goods.
The European Agency for Safety and Health at Work (EU-OSHA, 2014) promotes good safety and health at work environments as an integral part of the smart and inclusive growth objectives of Europe 2020. This model meets the priorities for occupational safety and health research in Europe for the years 2013-2020, which includes keeping people healthy and active for long periods, having a positive impact on global productivity and competitiveness. Thus, OSH research have a role to play in delivering smart, sustainable and inclusive growth. Reaching the high-level goals of Horizon 2020 and the overall EU policies for the next decades will depend on the success of new enabler technologies such as those needed for new energy policies, climate adaptation and future manufacturing. However, new technologies will succeed only if the benefits are clearly visible and the potential risks are regarded as acceptable by society. This requires identifying and addressing stakeholder and public expectations and responding to their concerns in order to build trust and confidence and to show that the new technologies are 'well under control'. This in turn requires identifying and assessing the safety and health risks associated with new technologies and integrating OSH aspects in the development of new technologies and processes, as well as strengthening risk communication and OSH communication.
According to reports of the Organisation for Economic Co-operation and Development (OECD, 2007), undoubtedly the capability to innovate and to bring innovation successfully to market will be a crucial determinant of the global competitiveness of nations over the coming decade, which is accommodate by our model. There is growing awareness among policymakers that innovative activity is the main driver of economic progress and well-being as well as a potential factor in meeting global challenges in domains such as the environment and health. It is reported in literature that the influence of R&D intensity on firms' growth is an issue of great interest and complexity. R&D investment increases absorptive capacity, i.e. the capacity to absorb knowledge created from the relationships formed with agents outside the firm, as well as the capacity to use that knowledge to increase firm performance. In consequence, firms have to adjust their priorities regarding the investments, namely in the OSH domain. In fact, firms are dealing with limited financial resources, and as a consequence, they need to make decisions about financial resources, being the management strategies for productive process often dissociated from OSH issues.

OSH shall contribute to research and development (R&D) related to anticipating, recognising, evaluating and controlling health hazards in the working environment with the objective of protecting worker health and well-being.

The economics of occupational safety and health (OSH) has been viewed for many little more than "how can better working conditions be made profitable for business?" (Dorman, 2000). Certainly, the financial costs and benefits involved in OSH are an important aspect of economic analysis, but above all, economics is a social science; its perspective is that of society as a whole, which includes workers, their families and their communities as well as enterprises, and it recognizes that not all the effects of ill-health show up in monetary transactions.

According to Dorman (2000), broadly speaking, there are three general purposes that economics can serve for OSH. Firstly, identifying and measuring the economic costs of occupational injury and disease can motivate governments to take these problems more seriously. This is true at all levels; the enterprise may be only dimly aware of the toll that worker ill-health takes on its performance and national governments may not realize the impact of OSH problems on economic growth and development. Secondly, understanding the connections between the way firms and markets function and the types of OSH problems that arise are crucial for the success of public policies. Finally, the author refers that the protection of worker health and wellbeing is not the only objective of OHS in a modern society. Economic analysis can help to show when safeguarding working conditions are also complementary to other social goals, and it can enlighten the trade-offs if they exists.

According to ILO (2013) the OSH becomes ever more important during an economic crisis because it can protect and promote better health and this can lead to increases in labour supply and productivity. Also, historically, health has been a major contributor to economic growth. Therefore it is important to assess what impact there has been on OSH management during the global economic crisis, as well as to determine the impact further economic decline and other organizational issues may have on OSH.

To our knowledge, McDermott (2002) was the first in the literature on endogenous growth to emphasize the benefit of industrial diversification, or a greater variety of intermediate production inputs, for human capital accumulation. According to Agénor and Dinh (2015) links between social capital, human capital, and product imitation are studied in an overlapping generations model of economic growth with endogenous time allocation. Social capital promotes imitation and there is a two-way interaction between imitation and human capital. Building social capital (which brings direct utility) requires time and access to infrastructure. Because life expectancy is endogenously related to human capital, time allocation between market work and social capital accumulation is also endogenously determined.

In the skill-biased technological change (SBTC) literature – e.g., Acemoglu and Zilibotti (2001) – labour endowments influence the direction of technological knowledge, which, in turn, drives the wages of skilled and unskilled labour. The SBTC literature has been interpreting the rise in the skill premium as a result of the market-size effect. We analyse the direction of technological knowledge in a dynamic setting where, in line with the literature on scale effects (e.g., Jones, 1995a, b), the scale effects are removed.

Moreover, we follow reports of the Organisation for Economic Co-operation and Development (OECD, 2007), which point out that the capability to innovate and to bring innovation successfully to market will be a crucial determinant of the global competitiveness of nations over the coming decade. Indeed, there is growing awareness among policymakers that innovative activity is the main driver of economic progress and well-being as well as a potential factor in meeting global challenges in domains such as the environment and health. It is reported in literature (see, e.g., Cohen and Levinthal, 1990; De Jong and Freel, 2010) that the influence of R&D intensity on firms' growth is an issue of great interest and complexity. R&D investment increases absorptive capacity, i.e. the capacity to absorb knowledge created from the relationships formed with agents outside the firm, as well as the capacity to use that knowledge to increase firm performance. In consequence, firms have to adjust their priorities regarding the investments namely in the Occupational Safety and Health (OSH).

In fact, firms are dealing with limited financial resources, and as a consequence, they need to make decisions about financial resources, being the management strategies for productive process often dissociated from OSH issues.

2. MATERIALS AND METHOD

2.1. Final goods sector

Following the contribution of Afonso (2006), each final good $n \in [0, 1]$ can be produced by the L-technology, which uses unskilled labour, L, complemented with a continuum of L-intermediate goods indexed by $j \in [0, J]$, or by the H-technology's, which uses skilled labour, H, complemented with a continuum of H-intermediate goods indexed by $j \in]J, 1]$. The output of n, Y_n, at time t is,

$$Y_n(t) = A\left\{\left[\int_0^J \left(q^{k(j,t)}\, x_n(k,j,t)\right)^{1-\alpha} dj\right]\left[(1\text{-}n)\, l\, L_n\right]^{\alpha} + \left[\int_J^1 \left(q^{k(j,t)}\, x_n(k,j,t)\right)^{1-\alpha} dj\right]\left[n\, h H_n\right]^{\alpha}\right\}. \quad (1)$$

A>0 represents the level of productivity, dependent on the country's institutions. The integrals sum up the contributions of intermediate goods: the quantity of each j, x, is quality-adjusted – the constant quality upgrade is $q > 1$, and k is the highest quality rung at time t. The expressions with exponent $\alpha \in]0, 1[$ represent the role of labour. An absolute productivity advantage of H over L is captured by $h > l \geq 1$. A relative productivity advantage of either type of labour is captured by n and (1-n), which implies that H is relatively more productive in final goods indexed by larger ns, and vice-versa.

Plugging the demand for the top quality of each intermediate good j by the producer of n into (1), the supply of final good n is

$$Y_n(t) = A^{1/\alpha}\left[\frac{p_n(t)\,(1-\alpha)}{p(j,t)}\right]^{\left(\frac{1-\alpha}{\alpha}\right)}\left[(1-n)\; l\, L_n\; Q_L(t) + n\, h H_n\, Q_H(t)\right], \quad (2)$$

where $Q_L \equiv \int_0^J q^{k(j,t)[(1-\alpha)/\alpha]}\, dj$ and $Q_H \equiv \int_J^1 q^{k(j,t)[(1-\alpha)/\alpha]}\, dj$ (3)

are two aggregate quality indexes, measuring the technological knowledge in each range of intermediate goods, adjusted by market power that is the same for all monopolistic producers; the ratio $D \equiv Q_H/Q_L$ is the relative productivity of the technological knowledge used together with H; and $p_n(t)$ and $p(j, t)$ are the prices of n and of j, respectively.

We define the aggregate output, *i.e.*, the composite final good, as:

$$Y(t) \equiv \int_0^1 p_n(t)\, Y_n(t)\, dn = \exp\left[\int_0^1 \ln Y_n(t)\; dn\right], \quad (4)$$

where we normalise its price at each time t to one. Resources in the economy measured in terms of aggregate output, Y, can be used in production of the intermediate goods, X, in the R&D sector, R, or consumed, C; *i.e.*, $Y(t) = X(t) + R(t) + C(t)$.

2.2. Intermediate goods sector

Since Y in (4) is the input in the production of $j \in [0, 1]$ and final goods are produced in perfect competition, the marginal cost is one. Since the production of j requires a start-up cost of R&D, profits at each date need to be positive for a certain time in the future. For this, there is a system of intellectual property rights that protect the leader firm's monopoly, but the technological knowledge on how to make j tends to be public.

The profit-maximisation price of the j firms yields $p(k, j, t) = p = 1/(1-\alpha)$, which is a mark-up, since $p > 1$. This mark-up is stable over t, across js and for all qualities, which makes the problem symmetric. Since the leader firm is the only one legally allowed to produce the highest quality, it will use pricing to wipe out sales of lower quality.

Such as Grossman and Helpman (1991, Ch. 4), for example, we assume that limit pricing strategy is binding and then is used by all firms, so that $p = q$. Since the lowest price that the closest follower can charge without negative profits is 1, the leader can capture all market by selling at a price slightly below q.

2.3. R&D sector

The value of patent relies on the profits at time t, and on the duration of the monopoly. The duration, in turn, is governed by the probability of successful R&D, which creatively destroys the current leading-edge design. The probability of success is thus at the heart of the model. Let $pb(k, j, t)$ denote the instantaneous probability at time t – a Poisson arrival rate – of successful innovation in the next quality intermediate good *j*, *k*(*j*, *t*)+1, which complements *m*-type labour (where $m = L$ if $0 \le j \le J$ and $m = H$ if $J < j \le 1$). Formally,

$$pb(k, j, t) = rs(k, j, t) \cdot \beta q^{k(j,t)} \cdot \zeta^{-1} q^{-\alpha^{-1} k(j,t)} \cdot m^{-1} \cdot f(j) \text{, where:} \tag{5}$$

rs(*k*, *j*, *t*) is the flow of aggregate final-good resources devoted to R&D; $\beta q^{k(j,t)}$, $\beta > 0$, represents learning by past R&D, being β the coefficient on past successful R&D experience, where a greater β depicts a better innovation capacity; $\zeta^{-1} q^{-\alpha^{-1} k(j,t)}$, $\zeta > 0$, is the adverse effect, *i.e.*, cost of complexity, caused by the increasing complexity of quality improvements, being ζ the fixed cost of R&D; m^{-1} is the adverse effect of market size, capturing the idea that the difficulty of introducing new quality-adjusted intermediate goods and replacing old ones is proportional to the size of the market measured by the labour employed. That is, for simplicity, the costs of scale increasing are reflected in R&D due to risk assessment, coordination among agents, processing of ideas, informational, organisational, marketing and transportation costs, as suggested by works such as Becker and Murphy (1992), Alesina and Spolaore (1997), Dinopoulos and Segerstrom (1999), Ramos et al. (2013), Ramos et al. (2015), Dinopoulos and Thompson (1999). *f* (*j*) measures an absolute advantage of *H* over *L* in R&D and we consider that

$$f(j) = \begin{cases} 1 & \text{if } 0 \le j \le J;\ i.e.,\ m = L \\ \left(1 + \dfrac{H}{H+L}\right)^{\sigma} & \text{if } J < j \le 1;\ i.e.,\ m = H \end{cases} \text{, where: } \sigma = 1 + \frac{H}{L}. \tag{6}$$

2.4. Consumers

The economy is populated by an infinitely-lived household who consumes and collects income from investments in financial assets and from inelastically supplying labour. We also assume that household has perfect foresight concerning the technological-knowledge progress over time and chooses the path of final-good consumption to maximise discounted intertemporal lifetime utility. Thus, the infinite horizon lifetime utility is the integral of a discounted CIES utility function,

$$U(a,t) = \int_0^{\infty} \left[\frac{c(a,t)^{1-\theta} - 1}{1-\theta}\right] exp(-\rho t)\, dt, \tag{7}$$

where: (i) $c(a, t)$ is the amount of consumption of the composite final good at time *t*; (ii) $\rho > 0$ is the homogeneous subjective discount rate; and (iii) $\theta > 0$ is the inverse of the inter-temporal elasticity of substitution.

The budget constraint equalises income earned to consumptions plus savings, which consists of accumulation of financial assets – *K*, with return *r*. The budget constraint, expressed as savings = income – consumptions, is

$$\dot{K}(a,t) = r(t) K(a,t) + w_m(t)\ m(a) - c(a,t) \text{, where : } m = H \text{ if } a > \bar{a} \text{ and } m = L \text{ if } a \le \bar{a}. \tag{8}$$

From the problem of optimal control, the solution for the consumption path, which is independent of the individual, is the standard Euler equation:

$$\hat{c}(t) = \frac{r(t) - \rho}{\theta}, \text{ where } \hat{c}(t) \text{ is the growth rate of } c. \tag{9}$$

3. RESULTS AND DISCUSSION

3.1. Equilibrium for given factor levels

The endogenous threshold final good $\bar{n}$ follows from equilibrium in the inputs markets and relies on the determinants of economic viability of the two technologies – i.e., *H*-technology is used in final goods $n > \bar{n}$ and *L*-technology in final goods $n \le \bar{n}$.

$$\bar{n}(t) = \left\{1 + \left[\frac{Q_H(t)}{Q_L(t)} \frac{h H}{l L}\right]^{\frac{1}{2}}\right\}^{-1}. \tag{10}$$

It can be related to prices since on the threshold both an *L*- and *H*-technology firm should break even. This yields the ratio of index prices of final goods produced with *L*- and *H*-technologies,

$$\frac{p_H(t)}{p_L(t)} = \left[\frac{\bar{n}(t)}{1-\bar{n}(t)}\right]^{\alpha}, \text{ where: } \begin{cases} p_L = p_n(1-n)^{\alpha} = \exp(-\alpha)\,\bar{n}^{-\alpha} \\ p_H = p_n\, n^{\alpha} = \exp(-\alpha)\,(1-\bar{n})^{-\alpha} \end{cases} \text{ since } \exp\int_0^1 \ln p_n \, dn = 1. \qquad (11)$$

The equilibrium aggregate resources devoted to intermediate-goods production, *X*, and the equilibrium aggregate output, *Y*, are expressible as a function of the currently given aggregate quality indexes,

$$X(t) \equiv \int_0^1\int_0^1 x_n(k,j,t)\,dj\,dn = \exp(-1)\left[\frac{A(1-\alpha)}{q\,(1-s_x)}\right]^{1/\alpha}\left[\left(Q_L(t)\; l\, L\right)^{\frac{1}{2}} + \left(Q_H(t)\; h H\right)^{\frac{1}{2}}\right]^2; \qquad (12a)$$

$$Y(t) \equiv \int_0^1 p_n(t)\,Y_n(t)\,dn = \exp(-1)\,A^{1/\alpha}\left[\frac{1-\alpha}{q\,(1-s_x)}\right]^{\frac{1-\alpha}{\alpha}}\left[\left(Q_L(t)\; l\; L\right)^{\frac{1}{2}} + \left(Q_H(t)\, h H\right)^{\frac{1}{2}}\right]^2. \qquad (12b)$$

The price paid for a unit of *m*-type labour, w_m, is equal to its marginal product. From (12b), the equilibrium growth rate of w_m and the equilibrium *H*-premium, *W* (a measure of intra-country wage inequality), are, at each time *t*, respectively:

$$\hat{w}_m = \frac{1}{\alpha}\hat{p}_m + \hat{Q}_m \text{ and } W \equiv \frac{w_H}{w_L} = \left(\frac{Q_H\, h\, L}{Q_L\; l\; H}\right)^{\frac{1}{2}}. \qquad (13)$$

3.2. Equilibrium R&D

The expected current value of the flow of profits to the producer of *j*, *V*(*k*, *j*, *t*), relies on the profits at each time, *Π*(*k*, *j*, *t*), on the interest rate and on the expected duration of the flow, which is the expected duration of the successful research's technological-knowledge leadership. Such duration, in turn, depends on *pb*(*k*,*j*,*t*). The expression for *V*(*k*, *j*, *t*) is

$$V(k,j,t) = \frac{\Pi\,(k,j,t)}{r(t) + pb(k,j,t)}. \qquad (14)$$

Under free-entry R&D equilibrium the expected returns are equal to resources spent,

$$pb(k,j,t)\; V(k+1,j,t) = rs(k,j,t). \qquad (15)$$

The equilibrium can be translated into the path of technological knowledge. The following expression for the equilibrium *m*-specific growth rate (where the equilibrium *m*-specific probability of successful R&D, pb_m, given *r* and p_m is plugged in) is obtained:

$$\hat{Q}_m(t) = \left\{\frac{\beta}{\zeta}\left(\frac{q-1}{q}\right)\left(p_m(t)\,A(1-\alpha)\right)^{\frac{1}{\alpha}}\,\bar{m}\; f(.) - r(t)\right\}\left[q^{\left(\frac{1-\alpha}{\alpha}\right)} - 1\right]. \qquad (16)$$

The equilibrium aggregate resources devoted to R&D, *R*, at each time *t*, are

$$R \equiv \int_0^1 rs(k,j)\,dj = \frac{\zeta}{\beta}\left\{Q_L\, L\; pb_L + Q_H\, H\; pb_H\right\}. \qquad (17)$$

3.3. Steady state

The stable and unique steady-state endogenous growth rate, which through the Euler equation (9) also implies a stable steady-state interest rate, $r^*(= r_L^* = r_H^*)$, designed by $g^*(= g_L^* = g_H^*)$ is:

$$g^* = \hat{Q}_L^* = \hat{Q}_H^* = \hat{Y}^* = \hat{X}^* = \hat{R}^* = \hat{C}^* = \hat{c}^* = \frac{r^* - \rho}{\theta} \Rightarrow \hat{p}_H^* = \hat{p}_L^* = \hat{\bar{n}} = 0. \qquad (18)$$

Thus, r^* is obtained by setting (9) equal to (16), and g^* results from plugging r^* into (9). p_m^* and $\bar{n}^*$ can be found by equalling the steady-state growth rates of Q_H and Q_L.

3.4. Subtitles Transitional dynamics and sensitivity analysis

Since our aim is to analyse the direction of technological-knowledge progress and its repercussion on *H*-premium, we can use (16) to obtain the differential equation:

$$\hat{D}(t)=\frac{\beta}{\zeta}\left(\frac{q-1}{q}\right)\left(A(1-\alpha)\right)^{\frac{1}{\alpha}}\exp(-\alpha)\left\{h\left(1+\frac{H}{H+L}\right)^{\sigma}\left[1+\left(D(t)\,\frac{h\,H}{l\,L}\right)^{-\frac{1}{2}}\right]^{\alpha}-l\left[1+\left(D(t)\,\frac{h\,H}{l\,L}\right)^{\frac{1}{2}}\right]^{\alpha}\right\}\cdot \tag{19}$$

We can thus verify first the stability of the relative productivity of the technological knowledge used together with *H*, $D \equiv Q_H/Q_L$ (a technological-knowledge bias measure). Then, we can characterise the behaviour of other variables, namely the *H*-premium in (13).

Using the 4th-order Runge-Kutta numerical method, we present technological knowledge's precise time path for a set of baseline parameter and labour level values:

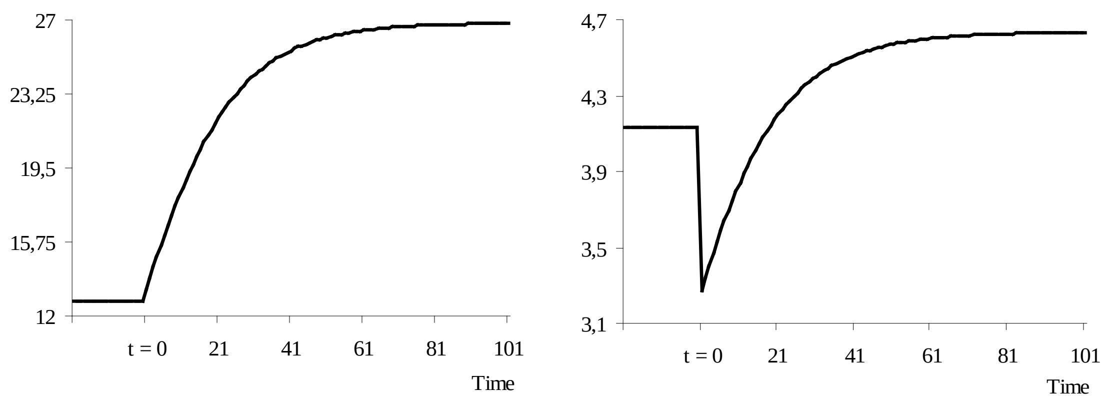
Baseline parameter values and baseline labour endowments

Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
A	1.50	α	0.70	ζ	4.00	H	0.90
h	1.20	q	3.33	θ	1.50	L	1.00
l	1.00	β	1.60	ρ	0.02	σ	1.90

Figures 1a and 1b below summarises the main results.

Figure 1. Transitional dynamics of

1a. The technological-knowledge bias *1b. The H-premium*



They compare the baseline steady-state paths of, respectively, the technological-knowledge bias, *D*, and the *H*-premium, *W*, with the ones resulting from an exogenous increase (at time $t = 0$) in skilled labour (from 0.9 to 1.1, 1.3 and 1.5). Table1 compares initial and steady-state values of *D* and *W* under different scenarios.

Table 1 - Comparing initial and steady state values of the variables

	Three different scenarios					
Variable	Scenario 1, H = 1.1		Scenario 2, H = 1.3		Scenario 3, H = 1.5	
	Initial	Steady state	Initial	Steady state	Initial	Steady state
D	12.784	15.967	12.784	20.499	12.784	26.810
W	3.734	4.174	3.435	4.350	3.198	4.632

Due to the increase in skilled labour, $f(j)$ in (6) jumps immediately. This biases the technological-knowledge in favour of *H*-intermediate goods (see Figure 1a). Such bias increases the supply of *H*-intermediate goods, thereby increasing the number of final goods produced with *H*-technology – see (10) – and lowering their relative price – see (11). Thus, relative prices of final goods produced with *H*-technology drop continuously towards the

constant steady-state levels. This path of relative prices implies that the technological-knowledge bias is increasing, from $D^*_{Baseline} = D(t=0) = 12.784$, but at a decreasing rate until it reaches its new higher steady state, D^* = 26.810 (see Figure 1a).
Figure 1b shows that an increase of skilled labour causes an immediate drop in the *H*-premium, at time t = 0, from $W^*_{Baseline} = 4.129$ to W = 3.198. This is because an increase in *H* raises its relative supply and lowers its relative wage – see (13); i.e., the *H*-premium falls instantly due to the rise in the supply of skilled labour without new endogenous technological knowledge and so without change in technological-knowledge bias.
By reason of complementarity between inputs in (1), changes in the *H*-premium are closely related to the technological-knowledge bias, as (13) clearly shows. As the increase in the supply of skilled labour induces technological-knowledge bias, the immediate effect on the level of the *H*-premium ends up being reverted in the transition. That is, the stimulus to the demand for *H*, arising from the technological-knowledge bias, increases the *H*-premium. Once in steady state, with a constant technological-knowledge bias, the *H*-premium remains constant. Moreover, we must highlight that the steady-state *H*-premium can be greater than that which has prevailed under the baseline case.
In summary, instead of the market-size channel emphasised by the skill-biased technological change literature, we propose another mechanism to explain the increase in the *H*-premium even when the relative supply of high-skilled labour has also increased. In particular, the market-size is neutralised by introducing risk assessment.

4. CONCLUSIONS

Instead of the market-size channel emphasised by the SBTC, we propose another explanation for skill-biased technological knowledge. By removing the scale effects, we propose a new mechanism by which the pool of labour increases the rate of technological-knowledge progress and thus determines the technological-knowledge bias. Indeed, through the price channel, the technological-knowledge bias increases but at a decreasing rate until it reaches its new higher steady state.
Concerning wage inequality, we find that an increase in skilled labour causes an immediate steep drop in the skilled premium since its relative supply decreases its relative wage. This immediate effect is reverted in the transitional dynamics towards the constant steady-state skilled premium, due to the stimulus to the demand for skilled labour resulting from the technological-knowledge bias. Moreover, we note also that with a sufficiently strong technological-knowledge-absorption effect, the steady-state high-skilled premium is greater than the previous one.

5. REFERENCES

Acemoglu, D. & Zilibotti, F. (2001). Productivity differences. *Quarterly Journal of Economics*, 116, 563-606.

Afonso, O. (2006). Skill-biased technological knowledge without scale effects. *Applied Economics*, 38(1), 13-21.

Agénor, P.& Dinh, Hinh, T. (2015). Social capital, product imitation and growth with learning externalities. *Journal of Development Economics* 114, 41–54.

Alesina, A. & Spolaore, E. (1997). On the number and size of nations. *Quarterly Journal of Economics*, 112, 1027-56.

Becker, G. & Murphy, K. (1992). The division of labour, coordination costs, and knowledge. *Quarterly Journal of Economics*, 107, 1137-60.

Cohen, W. & Levinthal, D. (1990). Absorptive capacity: a new perspective on learning and innovation, *Administrative Science Quarterly*, 35, 128-152.

De Jong, J. & Freel, M. (2010). Absorptive capacity and the reach of collaboration in high technology small firms, *Research Policy*. 39, 47-54.

Dinopoulos, E. & Segerstrom, P. (1999). A Schumpeterian model of protection and relative wages. *American Economic Review*, 89, 450-73.

Dinopoulos, E. & Thompson, P. (1999). Scale effects in Schumpeterian models of economic growth. *Journal of Evolutionary Economics*, 9, 157-85.

Dorman, P. (2000). The Economics of Safety, Health, and Well-Being at Work: An Overview. InFocus Program on SafeWork, International Labour Organisation. The Evergreen State College Technol [consulted February 2015]. Available at: http://www.oit.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/publication/wcms_110382.pdf.

European Commission (2010). Europe2020. A European strategy for smart, sustainable and inclusive growth. Brussels, 3.3.2010.

EU-OSHA (2014). European Agency for Safety and Health at Work. *Priorities for occupational safety and health research in Europe: 2013-2020*. ISBN 978-92-9240-316-4. Luxembourg.

Grossman, G. & Helpman, E (1991). *Innovation and growth in the global economy*, Massachusetts: MIT Press, Cambridge.

ILO (2013). Protecting Workplace Safety and Health in Difficult Economic Times – The Effect of the Financial Crisis and Economic Recession on Occupational Safety and Health. Retrieved from International Labour Organization.

Jones, C. (1995a). Time series tests of endogenous growth models. *Quarterly Journal of Economics*, 110, 495-525.

Jones, C. (1995b). R&D-based models of economic growth. *Journal of Political Economy*, 103, 759-84.
McDermott, J. (2002). Development dynamics: economic integration and the demographic transition. *J. Econ. Growth* 7, 371–409 (December).
OECD (2007). Organisation for Economic Co-operation and Development. Innovation and Growth: Rationale for an Innovation Strategy.
Ramos, D., Arezes, P. & Afonso, P. (2013). *The role of costs, benefits and social impact of injuries and prevention measures on the design of occupational safety programs*. Arezes et al. (eds), Occupational Safety and Hygiene, Taylor & Francis Group, London, ISBN 978-1-138-00047-6, pp. 153-157.
Ramos, D., Arezes, P.M., Afonso, P. (2015). Economic Evaluation of Occupational Safety Preventive Measures in a Hospital. Journal of Prevention, Assessment & Rehabilitation, *Work* 51, 495–504.

FRAM-AHP: A systemic methodology for occupational risk assessment

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Abstract

Traditional tools for occupational risk assessment like preliminary hazard analysis, hazard checklists, fault trees are based on the isolation of hazard activities from the entire process and the development of specific measures to avoid/minimize the occupational risk. Their basic assumption is that the system's structure and even its behavior are known and do not change with time. Such methods require the system linearization, a detailed description of the system and risk scenarios, and may not be adequate for systems that are dynamic, incompletely described, and underspecified, like most of modern socio technical systems. To deal with dynamic environments, where daily routine activities require flexibility rather than rigidity, Resilience Engineering (RE) has developed new methods and tools for system modelling. According to RE the main target for safety management is to increase the ability of the organization at all levels to adjust its operation to changes and disturbances. The Functional Resonance Analysis Method (FRAM) is based on RE principles and concepts aimed at describing and analyzing emergent behaviors in complex sociotechnical systems. This research utilizes FRAM combined with Analytic Hierarchy Process (AHP) – FRAM-AHP method - for occupational risk assessment. FRAM-AHP method is based on system functioning, not in the identification of specific hazards as traditional tools. According to FRAM the analyses of performance variability and how variability may combine and resonate are characterized as a quality rather than a quantity. The main steps of a FRAM analysis are: (1) setting the goal for modeling and describing the situation to be analyzed; (2) identifying the main functions of the process, and characterizing them, according to input, output, preconditions, resources, time and control; (3) characterizing the actual/potential variability of functions; (4) considering both normal and the worst-case variability; (5) defining functional resonances, based on potential/actual couplings among functions; (6) and providing ways to monitor the performance variability. The FRAM-AHP method aims to introduce a multi-criteria decision-support method to quantify FRAM analyses to be used for risk assessment purposes. Multi-criteria decision-support methods like AHP are used in situations involving multiple objectives, various decision-makers, and the simultaneous treatment of complex issues. In this sense, this research contributes to the evolution of FRAM, by proposing the application of the analytic hierarchy process (AHP), to investigate the relative importance of the criteria and alternatives used for the identification of phenotypes of performance variability, as well as the aggregation of variability. The construction and use of the AHP model are developed in four stages; namely: structuring the hierarchy in order to identify the main goal, criteria, sub-criteria and alternatives; data collection of value judgments issued by experts; calculating the priority of each alternative, and consistency analysis. The case study results indicated that FRAM-AHP enables the simultaneous participation of multiple experts in different steps of analysis, and led to the reduction of subjectivity associated with the occupational risk assessment in complex socio-technical systems.

Keywords: Risk assessment; The functional resonance analysis method, Analytic hierarchy process, Accident analysis, Resilience engineering.

1. INTRODUCTION

The approaches of risk assessments are structured from the engineering tradition, represented by methods such as hazard and operability analysis (HAZOP), and fault tree analysis (FTA) that were developed for technological systems and then adapted to include human actions and organizational functions. (Hollnagel, 2012).

Most of the existing methods for assessing occupational safety are linear and do not cope with system complexity. These methods believe that the system's structure and even its behavior do not change with time. Therefore, they do not provide efficient ways to assess the potential for

accidents in the ever-changing work environment, based on the actual execution of daily tasks, although they may indicate an estimated general risk and frequency of behaviors or unsafe conditions (Nieto-Morote and Ruz-Vila, 2009; Mitropoulos and Namboodiri, 2011); Harms-Ringdahl, 2001; Ismail, Doostdar and Harun, 2012).
Understanding the complexity of a risk, or a portfolio of risk, of an organization is crucial when selecting the appropriate option for the risk assessment (ISO/IEC, 2009; Mehta and Agnew, 2010; Fung et al., 2010).
To deal with dynamic environments, where daily routine activities require flexibility rather than rigidity, Resilience Engineering (RE) has developed new methods and tools for system modelling. According to RE the main target for safety management is to increase the ability of the organization at all levels to adjust its operation to changes and disturbances. The functional resonance model is based on RE principles and concepts aimed at describing and analyzing emergent behaviors in complex sociotechnical systems (Andersson et al., 2002; Levenson, 2004; Hollnagel, 2007; Steen and Aven, 2011).
The Functional Resonance Analysis Method (FRAM) has been developed to provide a method to deal with such systems, focusing on the nature of everyday activities rather than on systems' previously defined structure, or the nature of failures.
FRAM is able to accommodate past occurrences normally addressed by accident analysis, therefore being used as an accident analysis method, and to understand future occurrences normally addressed through risk assessment, or system modeling methods (Hollnagel, 2004; Hollnagel, 2012).
At the current stage of FRAM development, the analyses related to the identification of performance variability phenotypes, and to the variability aggregation to find potential resonances, are performed by experts' judgments, characterized by the subjectivity of evaluations. This makes it entirely possible to introduce a multi-criteria decision-support method. Among the more widely used of multiple-criteria decision analysis (MCDA) approaches, methods and techniques in various fields of research is the method of Analytic Hierarchy Process (AHP) that provides a good compromise between targets, understanding, and objectivity. AHP is based on the use of pairwise comparisons that lead to the elaboration of a ratio scale. Moreover, AHP permits the refinement of the decision-making process, while respecting the global coherence of the user's preferences, by calculating an overall consistency ratio (Saaty, 1980; Costa, 2006; Vidal et al., 2010).
The construction and use of the AHP model are supported by three basic principles (Saaty, 1990; Saaty, 1999; Figueira and Ehrogott, 2005; Costa, 2006):
• Structuring the hierarchy. This principle involves identifying the overall objective, the criteria that must be satisfied to fulfill the focus, sub criteria under each criterion and the alternatives
• Establishing priorities. This principle involves three steps. The first step is to make pairwise comparisons to specify the decision-makers' preferences, that is, to compare pairs of like elements in each level of a hierarchy against a criterion in the next higher level. The second step is to synthesize the judgments made in the pairwise comparisons to get the relative priorities of each element. Finally, average is calculated over the rows by adding the values in each row of the normalized matrix and then dividing the rows by the number of entries in each.
• Measuring the logical consistency. The AHP measures the overall consistency of judgments by means of a consistency ratio (C.R.). The value of C.R. should be 10 percent or less to be acceptable.
In this sense, this research contributes to the evolution of FRAM, by proposing the application of the analytic hierarchy process (AHP). The FRAM-AHP method aims to introduce a multi-criteria decision-support method to quantify FRAM analyses to be used for accident analysis and risk assessment purposes.

2. FRAM-AHP

The main steps of a FRAM-AHP analysis are:
• Setting the goal for modeling and describing the situation to be analyzed.
• Identifying the main functions of the process, and characterizing them, according to input, output, preconditions, resources, time, and control. According to FRAM, the basis for risk assessment and the analysis of accidents is the design of functional entities relevant to the scenarios or tasks. Functional entities are characteristic functions, and not system structures or physical units. Inputs (I) provide links to previous functions. Inputs may transform or be used by the function to produce outputs. Outputs (O) provide links to subsequent functions. Resources (R) are necessary for the function to process the input (hardware, procedures, software, energy,

and labor) to create the output. Controls (C) are the restrictions or controlling elements that serve to supervise or limit function (monitoring and tuning). Preconditions (P) are system conditions that must be satisfied before performance of a function (another process or step, and specific condition) can occur. Time (T) or time window (duration) is a special type of resource or constraint based on an allowed amount of time.

• Identification of phenotypes of performance variability. According to FRAM manifestations of variability are identified from outputs of functions, according to the ‘‘elaborate solution.’’ The ‘‘elaborate solution’’ uses phenotypes, or failure modes, normally used in safety studies. The necessary analyses involve four basic groups (time/duration; force/distance/direction; object; and sequence), which are shown in Figure 1.

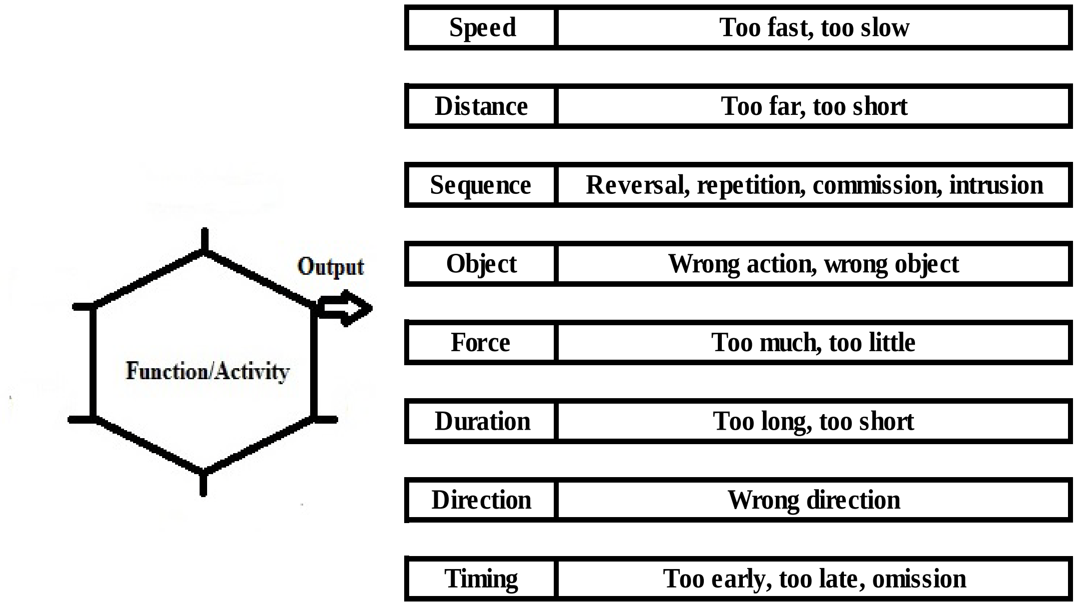

Figure 1: Dimensions of failure modes.

This step is supported by AHP, given the participation of multiple decision-makers (experts), and the concurrent treatment of complex issues. The AHP hierarchical structure characterizing actual or potential variability is shown in Figure 2.

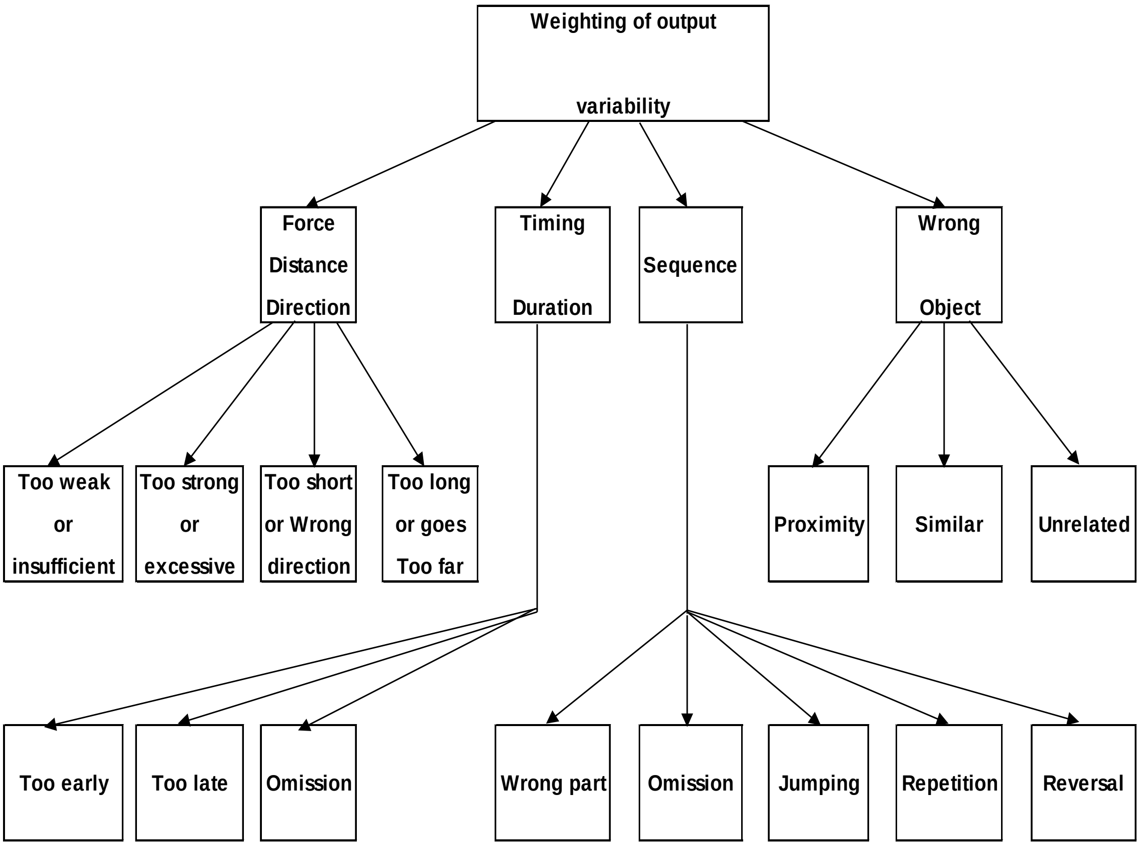

Figure 2: AHP Hierarchical structure for characterizing actual or potential variability

The questionnaire based on AHP hierarchical structure, shown in Figure 3, is used to obtain value judgments.

Judging output variability

1. Knowing the objective of determining the relative importance of phenotypes in relation to output variability, rate the following:

	minor importance				same importance	larger importance				
	extremely	a lot	little	slight		extremely	a lot	little	slight	
Force/distance/direction has										compared to time/duration
Force/distance/direction has										compared to sequence
Force/distance/direction has										compared to wrong object
Time/duration has										compared to sequence
Time/duration has										compared to wrong object
Sequence has										compared to wrong object
	1/9	1/7	1/5	1/3	1	3	5	7	9	

2. Knowing the objective of determining the relative importance of failure modes related to variability in terms of Force, Direction and Distance, rate the following:

	minor importance				same importance	larger importance				
	extremely	a lot	little	slight		extremely	a lot	little	slight	
Too weak or insufficient has										compared to too strong or excessive
Too weak or insufficient has										compared to too short or wrong direction
Too weak or insufficient has										compared to too long or goes to far
Too strong or excessive has										compared to too short or wrong direction
Too strong or excessive has										compared to too long or goes to far
Too short or wrong direction has										compared to too long or goes to far
	1/9	1/7	1/5	1/3	1	3	5	7	9	

3. Knowing the objective of determining the relative importance of failure modes related to variability in terms of Time, Speed and Duration, rate the following, rate the following:

	minor importance				same importance	larger importance				
	extremely	a lot	little	slight		extremely	a lot	little	slight	
Too early(premature output) has										compared to too late(delayed output)
Too early(premature output) has										compared to omission
Too late(delayed output) has										compared to omission
	1/9	1/7	1/5	1/3	1	3	5	7	9	

4. Knowing the objective of determining the relative importance of failure modes related to variability in terms of Sequence of Objects, Movements, or (state) Changes, rate the following:

	minor importance				same importance	larger importance				
	extremely	a lot	little	slight		extremely	a lot	little	slight	
Wrong part has										compared to omission
Wrong part has										compared to jumping
Wrong part has										compared to repetition
Wrong part has										compared to reversal
Omission has										compared to jumping
Omission has										compared to repetition
Omission has										compared to reversal
Jumping has										compared to repetition
Jumping has										compared to reversal
Repetition has										compared to reversal
	1/9	1/7	1/5	1/3	1	3	5	7	9	

5. Knowing the objective of determining the relative importance of failure modes related to variability in terms of Wrong Objects or Points to the Wrong Object, rate the following:

	minor importance				same importance	larger importance				
	extremely	a lot	little	slight		extremely	a lot	little	slight	
Proximity (neighbouring) object has										compared to similar object
Proximity (neighbouring) object has										compared to unrelated object
Similar object has										compared to unrelated object
	1/9	1/7	1/5	1/3	1	3	5	7	9	

Figure 3. Judging output variability.

• Aggregation of variability. According to FRAM the variability of a function can result from coupling to upstream functions, where outputs from upstream functions (used as input, precondition, resource, control, or time) may vary and therefore can affect the variability of downstream functions. Characterizing the actual or potential variability of each function involves analysis of five criteria, namely: input, preconditions, resources, time, and control under two alternatives (timing and precision). The analyses were also supported by AHP using the hierarchical structure shown in Figure 4.

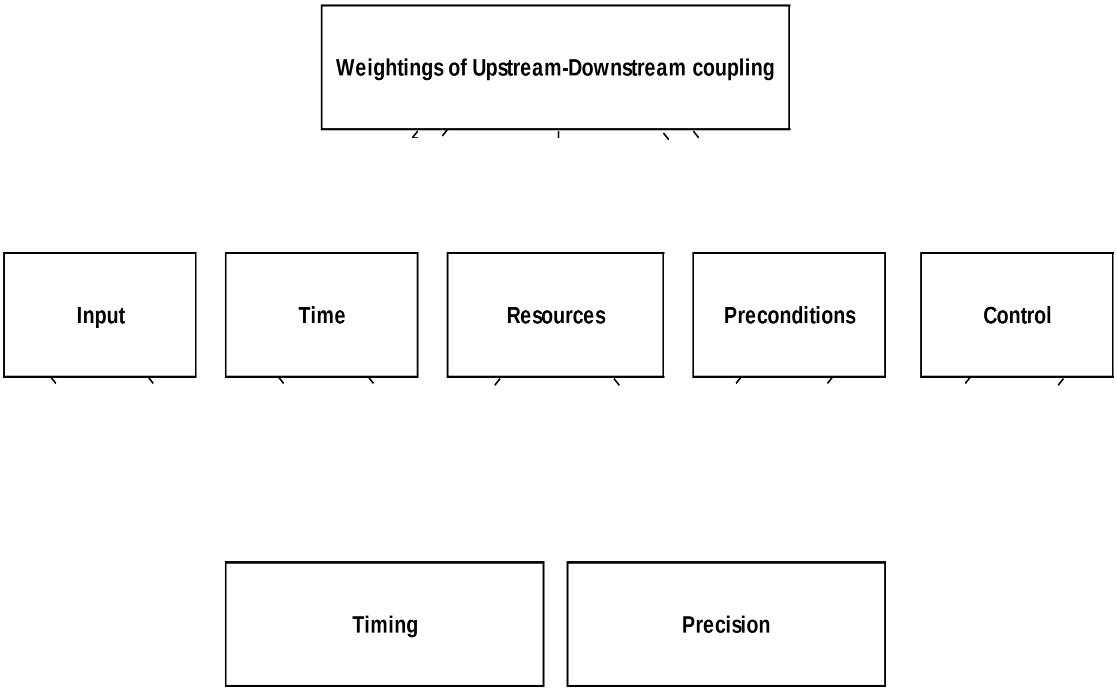

Figure 4: AHP Hierarchical Structure for characterizing variability aggregation

The questionnaire derived from the hierarchical structure, illustrated in Figure 5, is used to obtain value judgments.

Judging Functional Upstream-Downstream Coupling

1. Knowing the objective of determining the relative importance of aspects or features of the function in relation to Upstream Output variability, rate the following:

	minor importance				same importance	larger importance				
	extremely	a lot	little	slight		extremely	a lot	little	slight	
Input has										compared to time
Input has										compared to resources
Input has										compared to preconditions
Input has										compared to control
Time has										compared to resources
Time has										compared to preconditions
Time has										compared to control
Resources have										compared to preconditions
Resources have										compared to control
Preconditions have										compared to control
	1/9	**1/7**	**1/5**	**1/3**	**1**	**3**	**5**	**7**	**9**	

2. Knowing the objective of determining the relative importance of possible effects related to Input of the Function, rate the following:

	minor importance				same importance	larger importance				
	extremely	a lot	little	slight		extremely	a lot	little	slight	
Timing has										compared to precision
	1/9	**1/7**	**1/5**	**1/3**	**1**	**3**	**5**	**7**	**9**	

3. Knowing the objective of determining the relative importance of possible effects related to Time Feature of the Function, rate the following:

	minor importance				same importance	larger importance				
	extremely	a lot	little	slight		extremely	a lot	little	slight	
Timing has										compared to precision
	1/9	**1/7**	**1/5**	**1/3**	**1**	**3**	**5**	**7**	**9**	

4. Knowing the objective of determining the relative importance of possible effects related to Resources Feature of the Function, rate the following:

	minor importance				same importance	larger importance				
	extremely	a lot	little	slight		extremely	a lot	little	slight	
Timing has										compared to precision
	1/9	**1/7**	**1/5**	**1/3**	**1**	**3**	**5**	**7**	**9**	

5. Knowing the objective of determining the relative importance of possible effects related to Preconditions Feature of the Function, rate the following:

	minor importance				same importance	larger importance				
	extremely	a lot	little	slight		extremely	a lot	little	slight	
Timing has										compared to precision
	1/9	**1/7**	**1/5**	**1/3**	**1**	**3**	**5**	**7**	**9**	

6. Knowing the objective of determining the relative importance of possible effects related to Control Feature of the Function, rate the following:

	minor importance				same importance	larger importance				
	extremely	a lot	little	slight		extremely	a lot	little	slight	
Timing has										compared to precision
	1/9	**1/7**	**1/5**	**1/3**	**1**	**3**	**5**	**7**	**9**	

Figure 5. Judging functional upstream-downstream coupling

• Defining functional resonances, based on potential/ actual couplings among functions and providing ways to monitor and minimize the variability of performance. According to FRAM the determination of possible functional resonances is based on potential or actual couplings among functions. Analysis to determine functional resonance provides the necessary basis for identifying potential problem areas in the system's functioning, in addition to the more traditional analyses of failure modes or malfunctions. The high-priority coupling emerges as the simultaneous presence of a certain basic group of phenotypes, or failure modes in the output of a function, and in one of the downstream function entrances. These priority groups are used to characterize potential functional resonances in the system.
• The last step is to propose ways to damper functional resonance. According to FRAM this model can be used to identify the conditions where developments may potentially get out of control. This model can, therefore, be used as a basis for proposing indicators, hence as a basis for monitoring.

3. RESULTS AND DISCUSSION

Traditional methods of risk assessment applied in the construction industry are not providing the expected responses to reduce the level of occurrence of occupational diseases and accidents involving material and human losses. Moreover, the employee no longer dominates the process resulting from the loss of control over his job.
The major limitations of traditional methods of risk assessment when used in the construction industry are:
• Lack of adequate description for use in the operation.
• The complexity of the methods requiring specific training.
• Doubt about applicability in the industry.
• Specificity of the project not warranting application of the technique.
• Availability of reliable data and skilled analysts.
• Difficulty in the identification of benefit due to the high level of uncertainty.
• The low demand for risk assessment by customers.
• The great distance between the scientific model and the actual work (Gambatese et al., 2007; Pinto et al., 2011; Mitropoulos and Namboodiri, 2011).
The pilot of the method was done in the construction industry in the modernization of Maracanã for the soccer world cup in the City of Rio de Janeiro (Rosa et al, 2015). We apply the method in the process where demolished concrete was reused in the construction. This activity posed risks of accidents involving factors like noise, vibration, dust, thermal overload, postures, and other work accidents. This process has the following functions:
• Material selection (screening);
• Delivery of sorted waste for processing the crusher using loaders;
• Crushing the material using the mobile jaw crusher;
• Delivery of the crushed material.
According to FRAM first step, the identification of key functions is shown in Figure 6.

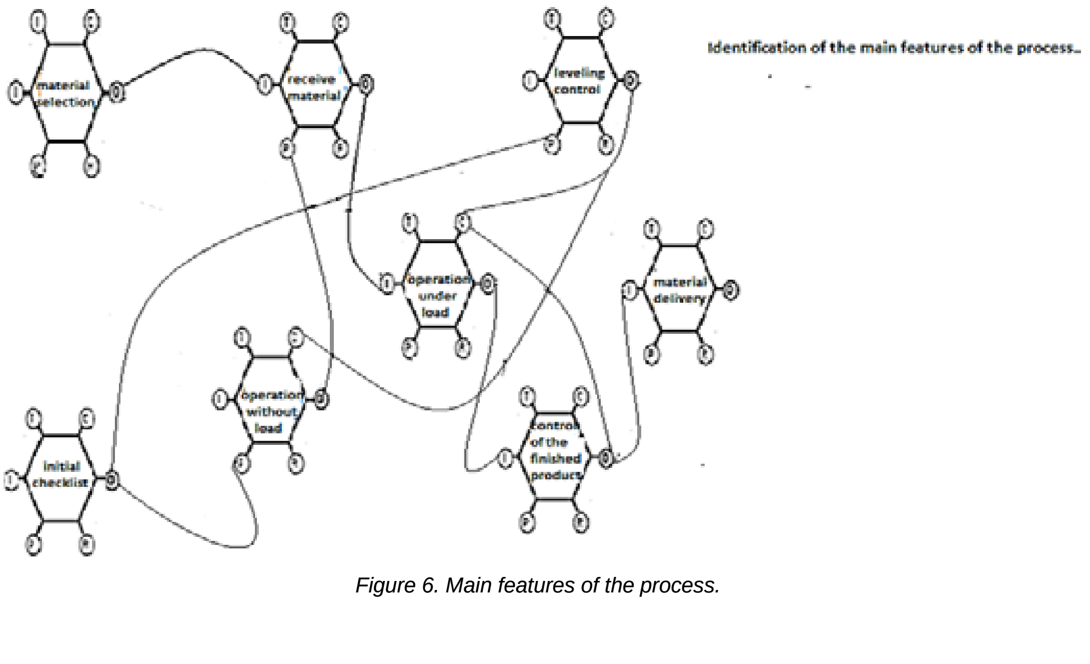

Figure 6. Main features of the process.

The analysis were performed by a team consisting of three experts in health, safety, and the environment, and three worker representatives. Figure 7 shows the relative importance of the output variability x functional couplings (FRAM-AHP) over the map of the main features of the process.

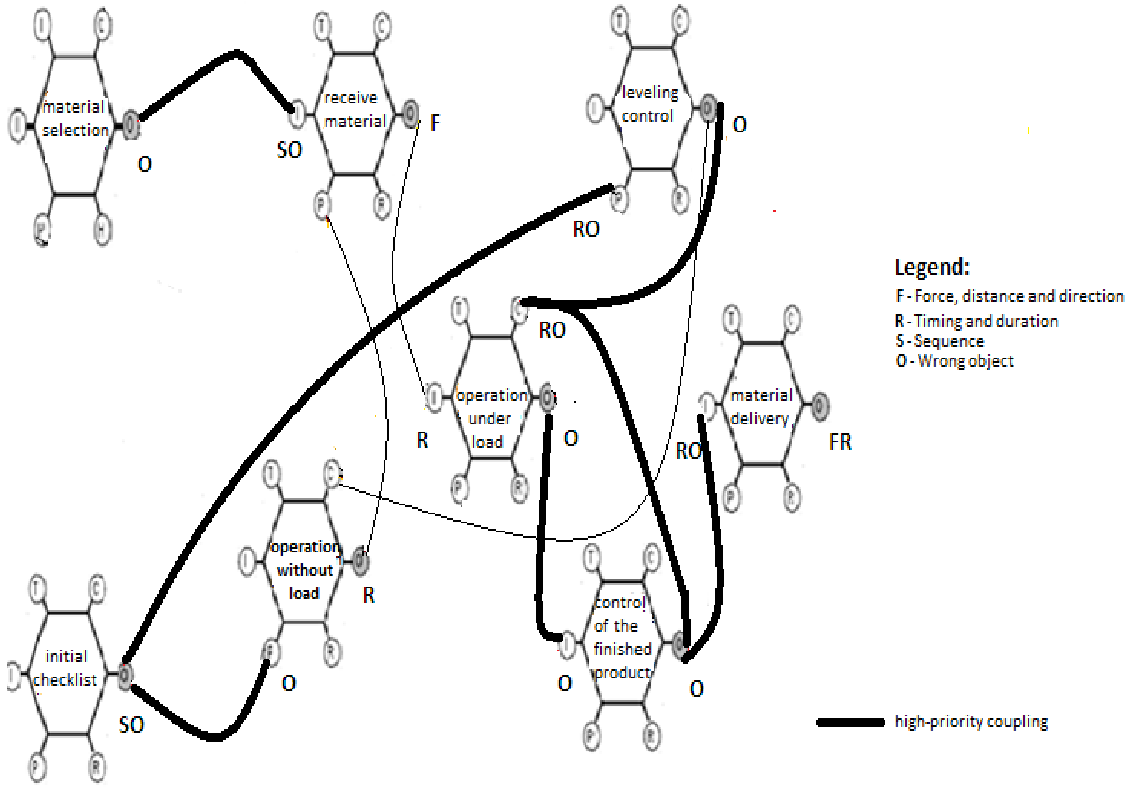

Figure 7. FRAM: instantiations of the model.

The analysis indicated that the efficacious performance of the system requires perfect levelling of the equipment. Perfect levelling leads to low consumption of energy, low noise level, low dispersion of pollutants, high productivity and a good level of safety for workers. If levelling becomes too variable, then charging and unloading will occur in adverse conditions and without adequate control. This can lead to a situation that is out of control.

4. CONCLUSIONS

Finding ways to improve occupation safety performance is a huge challenge to the scientific community, employees, and employers. Traditional methods for risk assessment and accident analysis do not provide the expected outcome, as indicated worldwide by stagnation in the level of occurrence of occupational illnesses and accidents, involving material and human losses (Geetha et al. 2007; ILO 2009).

The fact that normally used approaches to risk assessment and accident analysis require the linearization system and a detailed description of the system and the scenarios argues for the need to develop approaches that can be used in complex sociotechnical systems that are dynamic, incompletely described, and therefore underspecified.

This paper presents the motivation that led to the use of FRAM, to assess risk in sociotechnical systems, and highlights the proposal to adopt the AHP when performing the functional characterization of variability.

FRAM-AHP enables the simultaneous participation of multiple experts in different steps of analysis, and led to the reduction of subjectivity associated with the occupational risk assessment in complex socio-technical systems.

As methodological challenges for future research are the adoption of AHP in accident analysis with FRAM and developing of a FRAM-AHP app.

5. REFERENCES

Andersson N., Broberg A., Braberg A., Janlert L., Jonsson E., Holmlund K., Pettersson J. (2002). *Emergent interaction: a pre´- study.* Department of Computing Science, Umea University, Umea.

Costa H. G. (2006). *Multicriteria decision aid: AHP*. Abepro, Rio de Janeiro.

Figueira J., Ehrogott M., Greco S. (2005). Multiple Criteria Decision Analysis: State of the Art Surveys. International Series in: *Operations Research & Management Science*, Springer, 78.

Fung I. W. H., Tam V. W. Y., Lo T. Y., Lu L. L. H. (2010) Developing a risk assessment model for construction safety. *International Journal of Project Management*, 28, 593–600.

Gambatese, J., Rajendran, S., Behm, M. (2007). Green design and construction: understanding the effects on construction worker safety and health. *Professional Safety*, 52, 5–28.

Geetha M. W., Xiuwen S. D., Ted M., Elizabeth H., Yurong M. (2007). Costs of occupational injuries in construction in the United States. *Accident Analysis & prevention*, 39, 1258–1266.

ILO (2009). Inspecting occupational safety and health in the construction industry. *International Training Centre*, ISBN 978-92-9049-489-8.

ISO/IEC (2009). *Risk management: risk assessment techniques ISO/IEC 31010*. International Organization for Standardization/International Eletrotechinical Commission.

HARMS-RINGDAHL L. (2001). *Safety Analysis – Principles and Practice in Occupational Safety*. 2 ed.Taylor & Francis, London.

Hollnagel E. (2004). *Barriers and accident prevention*. Ashgate, Aldershot.

Hollnagel E (2007) Why do we need resilience engineering? Retrieved January 17, 2011, from http://www.sites.google.com/site/erikhollnagel2/whatisresilienceengineering%3F.

Hollnagel E. (2012). *FRAM: the functional resonance analysis methods*. Ashgate, Aldershot.

Ismail Z., Doostdar S., Harun Z. (2012). Factors influencing the implementation of a safety management system for construction sites. *Safety Science***,** 50, 418-423.

Levenson N. (2004). A new accident model for engineering safer systems. *Safety Science*, 42, 237–270.

Mehta R. K., Agnew M. J. (2010). Analysis of individual and occupational risk factors on task performance and biomechanical demands for simulated drilling task. *International Journal of Industrial Ergonomics,* 40, 584–591.

Mitropoulos P., Namboodiri M. (2011). New method for measuring the safety risk of construction activities: task demand assessment. *Journal of Construction Engineering and Management,* 137, 30–38.

Nieto-Morote A., Ruz-Vila F. (2009). A fuzzy approach to construction project risk assessment. *International Journal of Project Management*, 29, 220–231.

Pinto, A., Nunes, I. L., Ribeiro, L. A. (2011). Occupational risk assessment in construction industry – Overview and reflection. *Safety Science*, 49, 616-624.

Rosa L. V., Haddad A. N., Carvalho P. V. R. (2015). Assessing risk in sustainable construction using the Functional Resonance Analysis Method (FRAM). *Cognition, Technology & Work*, 10.1007/s10111-015-0337-z. Online publication date: 24-Apr-2015.

Saaty T. L. (1980). *The analytic hierarchy process: planning, priority setting, resource allocation*. McGraw-Hill, New York.

Saaty T. L. (1990). How to make a decision: the analytic hierarchy process. *European Journal of Operational Research,* 48, 9–26.

Saaty T. L. (1999). *Decision making for leaders: the analytic hierarchy process for decision in a complex world.* RWS publications.

Steen R., Aven T. (2011). A risk perspective suitable for resilience engineering. *Safety Science*, 49, 292–297.

Vidal A. L., Sahin E., Martelli N., Berhoune N., Bonan B. (2010). Applying AHP to select drugs to be produced by anticipation in a chemotherapy compounding unit. *Expert System with Applications,* 37, 1528–1534.

Safety of Textiles with Nanomaterials

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Abstract

There is a growing concern related to the effects of nanomaterials in safety and health. Nanotechnologies are already present in many consumer products, including textiles. In fact, the textile industry is already an important user of nanotechnologies.

Functionalities such as antibacterial (odour prevention), ultraviolet radiation protection, water and dirt repellency, self-cleaning or flame retardancy can be obtained more effectively than with traditional finishing processes. Although it is possible to incorporate the nanoparticles directly in the production of the fibres, the most frequent application is made in the final phase of the textile manufacturing process, which corresponds to fabric finishing. In this case, there is a higher rate of release of nanoparticles from the textile material, which can occur due to different effects (abrasion and other mechanical stresses, sweat, irradiation, washing, temperature changes, etc.). It is then expectable that "nanotextiles" may release individual nanoparticles, agglomerates of nanoparticles or small particles of textile with or without nanoparticles. These nanoparticles can then interfere with workers, consumers and natural ecosystems. In terms of occupational safety, it is important to consider the workers that are involved in the fabric finishing plants, which have to handle chemical preparations and fabrics containing nanomaterials. It is also essential to take into consideration all downstream workers, with special emphasis on the clothing manufacturing, In fact, the workers involved in cutting, sewing and garment finish have to manipulate all the time large quantities of fabrics, potentially releasing nanoparticles. It is important to understand the type of integration of the nanoparticles in textiles and the mechanism of release.

There are different exposure routes of the human body to nanoparticles. In case of textiles, skin contact in particularly relevant, although, inhalation and ingestion can also be relevant, in this case especially with babies who often suck textiles. Following a mandate, from the European Commission, several standards are being developed under the auspices of the European Committee for Standardization. In this paper, it is presented the development and application of a test method to evaluate the skin exposure to nanoparticles, to evaluate the transfer of the nanoparticles from the textile to the skin by the effect of abrasion and sweat. The method can be easily applied for instance in the case of nano-silver and nano-titanium dioxide, which are most frequently used in textiles.

Nanotechnology is very promising to obtain novel effects and to contribute to industrial competitiveness. However, it is also essential to identify the risks in terms of safety and health of the workers and of the consumers, as well as effects on the environment during all the life cycle of the nanotextiles. Further research is needed to better understand this subject.

Keywords: Nanotechnology, Safety and Health, Nanotextiles, Consumer Products, Skin Contact.

1. INTRODUCTION

Recently there has been a rapid emergence of nanotechnology into several consumer products, which has led to concerns as regards the potential risk for human health following consumer exposure. But there is also a concern in terms of occupational safety and health, related to the exposure of workers involved in manufacturing, processing and handling of consumer goods containing nanomaterials.

Textiles are one of the most heavily traded commodities in the world. The industry is very diverse and its products are used by virtually everybody from private households to large businesses. The textile industry is already an important user of nanotechnologies and there are a significant number of "nanotextiles" in the market, including many consumer goods, with the incorporation of nanoparticles. These include many textiles used in direct contact with the skin, such as underwear, shirts and socks but also interior textiles like cushions, blankets or mattress covers.

There is a knowledge gap between the technological progress in nanotechnology and nanosafety research which is estimated to be 20 years, and it is likely to expand. The European

Agency for Safety and Health at Work has established as priority for research related to the safety and health in Europe during the period 2013-2020 the increase of knowledge on nanomaterials in occupational settings, including new generation nanomaterials and understand their characteristics in relation to toxicity in biological systems.
The risk for the workers and for the consumer is linked to the characteristic properties of certain nanomaterials that make them different from their macroscale counterparts and will be determined by the chemical composition of the nanomaterial, its physicochemical properties, the interactions with the textile materials and the potential exposure levels. Ingestion exposure via the gut, airborne exposure via the lungs and dermal exposure are the most important exposure routes to be considered in a risk analysis. In addition, the increasing use of nanomaterials, including for industrial purposes, raises specific concerns regarding their disposal at the end of their life cycle with the unavoidable release to the environment that may lead to indirect human exposure.
The European Commission, in its action plan for Europe 2005-2009, defined a series of articulated and interconnected actions for the immediate implementation of a safe, integrated and responsible approach for nanosciences and nanotechnologies. In line with this commitments, it is important to determine the applicability of the existing regulations to the potential risks of nanomaterials. It was then concluded that the term “nanomaterials” was not mentioned specifically in European Union (EU) legislation but that existing legislation in principle covers the potential health, safety and environmental risks in relation to nanomaterials. It was then decided to publish an official definition of nanomaterial, which is a basis for the adoption and implementation of legislation, policy and research programmes concerning products of nanotechnologies. According to this definition, “Nanomaterial” means a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm-100 nm. But in specific cases and where warranted by concerns for the environment, health, safety or competitiveness, the number size distribution threshold of 50 % may be replaced by a threshold between 1 and 50 % (European Commission, 2011).
This definition, although based on available scientific knowledge, is wider that the present definition included in ISO / EN standards. The definition was supposed to be reviewed by the end of 2014 (especially in what concerns the increase or decrease of the number size distribution threshold of 50 %), but this revision has been postponed to 2016, based on the three reports published by the Joint European Research Centre (the last one was published in June 2015) and taking into account the consultation with stakeholders.
At present, some EU Regulations already include a specific mention to nanomaterials. This is the case of food (including additives and packaging), biocides and cosmetic products. But this is still not the case of textiles.
The General Products Safety Directive (GPSD) is intended to ensure a high level of product safety throughout the EU for consumer products that are not covered by specific sector legislation, which is the case of textiles. It is foreseen to modify GPSD into a Regulation, including then a specific mention to nanomaterials.
The growing concern about the possible negative effects of nanomaterials on humans and on the environment can lead to restrictions to “nanotextiles”. In fact, for instance, the 2014 version of the ecological label GOTS (Global Organic Textile Standard) fully bans the presence of nanofinishes in textiles. Also in the recent discussion of the new version of the EU ecolabel for textiles, there were several voices to exclude nanomaterials.
In the present paper, after making an overview of the use of nanotechnology in textiles, with special emphasis on textiles for major consumer applications, the safety and health concerns related to nanotextiles are presented. The paper includes then a case study concerning the development of a test method to evaluate the skin exposure to nanoparticles, mainly directed to the transfer of the nanoparticles from the textile to the skin.
This paper does not deal with the penetration of the nanoparticles into the skin. There are many studies about this topic, related for instance to sunscreens and cosmetics, which are often based on nanomaterials. In fact, only the smaller nanoparticles (diameter lower than 10 nm) seem to be able to penetrate in the undamaged skin, although in the skin is injured, larger nanoparticles can penetrate (see for instance Labouta et al, 2011).
This paper also does not concern the toxicological aspects related to nanoparticles. This topic has been and is being extensively studied in many research works. The safety and health concerns related to nanoparticles is very important for instance for the registration of chemical

substances in nanoform in the REACH system. Nanotoxicology is a very important science that will serve as a basis for future regulations, including possibly textile products.

2. USE OF NANOTECHNOLOGY IN TEXTILES

Often the first application of nanotechnology to textiles that comes to the minds is related to nanofibers.

Nanofibers are normally produced by the electrospinning process. The polymer must previously be dissolved in a solvent. The process makes use of electrostatic and mechanical forces to spin fibers from the tip of a fine orifice or spinneret, with evaporation of the solvent. This process produces in fact a nonwoven web and nanofibers normally cannot be used in common textile processing.

Nanofibers have applications in medicine, including artificial organ components, tissue engineering, implant material, wound dressing and drug delivery. In fact, all these products are not normally considered as textile products, as they do not fully enter in the definition of the EU Regulation no. 1007/2011 (they cannot be processed like traditional fibres) and they are not normally present in general consumer products. This paper will not further consider nanofibers.

In this paper we will also not include the use of carbon nanotubes. In fact, carbon nanotubes pose serious health problems but, due to the present high cost, are for the moment only used in high-tech products and not in "normal" textile products.

When we speak about "nanotextiles" we refer normally to traditional textile products in which engineered nanomaterials (normally nanoparticles) are incorporated or on which a nanostructured surface has been applied. In fact, nanotechnology is already very often used in textile products and involves the incorporation of nanoparticles in textile materials or the nanostructuration of the surface, in order to obtain specific functionalities (Wong et al., 2006; Gowri et al., 2010). The most common effects are:

- water and dirt repellency (including self-cleaning properties, also called "lotus leaf" effect);
- antibacterial properties:
- protection against ultraviolet radiation;
- flame retardancy.

Table 1 presents the nanomaterials that are more commonly used in the functionalization of textiles.

Table 1 – Nanomaterials used in the functionalization of textiles (adapted from Som et al., 2010)

Nanomaterial	Function
Silver (Ag)	antibacterial (odour), electrically conductive
Titanium dioxide(TiO_2)	UV protection self-cleaning water and dirt repellent
Zinc oxide	UV protection antibacterial self-cleaning abrasion resistance, stiffness
Silicon dioxide (SiO_2)	water and dirt repellent abrasion-resistant, reinforcement improved dyeability
Aluminium oxide (Al_2O_3)	abrasion resistance flame retardant
Nanoclays (e.g. montmorillonite)	abrasion resistance flame retardant support of active ingredients

Nanomaterials can be incorporated in textiles in two different ways: during fiber production or during textile finishing.

In fiber manufacturing, the nanoparticles are introduced by mixing in the polymer, before fiber spinning. The incorporation is made either in the melted polymer, in the case of melt spinning, or in the polymer solution, in the case of wet or dry fiber spinning processes. In both cases, the nanoparticles are evenly distributed inside the fiber volume. We can speak in this case of a "nanocomposite" material. The content of nanoparticles in the fiber can be as low as 0.1% to obtain a sufficient functionalization (Som et al., 2009). When the incorporation is done by this

process, the nanoparticles are firmly incorporated in the textile fiber and the effect is highly durable. The nanoparticles are inside the fiber and normally can only be released by means of abrasion. This fact poses low risk in terms of safety and health both for the workers involved in the subsequent textile processing and for the consumers.
Although the use of fibers functionalized by means of the incorporation of nanoparticles before fiber spinning has the advantage of having a very durable effect, it has as two major inconvenients: the process cannot be applied to natural fibers and there is a dependence on the fiber manufacturer. In fact, the textile manufacturing chain is very long, from yarn spinning to the final product, and it is normally much easier and cheaper to work with traditional textiles and apply the functionalization at the end of the textile process, during fabric finishing.
The incorporation of nanoparticles during fabric finishing can be obtained by traditional processes like dipping (exhaustion process), padding, printing or coating. To assure a good adhesion of the nanoparticles to the textile surface, organic polymers are normally used.
In this case, there are further concerns for the safety and health of the workers involved in the fabric finishing processing, due to the manipulation of the chemicals containing nanoparticles and of the textile itself. There must also be a concern for the workers in the garment manufacturing processes, which will be manipulating the textiles containing nanoparticles in all the cutting, sewing, pressing and packaging operations.
Most of the nanotextiles present in the consumer products are based on the application of nanoparticles by means of the fabric finishing process. The release of nanoparticles during the daily use is a safety and health concern, which will be dealt in the next section.

3. SAFETY AND HEALTH CONCERNS RELATED TO NANOTEXTILES

As there are different manufacturing processes by which nanoparticles can be integrated in fibres or textiles, there can be variation in how tightly bound the nanoparticles are into the textile material (fibre or coating). It is these factors and the use to which the textile is subjected that determine whether and to what extent nanoparticles can be released from it.
Depending on the location of the integration of nanoparticles in the textile, they can be more or less heavily exposed to external influences. In addition, there can be different degrees of binding of the nanoparticles to the textile material (covalent bonding, ionic bonding, hydrogen bonding, Van der Waals bonding). The strength level of bonding depends primarily on the following factors (Som et al., 2009):

- Type of nanoparticle (chemical composition, shape, etc.)
- Type of fabric
- Ageing of the nanoparticle functionalization (e.g. photo-oxidative reactions on the nanoparticle surface can cause the destruction of functional groups and the covalent bond to the fabric)
- Process engineering parameters during production
- Previous and subsequent finishing treatments of the textile fabric.
- The stability (durability) of the nanoparticles present in the textile is not only dependent on their binding to the fabric, but also on the impacts on the fabric during its life cycle (production, use, recycling / disposal), which can damage the textile material or the bond between the nanoparticle and the fibers:
- Abrasion
- Mechanical stress (such as strains, pressure)
- Ultraviolet radiation
- Body fluids (sweat, saliva, urine)
- Water (rain, washing)
- Solvents (during textile processing or dry cleaning)
- Detergents (either in textile processing or during laundry)
- Temperature changes; high temperatures (up to 225° C in textile finishing).

It is known that textiles can lose between 5% (in the case of continuous filaments) and up to 20% (in the case of staple fiber loose materials) of their mass during use as a result of abrasion, mechanical influence, irradiation, water, sweat, washing detergents or temperature variations. Even if the nanoparticles remain attached to the fibers, they will be released from the textile material to the environment (either to the human body, air, water, soil) together with the fibers. In fact, nanotextiles may release individual nanoparticles, agglomerates of nanoparticles or small particles of textile with or without nanoparticles.
For instance, in the case of textiles containing nano-silver, there are several studies concerning the release of silver nanoparticles during washing (e.g. Benn & Westerhoff, 2008, Geranio et al.,

2009, Mitrano et al., 2014). Some investigations that have been made show that some products can lose up to 35% of the silver in the washing water after only one wash; nevertheless, some suppliers of silver-based antibacterial finishes claim that there is practical no release during washing and that the finish remains effective after more than 50 washes.
Safety and health concerns related to nanotextiles should consider all the life cycle of the materials: safety for the workers during all the manufacturing stages, especially in the case of the application of nanostructured materials in the fabrics, as mentioned in the previous section, safety for all the people involved in the trade phases (distribution and retail), safety for the consumers. Nanoparticles released from textiles to the air, to the water and to landfill must also be taken into consideration, as they can directly or indirectly affect humans.
The nanoparticles can interact with the human body via three different ways of contact or penetration: inhalation, ingestion and skin contact. Although all the three pathways can be related to textiles, skin contact is of course the most relevant. This topic will be discussed in the next section.

4. CASE STUDY: DEVELOPMENT OF A TEST METHOD FOR SKIN EXPOSURE TO NANOPARTICLES

The European Commission has recently issued a mandate to the three European Standardization bodies (CEN, CENELEC and ETSI) specifically asking to develop standards for testing methods and tools for the characterization, behaviour and exposure assessment of nanomaterials. The exposure takes into account aspects of health and safety of workers as well as of consumers and the environment itself. This mandate identifies four areas for standards development:

- Methodologies for nanomaterial characterization in the manufactured form and before toxicity and eco-toxicity testing;
- Sampling and measurement of workplace, consumer and environment exposure
- Methods to simulate exposures to nanomaterials
- Health, safety and the environment.

This mandate is being handled by the Technical Committee CEN/TC352 – Nanotechnologies. A roadmap identified 45 standardization projects in the field of "characterization of and exposure to nanomaterials" and "health, safety and environment". Among these, ten are directly within CEN/TC 352 scope, clustered in three areas:
Area 1: Sampling and measurement at workplace, consumer and environment exposure
Area 2: Methods to simulate exposures to nanomaterials
Area 3: Health, safety and the environment
Within this mandate, an extensive standardization programme has been prepared and is being developed, with conclusion foreseen for 2018.
In area 2, one of the possible exposures of humans to nanomaterials is skin exposure. As this topic can be very relevant for textiles, the Technical Committee CEN/TC248 (Textile and Textile Products) is at present developing a test method named: "Guidance on measurement techniques relevant to different exposure routes to nanoparticles – Skin exposure". Although this method is specifically being developed for textiles, it can in principle be applied also to other products containing nanomaterials that can enter into direct contact with the skin.
In order to evaluate the migration of nanoparticles from textiles to the skin, a possible test can be based on the use of an artificial perspiration solution under physical stress. Artificial perspiration solutions (acid and alkaline) are described in standard EN ISO 105-E04 (Textiles – Tests for colour fastness – Part E04: Colour fastness to perspiration). The artificial perspiration acid solution is already used in the following document: prEN 16711-2 (Textiles – Determination of metal content – Part 2: Determination of metals extracted by acidic artificial perspiration solution), with expected publication during 2015.
In the standard EN ISO 105-E04, there is a simulation of contact with the skin of the textile to be tested, together with white standard adjacent fabrics, during 4h at 37ºC, but there is no mechanical stress. A possible alternative is to use a test similar to the test EN ISO 105-C06 (Textiles - Tests for colour fastness - Part C06: Colour fastness to domestic and commercial laundering), by immersing the textile to be tested in the artificial sweat solutions, under mechanical agitation in a thermostatic bad at 40ºC. Test is made both with the acid (pH 5.5) and with the alkaline (pH 8.0) artificial sweat solutions, with separate test specimens. The treatment is carried out during 30 minutes and involves the use of acrylic plastic balls to simulate physical stress. Nanoparticles, as well as their aggregates and agglomerates that can release nanoparticles, are then analysed in the extract solution.

This method has been developed by von Goetz et al (2013). These authors have tested commercially available textile products intended for sports or outdoor activities (shirts, pants trousers and socks, for adults and also for children) which included finishes based on nano-silver (antimicrobial effect) and nano-titanium dioxide (UV protection). The content of nanomaterials in the tested textiles was up to 183 mg Ag / kg of textile or 8543 mg Ti / Kg of textile. The tests show a significant release of nano-silver, which reached up to 14%. These results are much higher than other reported in the literature and contradict the producers that the claim that there is practically no release of nano-silver during the use of textiles and that the finish is permanent. In the case of titanium dioxide, no relevant release has been detected. It must be emphasized that sun protective lotions, which are put on the skin, are often based on nanoparticles of titanium dioxide or zinc dioxide.

Another possibility, which is also foreseen for possible inclusion in the standard test method to be developed, is the release from the textile by mechanical action, through a "linting" mechanism. This test could possibly be based in the method mentioned in the standard EN ISO 9073-10:2004 (Textiles - Test methods for nonwovens - Part 10: Lint and other particles generation in the dry state).

5. CONCLUSION

Nanomaterials have the potential to improve the quality of life and to contribute to industrial competitiveness in Europe. However, the new materials may also pose risks to the environment and raise health and safety concerns. The Scientific Committee on Emerging and Newly Identified Health Risks has concluded that, even though nanomaterials are not per se dangerous, there is still scientific uncertainty about the safety of nanomaterials in many aspects and therefore the safety assessment of the substances must be done on a case-by-case basis. In the case of textiles, there are still very few studies on the possible health risks involved with "nanotextiles".

The release of nanoparticles from textiles is particularly relevant when the incorporation is made by fabric finishing. It can occur by different mechanisms. In this paper, the release resulting from skin contact, involving abrasion and sweat, has been analysed more in detail, involving a possible standard text method. The studies made up to now involve silver and titanium dioxide nanoparticles, which are present in the most common nanotextiles in the consumer market. Nevertheless, there are still a lot of discussions on if these nanoparticles can really penetrate into the different skin layers and on the negative effects on human health.

In the case of titanium dioxide, it is very commonly used in sunscreens, the nanoparticles being deliberately spread over a large surface of the skin. Comparatively, the dermal exposure coming from textiles is much lower, so the relative relevance of skin exposure coming from textiles can be questioned.

Also in the case of nanosilver, it is used in deodorants, deliberately put on the skin, food packaging or even in toothpastes. Again the relevance of the silver nanoparticles from the textiles to the human body can also be questioned.

Further research work involving experts in the area of textiles, of safety and health and of toxicology is needed before the emergence of any regulation concerning nanotextiles.

6. REFERENCES

Benn, T. & Westerhoff, P. (2008). Nanoparticle Silver Released into Water from Commercially Available Sock Fabrics, *Environmental Science & Technology*, 42 (11), 4133-4139.

European Commission (2011). Commission Recommendation of 18 October 2011 on the definition of nanomaterial (2011/696/EU). *Official Journal of the European Union* of 20.10.2011, L275/38-40.

Geranio, L., Heuberger, M. & Nowack, B. (2009). The Behavior of Silver Nanotextiles during Washing. *Environmental Science & Technology,* 43(21), 8113-8118.

Gowri, S., Almeida, L., Amorim, T., Carneiro, N., Souto, A. & Esteves, M. (2010). Polymer Nano Composites for Multifunctional Finishing of Textiles - A Review. *Textile Research Journal*, 80 (13), 1290-1306.

Labouta, H. El-Khordagui, L., Krausc, T. & Schneider, M. (2011). Mechanism and determinants of nanoparticle penetration through human skin. *Nanoscale*, 3, 4989-4999.

Mitrano, D., Rimmele, E., Wichser, A., Erni, R., Height, M. & Nowack, B. (2014). Presence of Nanoparticles in Wash Water from Conventional Silver and Nano-silver Textiles. *ACS Nano*, 8 (7), 7208–7219.

Som, C., Halbeisen, M & Köhler, A. (2009). *Integration von Nanopartikeln in Textilien Abschätzungen zur Stabilität entlang des textilen Lebenszyklus*. EMPA, Swiss Federal Laboratory for Materials Testing and Research, St. Gallen.

Som, C., Nowack, B., Wick, P. & Krug, H. (2010). *Nanomaterialien in Textilien: Umwelt-, Gesundheits- und Sicherheits-Aspekte*. EMPA, Swiss Federal Laboratory for Materials Testing and Research, St. Gallen.

von Goetz, N,. Lorenz, C:, Windler, L., Nowack, B., Heuberger, M. & Hungerbühler, K. Migration of Ag- and TiO_2-(Nano)particles from Textiles into Artificial Sweat under Physical Stress: Experiments and Exposure Modeling (2013). *Environment Science & Technology*, 47 (17), 9979–9987.

Wong, Y., Yuen, C., Leung, M., Ku, S. & Lam, H. (2006). Selected Applications of Nanotechnology in Textiles. *Autex Research Journal*, 6(1), 1-10.

Achieving better safety at lower cost: good practice for learning with work accidents

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Abstract

Work accidents still represent social problem in Europe and the world. For long, research has acknowledged the relevance of accident information for prevention and learning and the need for companies to develop a reporting and learning culture. A learning culture means that the information is available, disseminated, discussed, and changes are implemented. Recently the Institute of Medicine emphasized the role of continuously learning for improving health care in America and simultaneously decrease costs. Few studies approached this issue comparing different learning strategies used by companies. Our study aims to explore how companies use accident information and develop strategies for learning with accidents, covering all the learning cycle phases through, a) identifying the learning patterns across companies and across activity sectors, b) checking for differences among certified and non-certified companies. Seventeen case studies were conducted with organizations operating in Portugal in different activity sectors (e.g., chemical industry; construction; transports; energy production, health care) that were identified as having good practices. Data was collected using long semi-structured interviews with key stakeholders. The interview protocol covered information such as: type of accident records; the formal procedure for accident investigation, the use of relevant information towards learning and improvement. Additionally, relevant documentation was also analyzed. All data was subjected to descriptive analysis, followed by a statistical treatment with Multiple Correspondence Analysis (MCA), which allows an analysis of multiple and interrelated categorical variables and it is used to detect underlying structures in a data set by representing the categories of the multiple variables as points in low-dimensional Euclidean spaces. Results from the preliminary descriptive analysis suggested that organizations have some standardization of the practices used for dealing with accident information. These practices cover the procedures, responsibilities and ways to collect, code, analyze and spread the information about accidents at all hierarchical levels. Simultaneously, it was observed that some (apparently) standardized procedures are characterized by non-standardization. For instance, some organizations accept that accident data might be collected by several persons, with different job responsibilities and training. The main MCA results showed two dimensions corresponding to the technical and social learning strategies and practices and four patterns were found. These patterns reveal different levels of learning practices from a level 1 corresponding to minimal practices used for learning to level 4 that reveal a high degree of learning, combining practices of a technical and social nature. Additionally, the results revealed that companies in the same activity sector can have very different practices, independently of the existence of OHSAS certification. The results allowed to conclude that organizations with good safety practices follow the learning cycle. Overall, these organizations have established procedures to report accidents and to collect information on them. Nevertheless, results also show that there are organizations that still do not maximize the means of learning with work accidents. Namely some critical practices require improvement: lack of internal discussion of accidents' causes, accidents learning process entirely centralized in persons with higher responsibilities; not all the hierarchical levels are involved in accidents analyses, discussion activities and on the resulting information diffusion.

Keywords: Organizational learning, Work accidents, Learning practices, Multiple Correspondence Analysis (MCA).

1. INTRODUCTION

Europe has been facing very difficult times due to the economic crisis and austerity that is installed in several countries to assure its sustainability. In this paper, it is our claim, that improving prevention through accident learning is the answer for improving safety outcomes and decrease organizational costs due to accidents or safety problems. This assertion is sustained in two main types of evidence: accident statistics and the role of learning in its prevention; reports on costs in Health Care and the role of learning from adverse events/errors for increasing quality and efficiency.

The European statistics on accidents at work reveal that the number of accidents have been decreasing but are still high, around 2.4 million leading to around 4500 fatalities (Eurostat, 2013). Considering all the efforts made in developing an European policy and legislation that enforce Safety and investments in changing attitudes and behaviour, those numbers suggest that all the efforts are still not enough. This can be the reason behind the fact that in the last 5 years, several papers were published focusing the need for improving learning from accidents and its prevention (e.g. a special number in Safety Science in 2011, see the editorial by Carrol & Fahlbruch; Hovden et al., 2011; Størseth et al., 2012; Jorgensen, 2015; Gotcheva et al., 2015).

Stock et al. (2007) emphasized that medical errors are linked to more than 98,000 deaths annually, and that 58% of these error-related deaths are preventable. In this study the authors stress the role of organizational culture and critical success factors, like reporting errors without blame, open discussion about errors, statistical analysis of error data that may lead to a reduction of medical errors. Recently the Institute of Medicine of the National Academies (2013) presented a report sustaining that the answer for having “best care at lower cost” requires continuous learning in the health care systems. Specifically it is stressed that it is possible to reduce the costs (excessive costs in Health Care) and at the same time improve the quality of the service. For instance in this report it is shown that “Missed Prevention Opportunities” represent a cost of 55 billion dollars, inefficiency in the delivered services (including due to mistakes and errors) are estimated to have 130 billion dollars of excess costs. The development of the continuous learning requires continuous knowledge development, improvement and application and enforcing a continuous learning culture.

1.1. Organizational Learning with accidents

Major accidents with catastrophic consequences have been analyzed by experts or teams of highly trained investigators and, typically, significant lessons can be learned from any single event. In contrast, with the “small” but very frequent accidents at work, meaningful conclusions leading to prevention are normally drawn up on statistical analysis of aggregated data. Preventing accidents at work, as any other type of accidents, involves learning and decision-making processes that require objective and reliable information. To be effective, it should be the final step of a deep-rooted learning process, rather than just the result of isolated corrective measures.

Organizational learning processes may be characterized using two main approaches (Easterby-Smith & Araujo, 1999): technical and social perspectives. The technical perspective stresses that learning requires information processing, interpretation and its respective consequences. The social perspective stresses the role of social interaction processes in learning. Together these two perspectives suggest three key assumptions about what groups need in order to learn from an event: (1) information about the event; (2) opportunity to share points of view about the event; (3) acquisition of new knowledge. Nevis et al. (1995) suggested learning facilitating factors, such as for instance: scanning imperative (seek out for information in the external environment); climate of openness (open communication and sharing errors); continuous education (providing resources for learning).

These proposals concerned organizational learning in general, in an effort to apply these perspectives to the safety domain Silva & Lima (2005) suggested 4 types of strategies for learning from accidents: diffusion, discussion, training and change. “Diffusion” refers to the dissemination of accidents information. “Discussion” goes a step further and includes the debate of accidents information. “Training” corresponds to the use of accidents to improve workers safety training. “Change” implies the organizational act of modifying something after an accident (e.g., changing rules, technologies, supervision, etc.). Each of these four strategies

can be applied to the whole organization (global) or only to a sector or department (local). Moreover, they can be applied to accidents that happened inside the organization (direct experience) or that occurred in other organizations (indirect experience).
Another approach relates learning to the organizational culture. Namely, it has been strongly recommended that organizations should develop a reporting culture and a learning culture (Reason, 1997). A reporting culture stresses the importance of getting knowledge from small accidents and near misses; a learning culture means that the information is available, disseminated, discussed, and changes are implemented. Moreover, Reason (1997) stresses that learning implies observing, reflecting, creating and acting. The cycle of information begins with the collection of accident data; in certain organizations this data is used internally for corrective action and, in fewer cases, for the systematic improvement of safety. In all cases, however, accident data is typically used for compensation purposes and for the production of official statistics, for which registration procedures and classification schemes are a key issue (Jørgensen 1998; Jacinto and Aspinwall, 2004). Furthermore, Koornneef & Hale (2004) and Kingston (2001) summarise several barriers that avoid learning from accidents, as for instance: do not collect or preserve information; do not use appropriate methods of analysis; only specialists make investigations; blame culture; lack of accountability; passive communication.

1.2. Learning and Occupational Health and Safety Management Systems

Ultimately, it is also important to explore how organizational safety and learning practices may be shaped by the certifications that companies have and its requirements. Safety and Health certifications constitute a key tool to help companies to improve the quality of work conditions and prevent occupational fatalities and diseases. Specifically, Occupational Health and Safety Management Systems (OHSAS) 18001 (2007) help organizations to manage and control their occupational health and safety risks, and thus improve their OH&S performance. OSHAS specify requirements for incident investigation. Namely, they strongly recommend that organizations shall establish, implement and maintain procedure(s) to record, investigate and analyse incidents in order to: determine underlying OH&S deficiencies and other factors that might be causing or contributing to the occurrence of incidents; identify the need for corrective action; identify opportunities for preventive action; identify opportunities for continual improvement; communicate the results of such investigations. The investigations shall be performed in a timely manner and any identified need for corrective action or opportunities for preventive action shall be dealt with in accordance with the relevant parts and the results of incident investigations shall be documented and maintained (OSHAS, 2007, 12-13).

1.3. Aims

Until now research about learning from accidents has been focusing on one case study or on one phase of the learning cycle, but few tried to articulate the theoretical assumptions with companies' practices. This study was part of a research project (CAPTAR – Learn to prevent) that had the goal of establishing strategies and processes to learn efficiently with accidents and that has covered all the cycle phases (from the collection of information to the spread of the lessons).
The present study intends to contribute for the increase of the understanding about how companies are using work accident information and developing strategies and practices for learning with accidents. Specifically it aims to identify learning patterns across companies and across activity sectors and explore its link with OSHAS certification.

2. METHODOLOGY

2.1. Sample

Seventeen case studies were carried out, involving organizations operating in 8 different activity sectors (e.g., manufacturing; construction; production and distribution of energy, etc.); participating organizations were identified considering three main criteria: size (medium/large); safety practices (known by having good practices and good reputation); certified management systems (safety management systems and/or quality management systems).
The majority of these organizations (see table 1) are located in Lisbon and Tagus River Valley (i.e. 15); they are either Multinational (i.e. 5) or National (i.e. 12). Almost all (15) have certified management systems (e.g. Quality - 12; Environment – 11; Safety and Health – 6; and Social Responsibility – 2). Four organizations also have certified management systems that are specific to their own activity. In terms of number of workers, four have less than 500 workers,

nine have between 501 and 3500 workers and four have more than 3501 workers. The majority of the sample organizations have faced changes in the last five years, especially concerning to organization's structure and management (e.g. stakeholder division, group's fusions). All have an occupational health and safety system ranging from one year of antiquity to 45 years. The majority have particular risks of operation (N=15, e.g. biological, chemical, explosion, transportation), of these seven also have activity specific risks (e.g. Construction activity sector), and some have special legal requirements to comply with (N=8, e.g. ATEX and/or Seveso legal requirements).
The response rate to this study is 61%: out of 28 organizations invited, 17 have accepted to participate.

Table 1 – Organizations characterization

Characterization	**Type**		**Size**		**Geographical location**	
Sector	**Multi-national**	**National**	**Med**	**Large**	**North**	**Lisbon and Tagus RIVER Valley**
Construction	1	4	-	5	1	4
Chemical (Manufacturing)	1	1	1	1	1	1
Services	1	1	-	2	-	2
Energy	-	1	-	1	-	1
Transportation	-	3	-	3	-	3
Food (Manufacturing)	1	-	1	-	-	1
Health Care	-	2	-	2	-	2
Vehicles manufacturing	1	-	-	1	-	1
Total	**17**		**17**		**17**	

2.2. Data collection

The data was collected using long semi-structured interviews with key organizational stakeholders. The interview protocol was developed considering the literature and previous work (e.g., Silva & Lima, 2005; Jacinto, 2003; Koornneeff, 2000; Reason, 1997).
The interview protocol is structured according to different information aims and includes both closed and open questions. The first part was designed to collect information aiming to characterize organizations in general (e.g. geographical location, activity sector, organization type). The second part focuses on information aiming to characterize the organizations` safety system using 19 items (e.g. "Have any certification on management systems?") and particular cases with 5 items (e.g. "Which are the particular risks in this company or activity sector?"). The main part of the interview protocol was designed to collect data concerning Reason's learning cycle. Namely, the interview protocol has three different aims for accidents and incidents information collection: 1) Gathering/recording information, 2) Analyzing and coding information 3) Information dissemination and discussion. The "gathering/recording" phase was operationalized using 27 items (e.g. "Which are the procedures for collecting, gathering and reporting an accident?"). Analyzing and coding information were operationalized by 11 items (e.g. "Do you run in-depth analysis of (all/any) accidents? Criteria?). The feedback learning cycle phase was operationalized considering the information discussion practices, with 17 items (e.g. "Accidents are discussed with all workers/employees?), and also considering the dissemination practices, with 16 items (e.g. "Are past accidents used on training sessions?"). To finish, there was also a section about the safety culture that included 8 items.
In addition to the interviews, some relevant organizational documentation was also collected and analysed in the majority of these organizations (e.g. accident forms, accident analyses procedures), especially all documents associated with the gathering of information on accidents. In some organizations it was also collected pertinent documentation regarding their health and safety activity in general (e.g. annual activity reports, statistical indicators or forms); information and records about the organizational activity in general were also provided by some organizations (e.g. organization presentation, financial reports).
For the data collection, key stakeholders from different companies identified by the criteria stated previously, were contacted. The contacts included informal phone calls followed by a formal letter explaining the research project aims, objectives and data collection procedures (i.e., copy of the protocol), and a confidentiality contract. Twenty-eight organizations were contacted and 17 accepted to participate (i.e. 61% response rate).

Interviews were conducted with persons from the health and safety department and most of them have included the head of the department. Overall, the interviews length varied between two and five hours and corresponded to a total around 170 pages of information.
After the interview, all the information collected was transcript and validated by the applicable interviewees, for which each file was sent out to the applicable interviewee for validation of the contents.

2.3. Data analysis
All collected data was coded according to the learning cycle phases and the statistical analyses have been developed considering this variable division.
In a first step, descriptive frequency analysis allowed to identify the most common learning practices used by companies (major similarities) as well as the less frequent (Silva et al, 2010).
In the second step, Multiple Correspondence Analysis (MCA) was used in order to find learning strategies patterns. We managed multiple categorical indicators and explored their inter-relationships.
MCA allowed us to identify the associations between the multiple categorical variables and provided a graphical display of the multidimensionality of the space, representing all the categories of the variables in a sub-space with the minimum number of dimensions possible (two). With MCA we mapped the structure of the interrelationships between variables and we defined the configurations of learning practices.

3. RESULTS

3.1. Descriptive Results
A preliminary descriptive analysis was conducted earlier (Silva et al, 2010) on the main similarities and differences within organizational formal practices considering the learning phases: collecting, analysing and information dissemination and discussion. These results suggested that organizations have some standardization on the practices they use for collecting, coding and analyzing accident information. These formal practices cover the procedures, responsibilities and ways to collect, code, analyze and spread the information about accidents at all hierarchical levels. Simultaneously, it was observed that some (apparently) standardized procedures are characterized by non-standardization. For instance, some organizations accept that accident data might be collected by several persons, with different job responsibilities and training.

3.2 MCA Results
The discrimination measures and the contributions of the active variables for both dimensions in analysis (inertias 0.266 and 0.218, respectively) are presented in Table 2. The two dimensions correspond, roughly, to the technical and social learning strategies and practices.
From the combination of the two dimensions we can find 4 profiles of learning practices that correspond to different levels of learning with accidents, from a level 1 associated to minimal practices used for learning to level 4 that reveals a high degree of learning combining practices with a technical and social nature (see Figure 1).

Table 2 –Discrimination Measures and contributions of the active variables

Active variables	Dimensions			
	1		2	
	Discrimination measures	Contribution (%)	Discrimination measures	Contribution (%)
Safety responsible	**0.481**	11.32	0.076	2.18
Safety technician	<u>0.196</u>	4.61	0.055	1.57
Supervisors	0.106	2.49	<u>0.118</u>	3.38
Function (other)	0.024	0.56	**0.400**	11.45
Specific Software accidents database	**0.244**	5.74	0.170	4.87
Formal analyses methods tools	0.067	1.58	**0.589**	16.86
Analyses level	**0.497**	11.69	**0.302**	8.65
Predefined classification schemes	0.105	2.47	**0.511**	14.63
Management system review	**0.386**	9.08	0.008	0.23

Newspaper/Newsletter	0.020	0.47	**0.489**	14.00
Feedback Supervisors	0.155	3.65	0.047	1.35
Feedback Workers	0.195	4.59	0.133	3.81
External diffusion sharing	0.016	0.38	**0.434**	12.42
Discussion Management	**0.624**	14.68	0.021	0.60
Discussion Supervisors	**0.524**	12.33	0.127	3.64
Discussion Workers	**0.610**	14.35	0.013	0.37
Total	4.250	100.00	3.493	100.00
Inertia	0.266		0.218	

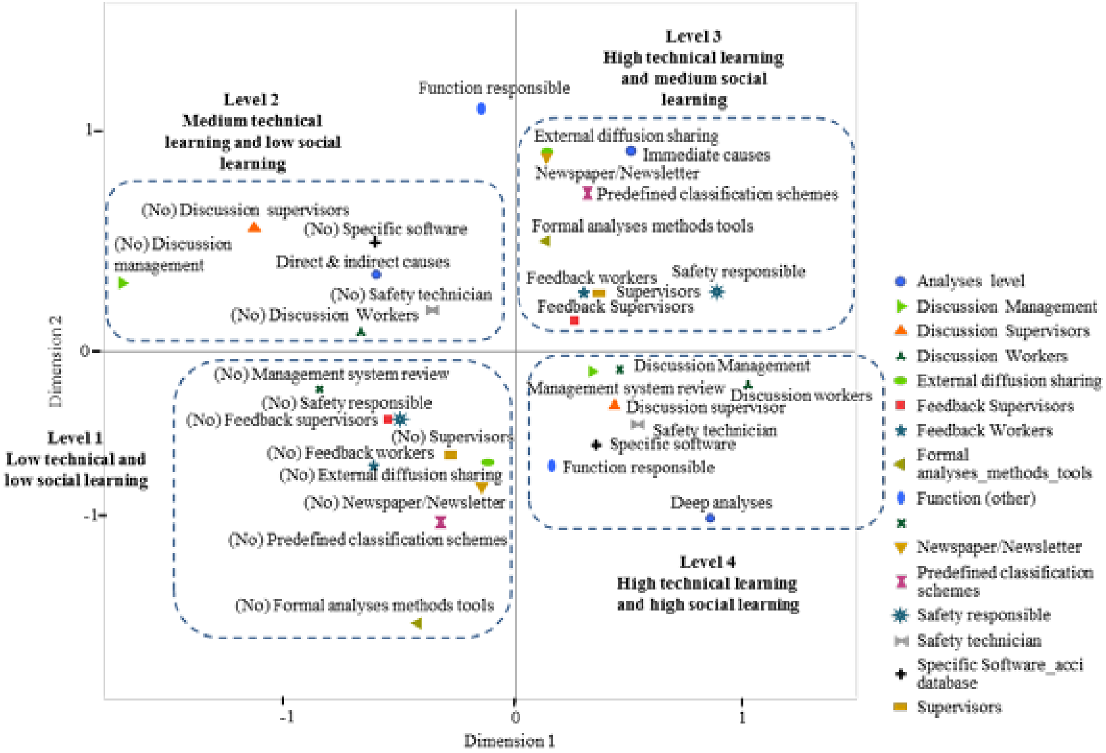

Figure 1 - Topological configurations of formal learning practices profiles

Comparing the position of companies according to these levels (Figure 2) and taking into account their activity sector, we observe that companies in the same sector can be very different from each other. For instance, the five construction companies are positioned in all the levels, one company (Construction 1) revealing a low level of learning, complying only to the legal requirements, and two companies (Construction 3 and 5) showing the highest level of learning practices, going far beyond legal requirements.

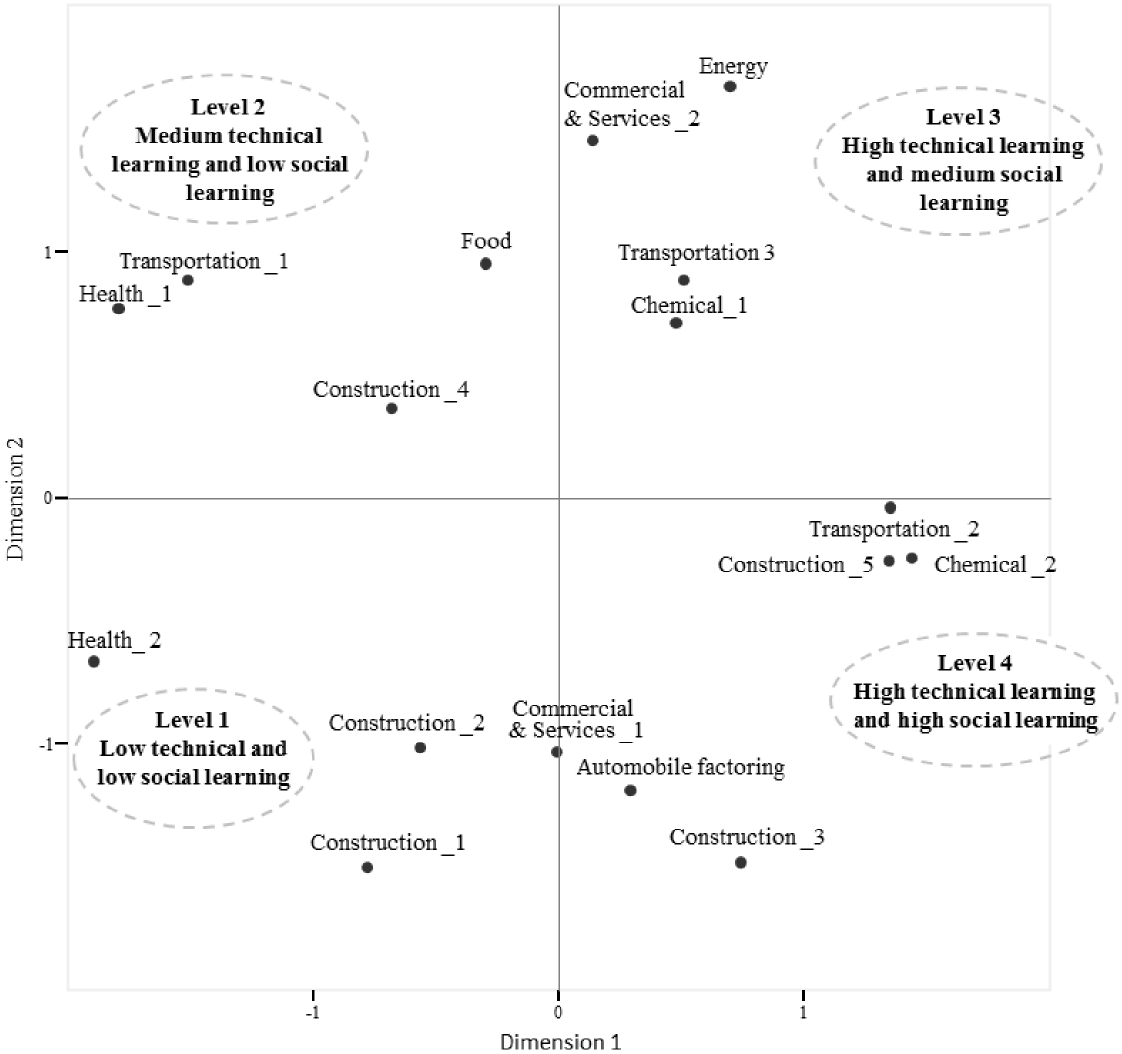

Figure 2 – Formal learning practices profiles: position of companies

Finally, the MCA results were also estimated for taking into account the potential relation with certification systems (see Figure 3). Namely, it was considered if companies had OHSAS certification (Health & Safety Certification) and if companies had an isolated or integrated system (Environment & Safety; Quality, Environment & Safety). Results reveal that OHSAS certification is not related to company's level of learning, but the type of system (isolated versus integrative) is related to different levels of learning practices; namely, the existence of an integrated system combining Quality, Environment & Safety seems to be a characteristic of companies that reveal higher levels of learning.

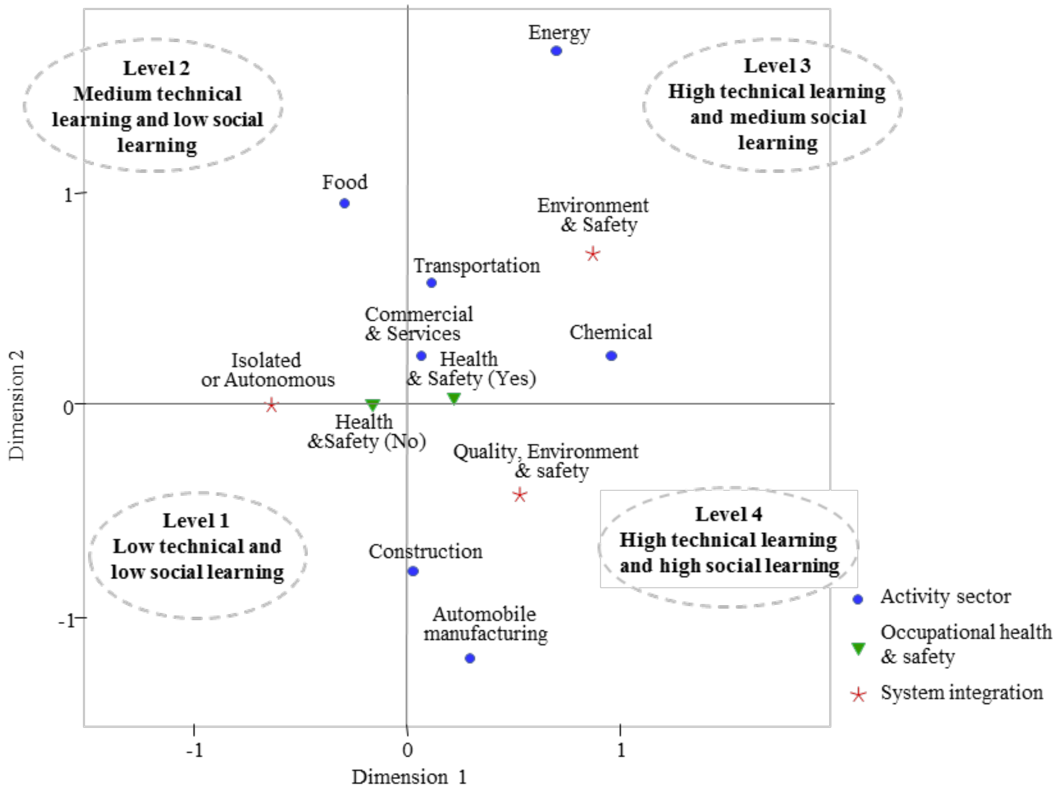

Figure 3 – Formal learning practices profiles: OSHAS certification and system integration

4. CONCLUSIONS

The results obtained with the 17 cases studied allowed concluding that organizations with good safety practices follow the learning cycle. Overall, these organizations have well established procedures to report accidents and to collect information on them. Their working definition of "occupational accident" is broader than the strictly legal one and much broader than the Eurostat's definition (+3 days lost), since they tend to record and analyze all accidents and incidents, even those without injury or days lost. All the organizations comply with Portuguese legal requirements in terms of accidents definition and reporting, information gathering, statistical analyses and information dissemination.

These organizations also tend to disseminate the relevant safety information across all hierarchical levels and to involve their workforce actively in the responsibility of collecting and reporting accident's information. The most significant results of their accident analysis, including causes and the lessons learned, are also disseminated thoroughly, in a way to prevent further and future occurrences. In synthesis data suggest three main strengths in organizational formal practices: 1) report accidents; 2) analyse almost all accidents and incidents, and 3) produce and use statistical data to support aggregate analysis and decision making.

Nevertheless, results also show that there are organizations that still do not maximize the means of learning with work accidents. In particular, some critical practices require improvement due to: lack of internal discussion of accidents causes' analyses; learning processes entirely centralized in persons with higher responsibilities; not all the hierarchical levels are involved in accidents analyses and discussion; lack of a good communication strategy for the information diffusion.

Results also show that OHSAS certification may represent different opportunities for learning and prevention of accidents, depending on the company. This suggests that certification is not always the (magic) answer/solution for a better safety system. Furthermore, an integrated system of Quality, Environment & OHS seems to be associated with more complex learning practices. However, it remains to be answered When, Why, How?

Considering some recent research (e.g., Cooke & Rohleder, 2007; Krstin, 2007) human resources practices and organizational practices play an important role in aiming to increase the potential learning from incidents and accidents. Therefore, it will be important to develop more research on this issue in order to effectively understand the role of practices and increase their preventive power.

To conclude, considering the economic costs of occupational accidents and all the benefits of learning with those events, having better safety at lower cost depend of our ability to develop and sustain a continuous learning culture.

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6. REFERENCES

Carroll, J., & Fahlbruch, B. (Eds) (2011). The gift of failure: New approaches to analyzing and learning from events and near-misses — Honoring the contributions of Bernhard Wilpert. *Safety Science*, 49(1), 1-4.

Cooke, D.L. & Rohleder, T.R. (2006). Learning from incidents: from normal accidents to high reliability. *System Dynamics Review* 22 (3), 213-239.

Easterby-Smith,M., & Araujo, L. (1999). Organizational learning: current debates and opportunities. In M. Easterby-Smith, J.Burgoyne e L. Araujo (Eds). *Organizational Learning and the Learning Organization* (pp. 1-21). London: Sage.

Eurostat (2013). European Statistics on Accidents at work. European Commission.

Gotcheva, N., Oedewald, P., Wahlström, M., Macchi, L. ,Osvalder, A-L, & Alm, H. (2015). Cultural features of design and shared learning for safety: A Nordic nuclear industry perspective. *Safety Science*. In press

Hovden, J., Størseth, F., & Tinmannsvik, R. K. (2011) Multilevel learning from accidents – Case studies in transport. *Safety Science*, 49(1), 98-105.

Institute of Medicine of the National Academies (2013) Best Care at Lower Cost: The Path to Continuously Learning Health Care in America. National Academy of Sciences.

Jacinto, C. and Aspinwall, E., (2004). A survey on occupational accidents reporting and registration systems in the European Union. *Safety Science* 42(10), 933-960.

Jacinto, C., (2003). A structured method for the investigation and analysis of occupational accidents. Unpublished Ph.D Thesis, School of Engineering, Mechanical and Manufacturing Engineering, University of Birmingham, UK.

Jørgensen, K., (1998). Reporting and Compiling Accident Statistics. In: *The ILO Encyclopaedia of Occupational Health and Safety*, 4th Edition, Vol. II, Part VIII-57.26, International Labour Organisation, Geneva.

Jorgensen, K (2015). Prevention of "simple accidents at work" with major consequences. *Safety Science*. In press

Kingston, J. (2001). *Organisational learning from incidents*. John Kingston Associates, Uk.

Koornneef, F. (2000). *Organised learning from small-scale incidents*. Delft: Delft University Press.

Koornneef, F. & Hale, A. (2004). Organisational learning and the theory of action. In J.H.E. Andriessen & B. Fahlbruch, (Eds). *How to manage experience sharing – From organisational surprises to organisational knowledge*. Elsevier, Oxford.

Krstin, L. (2007). Learning from pipework failures. *Loss Prevention Bulletin* 196, 21-25.

Nevis, E. C., DiBella, A. J., & Gould, J. M. (1995). Understanding organizations as learning systems. *Sloan Management Review*, 36, 73-85.

OHSAS 18001:2007 (2007. Occupational health and safety management systems – requirements. UK: BSI. (ISBN 978 0 580 59404 5)

Reason, J. (1997). *Managing the risks of organisational accidents*. Ashgate Publishing Ltd, Aldershot Hants.

Silva, S. & Lima, M.L. (2005). Safety as an organizational value: improving safety practices and learning from accident. In K. Kolowrocki (Ed.). *Advances in Safety and Reliability* (vol.2, 1817-1824). London: Taylor & Francis.

Silva, S.A., Oliveira, M.J., Carvalho, H., Fialho, T., Guedes Soares, C., & Jacinto, C. (2010). Práticas organizacionais formais utilizadas para a aprendizagem com acidentes de trabalho . In Occupational Safety and Hygiene - SHO 2010, ed. P. Arezes; J.S. Baptista; M.P. Barroso; P. Carneiro; P. Cordeiro; N. Costa; R. Melo; A.S. Miguel & G.P. Perestrelo, 497 - 500. ISBN: 978-972-99504-6-9. Guimarães: SPOSHO.

Stock*, G.,* McFadden*, K., & Gowen, C. (*2007*).* Organizational culture*,* critical success factors, and the reduction of hospital errors. *International Journal Production Economics*, 106, 368–392.

Størseth, F. & Tinmannsvik, R.K. (2012) The critical re-action: Learning from accidents. *Safety Science*. vol. 50 1977-1982.

Toft, B. & Reynolds, S. (1997). *Learning from disasters – a management approach*. Great Britain: Perpetuity Press.

Research into Zero Accident Vision: Success stories from EU companies

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Abstract

The Zero accident vision (ZAV) is a promising new paradigm, which has been developed in industrial practice and offers new perspectives for accident prevention. The basic idea of ZAV is that all (serious) accidents are preventable, and companies should therefore have the ambition to prevent all (serious) accidents (Zwetsloot et al 2013). However, ZAV is a development stemming from industry, not from scientific development. Companies from seven European countries participated in a first research effort dedicated to ZAV, a project called success factors for the implementation of ZAV. This paper focuses on the qualitative part of that research effort, and presents the preliminary findings on success factors for the implementation, good practices and challenges encountered from these companies.

At the time of writing the paper data from interviews in 19 companies were available, as well as data from 3 national workshops wherein all companies from the respective countries participated. A key success factor is embedding the ZAV commitment in the company; it should be clear that the commitment is not hype but is there to stay even in times of change and/or difficulties. The companies that participated in the research use various strategies in this respect. The most important findings in terms of good practices that came out of our analyses so far are presented in this paper. We distinguish good practices with respect to: (a) the sustainability of the commitment to zero accidents, (b) good strategic practices, and (c) good tactical and operational practices. Examples of each category are given. All in all we conclude that ZAV is the basis for inspiring and innovative approaches to improve safety as well as for the implementation of more traditional safety practices. It is part of an on-going challenge which has consequences for the processes, the work organisation, organisational culture and leadership. Most ZAV committed companies have only implemented a limited number of the more innovative good practices. There is therefore great potential to be gained from networking between such companies, and from identifying, disseminating and implementing inspiring good practices. This will generate added value for ZAV committed companies as well as for other companies that are seriously pursuing improvement of their safety performance.

Keywords: good practices, safety strategies, accident prevention, commitment, injury prevention

1. INTRODUCTION

The Zero accident vision (ZAV) is a promising new paradigm, which has been developed in industrial practice and offers new perspectives for accident prevention. The basic idea of ZAV is that all (serious) accidents are preventable, and companies should therefore have the ambition to prevent all (serious) accidents. There are several major new perspectives revealed by thy ZAV concept (Zwetsloot et al 2013):

The first perspective is the concept of a 'commitment strategy' for safety; this is different from the dominant 'risk control' strategy to improve safety (Zwetsloot et al 2013). Commitment strategies – as opposed to control strategies - are already known in human resource management since the mid-eighties (e.g. Walton 1985, Beer 2009). A long term commitment to prevent all (serious) accidents creates conditions in organisation wherein initiatives to improve safety are encouraged and can flourish. It is important to note that 'commitments to zero' are not so exceptional in the business world, as many safety engineers propose. Many companies today have committed themselves to several 'zeros' e.g. lean production (zero economic waste), zero defects (Halpin 1966), zero climate impact, or zero tolerance of unacceptable behaviour (e.g. bullying, unwanted sexual attention).

A second innovative perspective is the importance of 'vision zero' for the development of a 'prevention culture', which is usually defined as a culture fostering prevention in the area of safety and health at work (2nd Strategy Conference 2011). In this perspective the commitment to 'zero' is a cornerstone for promoting a culture conducive to accident prevention. A third perspective is that the goal of zero accidents cannot be realised sustainably with existing good practices only: innovative practices are needed. While in traditional safety the focus is on 'control', and innovations are associated with the introduction of new risks, innovations can also be an opportunity for better safety, and it makes sense to develop innovative safety practices. A fourth perspective is the ethical perspective: zero is the only goal that is ethically sustainable (Aaltonen 2007), and is compatible with modern corporate social responsibility and the growing attention to business ethics. Last but not least, there is the experience of the 'Zero Accident Forum' in Finland, wherein more than 300 companies currently participate. Exchanging inspiration and good practices in this network has supported the member companies to realize significant safety improvements over time, even though their safety performances were already much better than the national average when they joined the Forum (Virta et al., 2009). So far there is very little, if any, scientific research in this field, but there are good reasons to state that the zero accident approach as a very important innovation that deserves the full attention of safety researchers (Zwetsloot et al 2013).

The ambition to achieve accident free workplaces should not be confused with an accountable zero accident target. In the present era wherein managers and sometimes workers are made accountable for many things, and perhaps receive a bonus for reaching their target, there is, of course, the risk that the statistics may show zero accidents, but only because accidents are then no longer reported and documented. When 'zero accidents' is used as a target in a safety control strategy, linked with accountability and management by objectives, it can easily lead to false safety (Zwetsloot et al 2013).

In the current research project 'Success factors for the implementation of the Zero Accident Vision' the aim is to better understand the factors and activities that contribute to successful accident prevention in companies that have committed themselves to ZAV. The focus thereby is on four key areas: (1) commitment to ZAV, (2) safety communication, (3) safety culture, and (4) safety learning. In this paper the focus is on the analyses of the successes, good practices and challenges of the participating companies. As this research is, to our knowledge, the first to investigate the implementation of ZAV, the nature of our research is dominantly explorative in nature.

2. MATERIALS AND METHODS

The overall research project is carried out in a joint effort of seven research institutes in seven EU countries. 27 companies participate in the study, and all have committed themselves to prevent all (serious) accident, thereby explicitly or implicitly referring to a ZAV. In the first stage a survey (72 items, 11 dimensions) was developed that was carried out in the participating companies, in their national language. The focus of the survey was on the four key areas previously mentioned (safety commitment, communication, culture, learning). Each company received preliminary feedback on the results of the survey in their company. The analyses of the survey with respect to the four key areas are described in other papers or abstracts for the WOS conference. In this paper the focus is on the qualitative part of the research project only.

2.1. Data gathering

After the survey qualitative data were gathered in two ways:
Through a limited set of semi-structured interviews (usually 3 or 4 interviews including interviews with line managers, safety staff managers and worker representatives) per company. A common interview format was developed for use in each country, with focus on identifying the key factors that contributed to successes in the company in each of the four areas (safety commitment, communication, culture, learning). The interviewees were also asked what, according to them, were the most important challenges with ZAV for their company for the next year, and the next five years. Other questions addressed their involvement (or not) in safety relevant networking and benchmarking activities, and broader 'zero commitments' (e.g. zero harm, zero defects, etc.). Finally the interviewees were invited to tell a 'short story' which illustrated a convincing, interesting or unique 'good practice' in their company.

The interviews were reported in a standardised format whereby the results of the various interviews were integrated by the interviewer into a concise ‘company report’. In case of different opinions or perspectives between the interviewees, each perspective was mentioned briefly.

Through national workshops with the participating companies. The aims of the national workshops were twofold:

For the companies:
To give feedback on the results of the project to the participating companies (per country)
To create and use opportunities to exchange experiences and learn from other ZAV committed companies, again with a special focus on sharing the ZAV commitment, safety communication, culture and learning.

For the research team:
Acquiring a better understanding of the qualities, challenges, and needs of ZAV committed companies, and the roles of safety communication, culture and learning therein.
To share and discuss ‘the meanings’ of the outcomes of the quantitative survey with the company representatives
An opportunity to validate and better understand the successes and challenges (including possible hidden hurdles and pitfalls) of the ZAV policies of the companies (identified in the interviews); and to better understand how context or/company-specific they are.

Inputs for the national workshops were presentations about:
The findings from the (European) survey and quantitative data analyses, including European comparison data which was provided by the national research team.
The findings from the (national) interviews, especially the ‘success stories’ (provided by the national research team)
The experiences, stories, challenges, needs and questions of the participating companies (not only from the safety officers, but also from managers and workers representatives) provided by the company representatives.

From a research perspective these workshops were carried out as focus groups. All presentations were followed-up by reflective discussions. After all company stories were presented, the focus of the discussion was to go beyond apparent differences between the company activities, and to identify common underlying principles between the variety of approaches presented. From each national workshop a concise report was made, according to a standardised format.

At the time of writing this paper, some activities in the project were not beyond the stage of planning. Interview data were available from 19 out of the 27 companies that participated in the broader research effort, and data from national workshops in 3 out of the 7 countries were available. The overview of the sources of the available data used for this paper is given in table 1.

Table 1 – the sources of the qualitative data used in this paper

Country	Number of companies involved in total study	Data from company interviews	Data from national workshops
Belgium	3	2	-
Denmark	3	3	-
Finland	4	4	+
Germany	3	-	-
Netherlands	4	3	+
Poland	5	2	-
UK	5	5	+
Totals	**27**	**19**	**3**

2.2. Methods

In each country, the members of the research team that carried out the interviews, wrote a concise report integrating the main outcomes of the various interviews per company, following a standardised format. These interview reports were verified by the central contact person of the company.

A member of the national research team also made a report of the national workshops, wherein all companies involved in the broader project participated. The interview data were analysed, using qualitative data matrixes that were focused on respectively the ZAV commitment, safety communication, safety culture and safety learning, and challenges identified. For example, in the data matrix for 'ZAV challenges for the next year', the findings for each company were structured into columns addressing respectively: organisational synergy, procedures, safety climate, subcontractors, continual development, safety priority, culture of prevention, well-being at work, managing safety in a changing environment, and further steps towards ZAV.

Moreover a research workshop was held wherein researchers from the six countries that already had qualitative data available participated. Inputs to the workshop came from the analyses of the survey data, and the findings from the interviews and national workshops that were available (see table 1). The meaning and interpretation of the quantitative data were discussed. Discussions were used to clarify and asses the various experiences and perspectives on success factors, good practices and challenges for the implementation of ZAV. Special attention was paid to identifying and understanding 'remarkable' findings (mostly examples of tailor made solutions and innovative practices) that could be regarded as 'inspiring examples of ZAV implementation' as opposed to 'good traditional safety practices'.

The results of the analyses from the qualitative data matrix, the research workshop for the success factors, and challenges and success stories were synthesised for this paper.

3. RESULTS AND DISCUSSION

3.1. Results

We present here the most important findings have been derived from our analyses so far. We distinguish between: (a) the sustainability of the commitment to ZAV, (b), good strategic ZAV practices, (c) good tactical and operational ZAV practices, and (d) ZAV challenges for the next few years.

3.1. 1. Sustainable commitment to ZAV (i.e. to continual safety improvement)

Embedding the ZAV commitment in the company is very important; it should be clear that the commitment is not hype, but that it is there to stay, even in times of change and/or difficulties. The companies that participated in our research use various strategies in this respect.

Make safety an explicit part of the company identity (mission and strategy)

Make safety explicitly a corporate core value that guides all company decisions

Safety and pursuing zero accidents is recognised as an on-going challenge (not an effort limited in time)

Show safety leadership and develop a proactive safety culture, wherein the importance of safety is always clear (especially in decisions and actions), and wherein the mind-set of managers and workers is focused on prevention.

Through a multi-faceted accident prevention and safety promotion programme, with own logo and branding, which is key in formal company communication, but also in informal interpersonal communication and culture. The programme should allow for – and encourage - bottom-up initiatives.

Clarify and share that in ZAV committed companies safety is truly a win-win situation, everyone benefits from safety - from shareholders to employees. Potential shareholders see bad safety as a risk – there is a visible link to CSR.

Besides the commitments to zero accidents, several companies also had broader commitments. For example, one company had a comprehensive 'zero' company strategy covering four key areas: health (long and short term), safety, environment and security (e.g. aggressive and/or political incidents in global markets). There was great synergy between the four areas with some

acting as leading indicators for initiatives in other areas. Such an approach also ensures that safety is fully integrated with operational efficiency – instead of something additional or separate from operational performance. Some other companies had zero strategies for zero defects (production and quality), for environmental issues, or for psychosocial topics such as bullying and substance use (alcohol and drugs). The Finnish participants emphasized also the importance of well-being at work. Well-being at work is part of
a comprehensive view on safety.

Several factors are important in choosing the strategy: company history, the nature of the primary process, the company structure (centralised or decentralised), the personal conviction of top managers, being part of a multinational organisation, or being an independent family business, etc. Clearly, ZAV should serve as an aspirational goal, as it is about a process, a journey, not a target. There is a need to have clarity in terms of purpose and relevance of safety. Visible top management commitment is a prerequisite. But having defined and communicated safety as a company value, or having a clear aspirational safety programme and message can also be of help, as long as it is more than words. As many companies work decentralised, it is essential to allow and develop buy-in at local levels.

3.1. 2. Good strategic practices

In this section we present the main strategic safety practices provided by the companies, including principles, codes or values that guide company strategies for business and safety. These practices build on the commitment to ZAV, and help to integrate safety into the way the company and its production activities are managed and led. The strategic 'good practices' identified are:

- Safety is a part of professional work - it is not seen as a separate entity
- Bring the positive aspects of safety more to the forefront
- Implement multifaceted programs that allow decentralised initiatives
- Ensure that everybody understands that unsafe work should be stopped immediately, and can only be resumed after it is made safe.

Strengthen participatory practices, they are the key to strengthen dialogical communication.

Challenge people to think for themselves. Ask questions that promote reflection. Avoid pedantic messages. Stimulate that people solve problems themselves in their team (but with communication to company level)

Be aware of the diversity in the workforce (e.g. younger - older workers) – they may have different values, habits and perspectives that are relevant for safety, and behave differently

Consider strategies for rewards and sanctions in relation to safety. Rewards can be financial but certainly also social. Make sure they do not undermine the reporting culture and feelings of justice and trust. Also implementing truly just and fair accident investigation.

World-wide standardisation of best production practices (including safety aspects), followed-up with training and education

- Search and stimulate safety activities and awareness jointly with business partners such as clients, suppliers and contractors.

3.1.3 Good tactical and operational practices

In this section we present the most remarkable tactical and operational safety practices provided by the companies, including activities and procedures that are productive in generating greater safety in the workplace, in strengthening the safety climate on the shop floor, or in supporting the effectiveness of the safety management system. These practices are stimulated and encouraged though the visible commitment to ZAV. In the following list we start with practices that are already well-known from theory and the practice of frontrunner companies- these are not innovative in it-self, but still important and not always easy to implement. These are followed by the more innovative practices, and practices that are very much tailored to the organisation.

Focus on a limited set of key safety risks

Routinised toolbox meetings, and/or daily start up meetings

- Ensure feedback to those that raise a safety issue or report an near miss (incidents, observations); implement improvements quickly

Ensure safety is a serious part of job/employee introduction programmes

Stimulate people to take care of their own safety

Walk-arounds of management, acknowledging and social rewarding safe practices and challenging unsafe practices

Develop and disseminate easy to use tools (e.g. making use of apps for reporting)

- Make sure that lessons learned from accidents in similar departments and organisations are disseminated and understood
- Use videos - as a ”safety wake ups”, appealing to emotions

Empower first-line managers to take safety action when needed

- Visible safety leadership on the shop floor, i.e. by regular management safety walks and broad corporate communication, exemplary safety behaviour by managers (safety leaderschip).

Create a culture wherein people feel free to discuss safety, also with their superiors. In a positive safety culture employees are appreciated and encouraged to stimulate each other to improve their safety relevant behaviour

Use story telling after an incident. Take care of social rewards for the story teller (who might be a victim or by stander)

Implement an easy system to show which rescuers (i.e. trained in first aid, fire-fighting, etc.), are available in the workshop by placing green magnets on their names and pictures (all names and pictures on the wall)

Organise workshops with self-assessment of risks (and ensure follow up)

Invite workers for a few weeks to participate in the safety department – to encourage them to be safety champions in their workplace

Organise one-to-one support for people confronted with safety problems or dilemmas. Consider creating safety coaches

Train supervisors and foreman as moderators for theme-based safety discussions and/or make them ”safety believers” since they have a huge impact on workers.

Training that creates safety experiences from another perspective (e.g. to wear an eyepatch to experience what it means if your eye is damaged; breathing through a straw to simulate reduced respiratory capacity)

Discuss safety items in weekly progress meetings to reinforce the practices that are required for the site

Discussion and reflection on events that occurred in the previous week

Provision of training specific to the individual. Workers have their own training folder to monitor their in-house work-specific training

Ensuring that workers who speak and read other languages follow the local procedures, as it is essential that they understand what is required of them. Due to the high numbers of workers from other countries, safe learning practices across the organisation have to be consistent with all workers knowing what is required.

3.1.4 Challenges for the next few years

Each of the companies has its ZAV challenges for the upcoming years. While some have only defined their challenges for the year to come, others have defined challenges for a range of years. Like the good practices, companies differ in the challenges encountered, depending on their context, history etc. Below we present a limited number of challenges mentioned that seem to represent the various kinds of challenges encountered:

Being ‘smarter with our safety data’: Improved analyses and relevant communication with better quality data, relevant and proactive safety metrics and synergy between data sources

To simplify processes. The organisation has detailed processes and at times, these may hinder the message that needs to be highlighted. If processes are simplified, the workers know what is required and how to accomplish it

Attracting ‘change managers’ who can work with the company safety culture – not looking for quick fixes by specialists, but helping the local workforce to identify initiatives that will work for them in their context

- To change from ‘we must work safe’ to ‘we want to work safe’

Ensuring that the contractors on site work adhere to the same standards as the rest of the organization, and motivating them to develop a ZAV mind-set. Contractors regularly change and often work using their standards as opposed to that of the main contractor

A strong focus on changing the attitudes and behaviours of the line supervisors / foremen. More effort is required to change their perceptions about some work practices

Developing safety from a business priority to a constant company value

3.2. Discussion

In the introduction we proposed five new ZAV perspectives.

When we review the findings in the 19 companies, the first two principles are easily recognised in most of the participating companies:

The ZAV commitment strategy: is expressed in high levels of organisational as well as individual commitment to ZAV

ZAV as the basis for a prevention culture: clearly the genuine ambition to create accident free workplaces and the leadership associated with the commitment strategy, helps to generate a proactive safety culture

The three other perspectives are not as commonly shared by the 19 companies, and are recognised as important perspectives or challenges in only some of the companies.

ZAV leads to innovative practices: the companies develop their safety practices, and several innovative practices were identified; the need for and relevance of innovative safety practices, depends, however, also on the level and maturity of safety already achieved. Those companies that recently embarked on the 'road to zero', can achieve a lot of progress by also implementing more traditional good practices

Zero is the only ethically sustainable safety goal; the ethical dimension is visible in the (few) companies that regard safety as a company value

ZAV thrives in networking and co-learning. Learning through benchmarking, networking or from safety lessons learned by other companies was also identified as a good practice

This implies that most companies pursue only the first two innovative perspectives, and that the other three perspectives are currently only adopted in a limited way. Even in these ZAV committed companies – who often are frontrunners in safety in their sector or country – there are still new perspectives to further explore, thus implying relevant opportunities for improvement. This also explains why networking among such companies is useful.

This research project was the first (to our knowledge) to explore the opportunities and challenges implied by the implementation of ZAV. Several good examples of company strategies and challenges were identified. The results therefore provide a good impression of the relevance of such research, though there is still a lot to do to fully understand what makes these strategies and practices successful, and under what conditions they are useful. Clearly, there is still a need for more research in this innovative area.

4. CONCLUSIONS

Companies that implement the ZAV are serious in their strategies and practices to improve safety, and realise that it will be an on-going effort. Safety commitment, communication, culture and learning all play a key role in such implementation processes.

There is, however, not a blue print for implementing ZAV. Companies differ in their business context, primary processes, history, structure, culture and people, which imply that a tailored implementation strategy is to be preferred. It is very important that it is clear for everybody that the zero accident commitment is not hype, but is sustainable. It needs to be embedded in the company's identity, or core values, or major strategies and programmes. Examples of such practices were identified in the group of ZAV companies. The long-term commitments in the companies triggered several examples of good safety strategies. These were complemented by a range of good operational and tactical practices, some well-known from more traditional safety approaches (e.g. routinise toolbox meeting, and/or daily start up meetings), while others are more innovative (e.g. invite workers for a few weeks to participate in the safety department – to encourage them to be safety champions in their workplace)

All in all we conclude that ZAV is the basis for inspiring and innovative approaches to improve safety, as well as for the implementation of more traditional safety practices. Most ZAV committed companies have used two perspectives: a commitment strategy and to create a culture of prevention. The other three innovative ZAV perspectives are currently only used by a few of the participating companies. In addition to well-known good practices, we identified a range of more innovative practices that can form inspiring examples for other organisations. There is therefore still much to be gained by identifying, sharing and implementing inspiring good ZAV practices.

This will generate added value for ZAV committed companies, as well as for other companies that are seriously pursuing improvement of their safety performances.

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6. REFERENCES

2nd Strategy Conference (2011): Five Pillars for a culture of prevention in business and society - Strategies on Safety and Health at Work, 3-4 February 2011, DGUV Academy Dresden.

Aaltonen M., (2007). The Zero Effect Model. In: The Quality of Working Life: Challenges for the Future. Liber Amicorum for the 10th Anniversary of Prevent. Prevent. Brussels, pp. 166-170.

Aaltonen M, Aräväinen A, Vainio H. (2014, editors) From Risk to Vision Zero – Proceedings of the International Symposium on Culture of Prevention – Future Approaches, FIOH, Helsinki.

Beer M. (2009). High Commitment, high performance – How to build a resilient organization for sustained advantage, Jossey -Bass, San Francisco.

Halpin J.F. (1966). Zero Defects - a new dimension in quality assurance, McGraw-Hill, New York.

Virta H., Liisanantti E., Aaltonen M., (2009). Nolla tapaturmaa -foorumin vaikutukset ja kokemuks Loppuraportti Työsuojelurahastolle. Helsinki: Työterveyslaitos.

Walton R.E., (1985). From control to commitment in the workplace. Harvard Business Review, 63 (2), pp. 77-84.

Zwetsloot G., M. Aaltonen, J.L. Wybo, J. Saari, P. Kines, and R. Op De Beeck, (2013), The case for research into the zero accident vision, Safety Science 58, 41-48.

Safety Rules in the Board Room: incorporating requirements for senior executives in safety standards

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Abstract
Analyses of recent major disasters have drawn attention to poor safety decision making by those at the most senior level in organizations. In this paper we focus on the case for safety rules at a senior executive level to both control and support key aspects of their behaviour. Whilst rules are a commonly used means of supporting safety in operations, they are less commonly applied to management. The paper draws on literature about the role of rules in operational safety situations and analyses of senior executive failings that have contributed to past accidents, in order to show that some key senior management failings can be appropriately addressed by rules. In particular, communication of key safety information upwards from technical experts to senior management is amenable to formulation as a rule. The analysis shows that such process-based rules aimed at improved communication between technical specialists and senior decision makers are not overly restrictive and may provide benefit. The paper argues that the main objection to use of rules to promote safe behaviours at a senior executive level comes from underlying management attitudes to rules in general and concludes that a small number of new rules targeted at senior executives are likely to improve safety.

Keywords: safety rules; management responsibility; standards; signatures.

1. INTRODUCTION

Compliance with rules of various kinds is seen as a key strategy for safety performance assurance. Much has been written about how to categorise rules and the best types of rules to apply in various situations (see for example Bieder & Bourrier, 2013; Hale & Borys, 2013a, 2013b). Rules can vary significantly in the degree of freedom that they give to the user, which must be commensurate with the degree of uncertainty in the activities governed by the rules in order to achieve the best outcome. Analysis of the role of rules has focused primarily on technical and operational decisions impacting safety. In summary, for routine tasks undertaken by lower skilled workers, a high degree of specificity is appropriate. The other end of the spectrum is often seen to be rules that allow significant application of judgement on the part of the user, in order to allow for the idiosyncrasies of each specific situation. This is the domain of experienced and highly skilled workers such as doctors, nuclear power station technicians, air traffic controllers, pilots and engineers.

In parallel with research on the role of rules, the concept of the organizational accident has remained popular and continues to inform both safety research and practice. This view of safety and of accident causation in particular, emphasises the importance of senior executives in preventing accidents. In addition, studies of safety culture and leadership, and also analyses of numerous major disasters (Hayes, 2012; Hayes & Hopkins, 2014; Hopkins, 2008, 2012; Snook, 2000) have highlighted the key role of senior management in setting strategic organizational priorities both formally and informally and as a result ultimately impacting on and influencing the day to day actions of professional staff and those working in the field.

Looking at these two views of what makes for excellent safety performance raises the question as to why senior management actions are so rarely specified in the form of rules. One explanation appears to lie in what managers understand to be the primary purpose of rules. If formal written rules are seen as a mechanism of command and control management, then it makes sense that those in the most powerful positions in organizations rarely create such rules to apply to themselves. After all, why would those who wish to use rules as a way of enacting and exercising their authority over others, create rules that are designed to control their own actions? Such rules would need to be externally generated i.e. to be in the form of either standards or legislation. This paper explores the idea of including basic requirements for senior executives in externally imposed rules such as standards and legislation.

We begin by examining the role of rules in achieving safe outcomes and how this varies from the way in which senior managers view rules. We then review the literature on organizational accidents to determine what is known about senior executive actions supporting safety. The paper then explores the extent to which such actions can be usefully put into the form of rules using the concept of due diligence.

How these issues might be put into practice is then explored using the case study of the Australian Standard for high pressure hydrocarbon pipelines.

2. RULES AS A SAFETY STRATEGY

Rules come in a wide range of forms depending on the particular situation they are designed to address. Before we can consider if and how safety rules might apply to senior managers it is useful to focus on the breadth of options available. Research also provides insights into common attitudes of managers towards rules in general. This is relevant since it will directly impact the views of managers themselves as to whether rules should be applied to their own activities.

Rules are a key mechanism by which actions and decisions are informed by the skills and knowledge of others. In following a well-written procedure when making a decision, an individual indirectly draws on the experience of peers and of professionals of various disciplines past and present, in the same organization or across an industry sector. Whilst the experience and judgement of the decision maker is also critical, in design and operation of complex and hazardous systems the best decisions are rarely made without reference to some kind of rules.

Various authors (Bluff & Gunningham, 2004; Hale & Swuste, 1998) have proposed that safety rules are of several distinctly different kinds such as:

- rules that specify goals to be achieved,
- rules that define the process to be followed in order to decide on a course of action, and,
- rules that define a specific concrete action or system state.

Goal-based rules give the highest degree of freedom to the decision maker. This type of rule specifies only the general outcome required and leaves unspecified the details of how the goal is to be achieved.

Process-based rules describe the sequence of steps that the decision maker is required to complete before coming to a decision about the course of action required. The steps often involve consultation with people with diverse views of the task at hand. In this case, the detailed outcome is not specified (although a general goal is usually inherent in the context of the prescribed process).

Action rules specify tightly the behaviour required of an individual. They involve much less interpretation than the other two types of rules. Examples are hard and fast requirements to wear specific protective clothing to undertake certain activities or requirements for staff to be licensed in order to carry out certain tasks. Similar tightly specified rules may cover system state such as a rule that specifies that three independent well control devices must be in place at all times during drilling operations.

Any real rule may include some features of each of these kinds of rules but many procedures aimed at technical and professional staff are primarily process-based rules. Process rules have a significant degree of freedom for those following the rules. Many of them focus on a communication process that the user must adhere to before reaching a conclusion. Examples include permit to work systems and procedures for conducting risk assessments. The basic assumption behind such rules is that, by involving and informing representatives of different functions, and prompting them to consider a range of specific questions in relation to the planned activity, the interests and perspectives of all functions will be brought to bear on the task at hand and work will be carried out in a safe and timely manner. To put it another way, those following the process as laid down must have sufficient knowledge and experience to bring to the task at hand. Since details are not specified but rather left to the user to determine, this requires thought and judgement.

We have found in previous research that senior managers tend to overestimate the degree to which the actions of their employees are controlled and constrained by company procedures (Hayes, 2013). Managers tend to think of all rules as being in the form of action rules as described above. In the context of operational decision making, overestimating the role of rules masks the extent to which organizations rely on the experience, expertise and judgement of professional staff in ensuring safe outcomes. When it comes to application of rules to managers' own work, overestimating the extent to which rules in general impose control is likely to increase resistance to the idea that rules could be useful in this context. The overall view of the role of rules implicit in such considerations is that, in the ideal world, there is one best way for any particular task to be conducted and that this can be known in advance and completely specified.

This is what Dekker calls Model 1 thinking about rules (2005). This view is essentially top-down, with managers having the role of 'enforcers' of rules which apply to the operational workforce.

Consistent with this understanding of the role of rules, many managers see rules primarily as a method of normalising worker behaviour. Owing much to foundations in Taylor's scientific management, workers who fail to comply are viewed by management as lazy, complacent and/or stupid (Hayes & Hopkins, 2014). This way of thinking about rules places the authority to dictate what it means to be safe squarely with management, rather than workers. As Schulman puts it, a key assumption in preparation of procedures is very often that 'those who write procedures will have a more reliable and comprehensive concern for safety than those who are constrained to follow them'(2013, pg 245). Whilst senior managers may not personally write such procedures, they are certainly issued, and compliance is required, under their authority. If rules are something that competent managers impose on incompetent workers, then it is hardly surprising that some managers see no need for rules to constrain their own behaviour and are offended by the very idea.

The literature on rule violations at a working level gives us further insights into why senior managers may not respond well to the idea of rules that apply to them. Self-efficacy, or a belief in one's own abilities to work safely has been consistently found to be a key factor in the motivation of workers not to follow safety rules (Iszatt-White, 2007; Mascini, 2005). Extrapolating this finding to higher levels of the organization, managers believe themselves to be competent and consistent with this, some may be unlikely to see any benefit in a compliance framework in order to make good safety decisions.

The strong move in recent decades to implement management systems based on the well-known Deming Cycle (plan, do, check, act) has reinforced this view of managers as the origin of legitimacy regarding safety requirements (Defoe & Juran, 2010). For the first time, such frameworks begin to specify processes in which senior managers have a direct role and a direct responsibility, but this primarily takes the form of setting policies. Policies are the foundation of all management system requirements and the source of legitimacy for the ever more specific requirements that are promulgated through organizations and with which those lower in the organizational hierarchy are required to comply.

Paradoxically, whilst attitudes to rules demonstrate senior management beliefs about their relatively higher competence on safety matters, procedures also form a powerful framework for moving responsibility for safety from management to workers. As La Porte says, many procedures are written '… to assure that responsibility/blame is placed on the workforce, not placed on senior institutional actors ...' (2013, pg 259). Some studies have even shown complicity in violations, indicating that the main purpose of rules is no longer achieving a safe outcome but rather ensuring that management has no liability should something go wrong, whilst at the same time allowing production to continue. This has been found to be a particular issue for middle management or supervisory staff who have been exhorted to report non compliances by staff lower in the organizational hierarchy, and yet are themselves violators in the interests of getting the job done. The classic example of how organizations can be constrained in this way by poor quality rules is 'work to rule' by British Rail staff that slowed the British railways to a snail's pace as part of collective action on industrial issues. Normal functioning of the system required ongoing routine violations by workers. When they instead obeyed all rules as written, the system quickly descended into chaos (Morgan, 1997, pg 177).

In this way, rules can take on a political dimension whereby organizational actors at various levels use rules from their own purposes. Iszatt-White calls this '…"gambits of compliance" whereby individuals superficially appear to be obeying the rules but are actually finding ways of making the rules suit their own way of working.' Workers behave in this way 'thus enabling them to finish allocated jobs which would otherwise have to be left incomplete' (2007, pg 457). The middle management response is to 'turn a blind eye'. Again, it is hardly surprising that some managers would see any suggestion that safety rules could apply to their activities as anathema.

In summary, rules come in a wide range of forms. Process-based rules in particular are commonly used for technical and professional staff as they represent a balance between constraint to prevent repetition of past mistakes and freedom to exercise judgement to take into account specific circumstances. This type of rule would appear to have potential for application to senior managers. On the other hand, research suggests that managers sometimes misunderstand the role of rules in ways that are likely to make them hostile to imposition of rules on their own activities. At worst, managers in a range of industries have been found to use rules in two ways that are not directly related to achieving good safety outcomes. This is to control workers and to shift liability. Neither of these motivations for imposing safety rules on workers gives senior management any reason to understand that they too could usefully be guided by appropriately formulated safety rules.

3. SENIOR MANAGERS AND SAFETY

The evidence that senior managers' decisions would be improved by compliance with some basic rules is found in the literature on culture and leadership, and in analysis of the causes of past disasters. It is also consistent with the organizational view of accidents widely adopted by social science.

The literature on safety culture places a strong emphasis on the role of senior executives in ultimately driving positive safety outcomes, usually by reference to the need for leadership. Leadership is often taken to mean a focus on safety. Hale's analysis of what makes for a good 'culture of safety' includes 'the importance which is given by … top managers to safety as a goal, alongside and in unavoidable conflict with other organizational goals' (2000, pg 12) as one of eight necessary elements. Similarly, Pidgeon and O'Leary (2000, pg 18) postulate that 'senior management commitment to safety' is a factor that both fosters and sustains a good safety culture. Schein's famous definition of culture as 'the way we do things around here' stems from priorities and behaviours set from the top. In his words, "[l]eaders create and change cultures, while managers and administrators live within them" (1992, pg 5).

Moving from theories of accident prevention to accident causation, the organizational view of accidents epitomised by Reason's Swiss cheese model (1997) also emphasises the influence of top management by seeing them as ultimately responsible for the latent failures that allow small errors to result in major disasters.

Similarly, analyses of the causes of major disasters have also highlighted the role of management. Such research necessarily takes a bottom up approach and so gives insights into management practice, as well as values. Senior management failings such as cost cutting and/or a focus on production without understanding the safety implications and a lack of understanding of the difference between personal and process safety have been consistently highlighted (Hayes, 2012; Hayes & Hopkins, 2014; Hopkins, 2008, 2012; Snook, 2000). These studies and many others emphasise the importance of senior management practices – how they behave and the decisions that they make. It is values 'in practice' that directly impact budgets for maintenance and other similar decisions that require the best balance between safety and other organizational goals to be determined. It is important to note that this is not simply a matter of emphasising to staff that safety is important. Leadership on safety matters in isolation of other organizational priorities is not sufficient. Delegation of decision making on all technical safety issues is also not sufficient. Safety needs to be integrated into senior management decision making at the highest level so that decisions are made in a way that is mindful of the long term safety implications.

Of course it is not possible to mandate values for senior managers (or any other group) in the form of rules, but it is possible to mandate aspects of management practice by rules requiring specific actions to be taken. The evidence suggests that effective management practices are needed and we cannot expect to achieve this with so few procedures controlling management actions in place. As described earlier, procedures can be conceptualised as 'experience carriers'. This idea can apply equally to senior executives as to other professional and skilled groups. Without such rules in place, senior executives are reliant on their personal experience or tacit learning from colleagues. Senior managers often do not have the necessary expertise personally and so rules to support communication upwards could be a major improvement.

So where does that leave us in the quest for safety improvements? Senior managers think that rules do not, by definition, apply to them and yet evidence shows that their performance collectively could be improved by compliance with some basic rules. The answer lies in a redefinition of the role of rules.

An alternative view of rules (Dekker's Model 2) considers them to be dynamic, generated from collective experience (of both rule writers and rule users), always incomplete, only as specific as they need to be to ensure safe outcomes and necessarily incorporating some scope for variation in action in the face of complexity and uncertainty. A third view comes from Grote and Weichbrodt who maintain that effective rules support effective behavioural routines by coordinating work processes (2013). Further they maintain that ideally this should be the primary role of rules, rather than providing a framework for legal accountability. For professional and managerial personnel, the Grote and Weichbridt definition has much in common with the concept of process-based rules.

Decisions made by senior managers are critical to safety. There is a great deal of evidence to support this. The safety culture literature in particular highlights the need for senior management leadership on safety matters in order to set a good example, but accident analysis demonstrates that senior management decisions have a direct impact on safety, too, when it comes to cutting maintenance budgets and similar. On the other hand, managers are likely to be justifiably wary of rules that they see as imposing an unnecessary and unreasonable constraint. An alternative view of rules as capturing collective senior management experience and co-ordinating their actions with those of technical experts who advise them may make it easier for those at senior levels of organizations to see well designed safety rules as a support, rather than a hindrance.

4. SENIOR MANAGERS AND REGULATION

Given the attitudes of many managers, rules for senior managers are unlikely to gain wide acceptance inside organizations without an external driving force and this is indeed what is happening. In jurisdictions that favour performance-based safety legislation, the most senior levels of management are already effectively subject to some externally imposed safety rules. In Australia, as in the UK, safety legislation imposes general duties on organizations in control of potentially hazardous activities to ensure that risk is reduced so far as is reasonably practicable. Although the details can vary, such duties typically extend to senior management who may face penalties in the event of an accident. These are goal-based rules with only the desired outcome specified and so provide room for discretion. Recent regulatory changes in Australia are extending regulatory reach when it comes to the duties of top managers.

Australia has recently gone through a process of ‘harmonisation’ of general workplace health and safety legislation across all states. A key step in this process has been to agree on a new model Workplace Health and Safety (WHS) Act. Arguably the biggest change in the model WHS Act from previous legislation was the introduction of proactive duties for company officers (see s27 of the model WHS Act (Safework Australia, 2011)). Before the states introduced new WHS legislation that was harmonised with the model Act[1], company officers did not have legislative duties imposed on them directly as individuals, rather they could have liabilities attributed to them in some circumstances (which varied from state to state) regarding the conduct of their company in the event of an accident (Foster, 2012; Johnstone & Tooma, 2012).

Since at least the time of the UK Robens review (1972), the benefit of assigning a duty to senior managers has been recognised by policy makers, but it is only with the recent model Act that this has been adopted into legislation wholeheartedly. To be clear, it has long been common for organizations to have a general duty to reduce risk so far as is reasonably practicable. This is also a requirement of the model WHS Act, but critically the Act also includes duties that are targeted directly at company officers as individuals and sets specific requirements for them that apply prior to any accident. They must exercise due diligence to ensure that the organization complies with its obligations and duties under the Act. This approach is new for safety, but common in the context of corporations law where company directors (for example) are required to exercise care and diligence in financial affairs including such matters as understanding a company’s financial position well enough to form an opinion as to the company’s solvency.

To paraphrase and summarise the legislation, senior managers of all organizations that have duties under workplace health and safety legislation are required to exercise due diligence on relevant matters. Summarising the model Act, requirements for company officers’ due diligence are:

- having knowledge of work health and safety matters,
- understanding the nature of operations and the associated hazards and risks,
- ensuring that appropriate processes and resources are in place to manage those hazards and risks,
- ensuring that the organization has effective learning and feedback processes in place,
- ensuring that the organization complies with other parts of the Act, and
- verifying that all of the above is in place and working.

Importantly, these requirements take the form of goal-based rules. They specify an outcome (that company officers must have knowledge of work health and safety matters etc.) but leave

[1] All States of Australia have introduced legislation in line with the model WHS Act except Western Australia and Victoria. In WA, public comment on the new Work Health and Safety Bill 2014 closed on 30 January 2015. This Bill includes section 27 of the model WHS Act verbatim. In Victoria, the Occupational Health and Safety Act 2004 does not specifically include duties for company officers linked to due diligence. In Queensland, general workplace health and safety is legislated by the Work Health and Safety Act 2011 which includes due diligence requirements.

the process by which that outcome is to be achieved up to each company to determine. Equally importantly, these requirements are proactive duties that must be in place (and hence may be audited by regulators) before any accident occurs. This clearly places the onus on organizations operating under this legislation to have process-based rules in place in order to demonstrate that company officers are meeting these requirements because if they are not then they may be personally open to prosecution.

5. CASE STUDY – THE AUSTRALIAN PIPELINE INDUSTRY

We have been presented with an opportunity to put our work on this subject into practice via our involvement with the Australian pipeline industry. As with many industrial sectors, the pipeline industry has suffered several recent failures that have gained iconic status. For the natural gas transmission pipeline sector, such an accident occurred at San Bruno in California in September 2010 when a pipeline ruptured due to a construction flaw dating from 1956 that had remained hidden for more than five decades. The US National Transportation Safety Board report into the incident identified many failings in the operating company's integrity management system (NTSB, 2011). As with all similar accidents, those professionals who had been involved over many years no doubt did not intend to do such a poor job. Looking more deeply at the organizational circumstances has identified cost cutting on maintenance and inspection initiated from the most senior management levels and also highlighted the lack of understanding of key risks and the potential consequences (Hayes & Hopkins, 2014). The incident has provided this sector with a specific incentive to think about how information on key safety issues can be better communicated to top managers and how they can be made more aware of the potential consequences of their decisions.

The full project lifecycle for high pressure gas pipelines in Australia is covered by a suite of standards, AS/NZ 2885. The standard is called up in legislation in every state of Australia giving it significant power over safety practices in this sector. As part of the current consideration of revisions to the standard, serious consideration has been given to what the standard should require of senior executives in order to effectively take responsibility for safety of the general public and workers (in addition to protection of the environment and security of supply as is also required by the standard). This has led to consideration of four specific issues as described below.

5.1 Addressing Requirements of a Standard to Management

The proposal is that some rules for senior managers be included in AS2885. Until now, the primary intended audience for the standard has been technical professionals – those with direct responsibility for designing, operating and maintaining pipelines. The plan to broaden this audience calls into consideration the background to and history of standards generally to consider whether this broader role is appropriate.

Standards are a special type of rule that has broad application to a given field. According to the Standards Australia website, '[s]tandards are published documents setting out specifications and procedures designed to ensure products, services and systems are safe, reliable and consistently perform the way they were intended to. They establish a common language which defines quality and safety criteria.' (Standards Australia, ND) Standards have a dual role – setting minimum standards related to quality of life issues such as safety and environmental performance, and maximising competitiveness by standardisation of output. They have been strongly promoted by the Productivity Commission as a factor in ensuring Australian industry's global competitiveness (Productivity Commission, 2006). Many engineering standards used in Australia are published by the American National Standards Institute (ANSI). According to their website ANSI also works to balance these two functions of standards: The mission of the organization is 'To enhance both the global competitiveness of U.S. business and the U.S. quality of life by promoting and facilitating voluntary consensus standards and conformity assessment systems, and safeguarding their integrity.' (ANSI, ND)

Standards are typically developed by a committee process with relevant experts conferring on requirements. Consistent with this, Hale et al (2007) call engineering standards 'experience carriers'. Codes and standards are therefore a key repository of professional experience in safe and efficient design. Standards are often updated following an accident or serious incident in order to prevent recurrence (for example following the incident at La Spezia in Italy in 1971, LNG storage tank standards were updated to address the issue of rollover due to density stratification). Professional societies such as the American Society of Mechanical Engineers (ASME) have played a key role in standards development. Varrasi (2009) describes ASME standards committees as ‘a tradition of public service and professional responsibility that dates to the late nineteenth century industrial age’. His article documents the two drivers for standards – safety and cost. An early focus area for ASME was standards for fittings, screw threads and flanges – initially seen as an issue of production efficiency, but brought into safety focus when fire fighters brought in from neighbouring areas to assist in fighting a major fire in Baltimore in 1904 could only watch helplessly as their hose fittings did not fit local hydrants. At this early stage, standards were primarily action rules, designed to completely specify aspects of component design.

In recent years, there has been a move away from prescriptive, action-based rules to more process-based standards, often called management system standards, based on the Deming cycle mentioned earlier. AS2885 includes some prescriptive requirements but these are generally within the overall process-based framework. It is this framework that moves the style of the standard away from simply a list of detailed technical requirements regarding how work must be done, to a document that in some places specifies overall processes that experts are expected to use in order to ensure that complex decisions receive input from all relevant parts of the organization. In safety matters, the backbone of the standard is the Safety Management Study process (Tuft, 2008) which is an example of exactly this type of rulemaking. This shift to process-based requirements means that the requirements of standards can readily be imposed on any experts for whom process-based rules are relevant, including top management.

In summary, standards reflect the accumulated knowledge of a particular industry. They can require a high level of performance or they can be pitched at the level of minimum requirements. They can focus on prescription, or on setting processes and providing guidance. Whilst the historical focus of standards has been on technical matters, the move to process-based standards makes them more amenable to inclusion of managerial matters.

5.2 Individual or Company?

The Standard uses formal, documented approvals of various key engineering documents as the mechanism for communication of key issues both up and down the organization. In this way, key engineering information is acknowledged by those who approve any given document and the implication is that the approver is also authorising allocation of any necessary resources. In other words, decisions are made by those with the appropriate competence and authority. A key question that has been considered by the standard writers is whether duties such as these should be imposed on individuals or organizations.

According to the Standard, the ultimately responsible entity is the Licensee. The Licensee is defined as ‘[t]he organization responsible for the design, construction, testing, inspection, operation and maintenance’ (Standards Australia, 2012, Section 1.6.27). Note the reference to an organization, rather than a specific role. Prior to revision, AS2885.0 included a list of nine specific documents that require approval (for new versions and revisions) from the Licensee (Standards Australia, 2008, Section 3.4). The list includes a range of key engineering plans and records. The Standard also requires that organizations develop and document an ‘approvals matrix’ which defines what position holds authority to approve which document (Section 3.2). Delegation from the arrangements defined in the approvals matrix is prohibited. The intention of those who wrote this requirement had been to ensure that senior technical professionals are aware of and formally approve key design and operating features of each pipeline. In practice, since the Licensee is defined as an organization, the authority for approval of many documents has been fixed by the approvals matrix as a middle level technical professional. The most senior levels of management have no role in this system given the technical, voluminous nature of the various documents requiring formal approval. This has been compounded by the fact that some pipeline companies hold licences for many pipelines resulting in literally scores of documents that require approval by the Licensee.

The regular program of Standard revisions has given the pipeline sector an opportunity to reconsider this issue in the light of recent research. The proposed revised definition is ‘the entity that the regulatory authority holds accountable for the pipeline.’ (AS2885.0-2008 markups for revision – section 1.5.2). This immediately raises the option of the responsible entity being an individual company officer, rather than an organization, and places responsibility for this definition with the regulators, rather than in an industry based standard. As explained above, the trend in Australia has been to define responsibilities for specific roles in general workplace safety legislation and these changes to the pipeline Standard ensure that no conflict arises with this aspect of legislation should it apply to pipelines.

5.3 The Value of Signing Documents

The list of documents that require approval by the Licensee has also been critically reviewed. The intention has been to differentiate between those documents requiring the formal approval of senior technical professionals and the key information of which senior executives must be aware in order to effectively fulfil their governance role on process safety issues. To achieve this, technical and managerial approvals have been separated so that the number of documents requiring formal approval of the Licensee has been reduced substantially. In such cases, this responsibility is enacted in practice by requiring that specific documents are signed by senior executives. It is therefore appropriate to consider the meaning that is attached to a signature and the associated act of signing.

Research on the effectiveness of this type of process-based rule as a safety strategy is scant. Limited research has been conducted in the accounting sector linked to the introduction of international requirements for accounting firm partners to personally sign audit reports. As Carcello and Li (2013) report, the CFO of a large multinational corporation said publicly of the new arrangements, 'I used to sign off in the name of the firm. Now I'm certifying financial statements … in my personal name. I would like to believe ... that it wouldn't have made a difference, but it does. It is psychologically different.' (pg 1512). Further Carcello and Li found that the quality of audits increased in the UK following introduction of such a requirement. Similarly Yen, Chang, and Hui-Ling (2013) conducted a perception survey among the accounting profession in Taiwan following the introduction of the same requirements and found that the profession overall believed that introduction of these international requirements for additional signatures had improved audit quality. Further the main reason for this improved quality was seem to be increased personal accountability linked to signing.

This limited research appears to confirm what we would intuitively understand to be the case. Requiring personal 'sign off' increases attention. A signature is much more than simply ink on paper (or some electronic variation). As the Oxford English Dictionary says, a signature is 'a person's name written in a distinctive way as a form of identification'. An alternative meaning is 'a distinctive pattern, product, or characteristic by which someone or something can be identified' such as a chef's signature dish. In this way, a signature becomes a symbol of the person who signs, an embodied presence of that individual, even when they are not physically present.

It is perhaps also worth commenting on the question of multiple signatories. In his work with health professionals and families, Hopwood (2014) found that requiring key medical documents to be signed by both health professionals and family members engendered a sense of shared responsibility. In this case, it is reported that the division of responsibilities was also clearly understood.

This is not always the case. Group decision making as epitomised by multiple signatories can fall down due to two well-known psychological processes. The first is groupthink (Janis, 1982) where no one challenges the status quo. In this case, later signatories will just go along with those who have already signed as a way of keeping harmony within the group. The second is social loafing (Karau & Williams, 1993) where some group members put no intellectual effort into the pros and cons of their decision but rather follow the lead of the rest of the group instead of making an independent decision.

Anecdotally, an industry organization with which we work has recently critically reviewed the signatories of a key document detailing integrity management plans and arrangements for formal acceptance. The documents initially required nine signatories. We were told that most people did not look critically at the document before signing it but rather at who else had already signed it. As a result the work was receiving very little review. From an initial nine signatories, the number has been reduced significantly. The four signatories who remain hold overall accountability for the implementation of the plan. The work program has been adjusted to include a formal presentation of the plan by technical experts to those four people prior to seeking their sign off. As a result the quality of the plans has improved and the awareness of the signatories regarding their own responsibilities has increased.

In summary, the effectiveness of signing documents as a form of approval has been little researched but there is some evidence suggesting that a requirement to sign can focus attention. On the other hand, more is not necessarily better. Multiple signatories can distribute responsibility to the point where signatures become tokenistic and so effectively meaningless.

5.4 Senior Management Understanding of Key Risk Data

The overall integrity of pipelines is managed through the design process described in AS2885 by a detailed safety management study (Tuft, 2008). The requirements for the study are detailed in the standard and whilst there are some unique details, the overall framework would be familiar to anyone used to risk assessment as a key design verification tool. Consideration has been given to the best way to ensure that key risk information is known to and understood by senior management.

There are two problems with simply requiring that safety management study reports are signed off by senior management. The first is the issue of the volume of reports and information that would be put in front of senior people if this were to be the requirement as described earlier. The second issue is that reports are written by technical specialists whose overall desire is to communicate both that they have done their work well and also that risks are appropriately controlled. This is perhaps especially the case for documents that will be sent to regulatory bodies for approval.

At worst, risk assessment reports can take on the qualities of ‘fantasy planning’ (Clarke, 1999) in the sense that the purpose of the documents becomes asserting to outsiders that the uncontrollable can actually be controlled. Having said that, even risk assessments that remain firmly grounded in reality are bound to conclude that, if all the necessary controls are in place and functioning as designed, then the risk will be controlled sufficiently. This might be relevant information for top management in a governance sense, but as discussed earlier top management decisions can impact the ongoing validity of such a conclusion e.g. if controls are compromised by budget decisions. Risk assessment reports are rarely written with communication to senior management of their responsibilities in mind.

Another important factor is the treatment of low frequency but high consequence events in particular. In such cases, there is usually a high degree of uncertainty about the frequency calculation and yet ultimately risk is deemed to be acceptable because of frequency-based arguments. This is fundamentally problematic (Aven, 2009; Hopkins, 2015) and, worse, hides from top management the magnitude of the potential consequences of their decisions.

To return to AS2885, in order to provide a better basis for top management decision making, consideration is being given to use of a summary statement that focuses on the consequences and key risk controls of the most serious failures that could occur on a pipeline. It is this information that needs to be considered by senior management when signing off on risk assessment conclusions that no significant danger remains or will be introduced by their own budgetary choices.

These relatively small changes to the standard are an important repositioning of the document to promote processes that make key safety information more visible to those at the top of pipeline companies who ultimately have a high degree of control over long term safety outcomes.

6. CONCLUSIONS

Investigations into numerous accidents have shown that senior management (like all other workers) are sometimes fallible when it comes to safety decision making. The saving grace is that management actions rarely have an immediate impact on outcomes, but rather take weeks, months or even years to impact activities on the ground (as a result of budget decisions for example). This means that there is time to uncover mistakes and respond.

Nevertheless, history shows that actions of senior managers cannot be unconstrained if the best safety performance is to be achieved. They need help to know what is right. In some circumstances it is appropriate for behaviour of senior managers to be guided by process-based rules.

Our work with the pipeline industry and in particular AS2885 gives several examples. Firstly, ensuring that management individuals have duties not just organisations. Secondly considering carefully who needs to sign what to maximise the sense of personal responsibility that goes with the act of putting one’s name to something. Finally ensuring that the most important aspects of risk documents are highlighted in communication to senior management rather than lost – either in the detail, or in the overall argument that risk is controlled sufficiently.

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8. REFERENCES

ANSI. (ND). About ANSI. Retrieved 15 July 2015, from http://www.ansi.org/about_ansi/overview/overview.aspx?menuid=1

Aven, T. (2009). Perspectives on risk in a decision-making context - Review and discussion. *Safety Science, 47*, 798-806.

Bieder, C., & Bourrier, M. (Eds.). (2013). *Trapping Safety into Rules: How Desirable or Avoidable is Proceduralization?* Farnham: Ashgate.

Bluff, L., & Gunningham, N. (2004). Principle, process, performance or what? New approaches to OHS standards setting. In L. Bluff, N. Gunningham, & R. Johnstone (Eds.), *OHS Regulation for a Changing World of Work* (pp. 12-42). Sydney: The Federation Press.

Carcello, J. V., & Li, C. (2013). Costs and benefits of requiring an engagement partner signature: Recent experience in the United Kingdom. *Accounting Review, 88*(5), 1511-1546.

Clarke, L. (1999). *Mission Improbable: Using Fantasy Documents to Tame Disaster*. Chicago: University of Chicago Press.

Defoe, J., & Juran, J. M. (2010). *Juran's Quality Handbook: The Complete Guide to Performance Excellence* New York: McGraw Hill.

Dekker, S. (2005). *Ten Questions About Human Error: A New View of Human Factors and System Safety*. New Jersey: Lawrence Erlbaum.

Foster, N. (2012). *Workplace Health and Safety Law in Australia*. Australia: LexisNexis Butterworths.

Grote, G., & Weichbrodt, J. (2013). Why Regulators Should Stay Away From Safety Culture. In C. Bieder & M. Bourrier (Eds.), *Trapping Safety into Rules: How Desirable or Effective is Proceduralization?* (pp. 225-240). Farnham, Surrey: Ashgate.

Hale, A. (2000). Culture's confusions. *Safety Science, 34*, 1-14.

Hale, A., & Borys, D. (2013a). Working to rule, or working safely? Part 1: A state of the art review. *Safety Science, 55*(June 2013), 207-221.

Hale, A., & Borys, D. (2013b). Working to rule, or working safely? Part 2: The management of safety rules and procedures. *Safety Science, 55*(June 2013), 222-231.

Hale, A., Kirwan, B., & Kjellén, U. (2007). Safe by design: where are we now? *Safety Science, 45*(1-2), 305-327.

Hale, A., & Swuste, P. (1998). Safety Rules: procedural freedom or action constraint? *Safety Science, 29*, 163-177.

Hayes, J. (2012). Operator Competence and Capacity - Lessons from the Montara Blowout. *Safety Science, 50*(3), 563-574.

Hayes, J. (2013). *Operational Decision-making in High-hazard Organizations: Drawing a Line in the Sand*. Farnham: Ashgate.

Hayes, J., & Hopkins, A. (2014). *Nightmare pipeline failures: Fantasy planning, black swans and integrity management*. Sydney: CCH.

Hopkins, A. (2008). *Failure to Learn: the BP Texas City Refinery disaster*. Sydney: CCH.

Hopkins, A. (2012). *Disastrous Decisions: The Human and Organisational Causes of the Gulf of Mexico Blowout*. Sydney: CCH.

Hopkins, A. (2015). How much should be spent to prevent disaster? A critique of consequence times probability. *Journal of Pipeline Engineering, 2nd quarter, 2015*, 69-78.

Hopwood, N. (2014). A Sociomaterial Account of Partnership, Signatures and Accountability in Practice. *Professions & Professionalism, 4*(2).

Iszatt-White, M. (2007). Catching them at it: An ethnography of rule violation. *Ethnography, 8*(4), 445-465.

Janis, I. (1982). *Groupthink: Psychological Studies of Policy Decisions and Fiascos*. Boston: Houghton Mifflin.

Johnstone, R., & Tooma, M. (2012). *Work Health & Safety Regulation in Australia: The Model Act*. Sydney: The Federation Press.

Karau, S. J., & Williams, K. D. (1993). Social Loafing: A Meta-Analytic Review and Theoretical Integration. *Journal of Personality and Social Psychology, 65*(4), 681-706.

La Porte, T. (2013). Postscript: Reflections on Procedures, Trial and Error and Functional Forgiveness. In C. Bieder & M. Bourrier (Eds.), *Trapping Safety into Rules: How Desirable or Avoidable is Proceduralization?* (pp. 257-271). Farnham, Surrey: Ashgate.

Mascini, P. (2005). The Blameworthiness of Health and Safety Violations. *Law & Policy, 27*(3), 472-490.

Morgan, G. (1997). *Images of Organization*. Thousand Oaks: Sage Publications.

NTSB. (2011). Pipeline Accident Report: Pacific Gas and Electric Company Natural Gas Transmission Pipeline Rupture and Fire, San Bruno, CA, September 9, 2010. Washington: National Transportation Safety Board.

Pidgeon, N., & O'Leary, M. (2000). Man-made disasters: why technology and organizations (sometimes) fail. *Safety Science, 34*, 15-30.

Productivity Commission. (2006). Standard Setting and Laboratory Accreditation Research Report Overview: Australian Government, available online http://www.pc.gov.au/inquiries/completed/standards/report.

Reason, J. (1997). *Managing the Risks of Organizational Accidents*. Aldershot: Ashgate.

Robens, A. L. (1972). Safety and Health at Work (Report of the Committee 1970-1972). London: HMSO.

Safework Australia. (2011). Model Workplace Health and Safety Act. Canberra: Safework Australia.

Schein, E. (1992). *Organizational Culture and Leadership*. San Francisco: Jossey-Bass.

Schulman, P. (2013). Procedural Paradoxes and the Management of Safety. In C. Bieder & M. Bourrier (Eds.), *Trapping Safety into Rules: How Desirable or Effective is Proceduralization?* (pp. 243-255). Farnham, Surrey: Ashgate.

Snook, S. A. (2000). *Friendly Fire: The Accidental Shootdown of US Black Hawks over Northern Iraq*. Princeton: Princeton University Press.

Standards Australia. (2008). AS2885.0 Pipelines - Gas and Liquid Petroleum Part 0: General Requirements. Sydney: Standards Australia.

Standards Australia. (2012). AS2885.1 Pipelines - Gas and Liquid Petroleum Part 1: Design and Construction. Sydney: Standards Australia.

Standards Australia. (ND). What is a Standard? Retrieved 13 July 2015, from http://www.standards.org.au/StandardsDevelopment/What_is_a_Standard/Pages/default.aspx

Tuft, P. (2008). *IPC2008-64622 THE AUSTRALIAN APPROACH TO PIPELINE SAFETY MANAGEMENT.* Paper presented at the 7th International Pipeline Conference, Calgary

Varrasi, J. (2009). to Protect and Serve. *Mechanical Engineering, 131*(6), 28.

Yen, S.-H., Chang, Y.-S., & Hui-Ling, C. (2013). Does the signature of a CPA matter? Evidence from Taiwan. *Research in Accounting Regulation, 25*(2), 230-235.

Arguments and drives to change your safety culture

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Abstract
Nowadays for many industries working on a safety culture has become a common practice. To do so, several culture programs are available consisting of a variety of methods and implementation strategies, depending on needs, size and companies' budgets. Consultants and researchers of AdviSafe Risk Management B.V. are supporting a diversity of companies to set up activities for strengthen their safety culture. We are able to conduct and tailor made a variety of research and interventions. However we daily witness the progress companies are making in further developing and strengthening their safety culture, we became interested in drives and arguments companies make before starting a safety culture program and with what expectations. Our question therefore is why and with what perspective in mind companies starting safety culture programs? To answer this question we used data of three companies where we recently have conducted safety culture analysis and interventions, and we compared these outcomes with change management theories and literature of successful safety culture interventions. Our main conclusion is that cultural change in organizations, including safety culture, may benefit from motives and perspectives to be explicit and shared within the company. With these outcomes we aim to feed the discussion if current available methodologies are actually helping companies moving forward in strengthen their safety culture.

Keywords: qualitative research; safety; organizational culture; hearts & minds; change management

1. INTRODUCTION

The concept of organizational culture is often used to describe shared corporate values that affect and influence members' attitude and behaviours. Guldenmund (2000) gave an overview in his research of a variety of 18 definitions on safety culture and safety climate. This overview showed that to give a distinct definition on safety culture remains to be difficult. In this paper we define a safety culture as the attitude, values (implicit) assumptions, perceptions and customs of the members of an organisation handling safety risks. As a result, the safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behaviour that determine the commitment to organisation's health and safety management. Safety culture is always connected to the broader organisation culture and therefore relevant at all levels in the organisation, in policy making, in perceptions and handling of higher management, in employees' attitudes and perceptions of daily risks at the work floor. In practice, we notice that safety culture is often used in a positive way to emphasize that organisations feel responsible for safety and act accordingly.

In reflection to all these definitions of safety culture Cooper (2000) stated that safety culture <u>is</u> rather than something the organisation <u>has.</u> An interesting notion which raises the question if all stakeholders in organisations are aware of the current safety culture <u>is-</u>situation and aligned to become a desirable safety culture <u>has</u>-situation. One of the ways to capture safety culture forward in a <u>has</u>-situation for companies is to build a roadmap. This roadmap is based on the goal setting paradigm, placing safety culture as a super-ordinate goal which can be achieved by dividing the tasks into a series of sub goals. These sub goals are intended to direct people's attention towards improvement of safety culture. When using this goal setting theory for analysing, interactive relations between psychological, behavioural and situational factors should be taken into account.

However, changing a safety culture emphasizes more than goal setting. According to Schein (2004) organizational culture can be changed intentionally given the right circumstances and initiatives. Culture is seen as a stabilizing force that serves an anxiety reducing function, as it gives people a frame of reference for how to act, think, and feel in new situations. In that sense culture is a learned defence mechanism against uncertainty and change. Therefore, cultural change is an anxiety provoking process that is only undertaken if there is a large enough motivation to change. This might be the case if the organization senses a large enough threat, crisis, or dissatisfaction with the current state of affairs to warrant a change in its basic assumptions. Or, if the ambition is big and urgent enough, for example to build up a new company brand (De Witte, 2014).

Our research question why and with what perspective in mind companies starting safety culture programs will gain more insight in arguments and drives of organisations to change safety culture: is it goal setting, crisis or dissatisfaction with the current state of affairs or neither of those. Our study also aims to contribute to the lack of culture change intervention studies in the safety literature (Hale, Guldenmund et al 2010).

2. MATERIALS AND METHODS

To answer our research question what arguments and drives organisations have to change their safety culture we used the following materials:

- Key references of change literature (Schein, 2002; Kotter, 2002; Cozijnsen, 2014)
- A limited literature survey on interventions for improving safety culture and arguments for starting interventions (Zwetsloot & Dijkman, 2010; Hale, Guldenmund et al, 2006, Guldenmund 2010, Zwetsloot et al 2013)
- Qualitative survey data and workshop reports of three companies, that is: oil and gas industry (company A); energy provider (company B) and a ship yard (company C). The survey data consists of semi-structured interviews based on intervention 'understanding your culture' of the Hearts & Minds program of the Energy institute (Fleming, 2001). Surveys and workshops were held in the period 2013- spring 2015.

Based on these literature and qualitative data we subsequently developed two topic lists, one for motives and one for perspectives and preconditions (see also 2.5.). We first scored all companies to the topic list of motives to get an overview on the essential why the company intends to start with safety culture. Then, in a second step we organised all data into the topic list of perspectives to unravel perspectives in terms of goal settings, how problems and ambitions should be met.

2.1 Reasons to start with safety culture

An overview with examples of reasons why organisations start activities for safety culture changes is compiled by Zwetsloot & Dijkman (2010). This overview is in general 'problem-driven' and based on expert opinions and reports on practical experiences in a variety of industries. These main reasons are:

1. Our safety performance lags behind of our concurrent
2. Too much loss of productivity due to incidents and disturbances
3. A serious accident
4. General bad project preparation (do first, instead of think first)
5. Insufficient report of incidents, near misses and deviations
6. Overruling of procedures and rules
7. Labour inspection enforces to better performance on safety

Behind those arguments for starting activities to improve a safety culture lies the assumption that change of organizational culture will contribute to solve those problems. However safety problems can be a drive to improve the safety culture, at the same time, we notice that safety culture is often used in a positive way to emphasize that organisations feel responsible for safety and act accordingly. Therefore, arguments for changing organisation's safety culture can also be ambition driven. Examples of these ambition driven activities are found in the zero vision strategy (Zwetsloot et al 2013), meaning prevent all kinds of accidents as business principle (see: www.ttl.fi/zeroaccidentforum) or strengthen the resilience of the organisation. Resilience is explained as "the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions" (see: http://www.resilience-innovationlab.org/resilience)

In addition to either problem driven, or ambition driven arguments to invest in safety culture, in our view, it is important how companies understand their current safety culture, and what issues with what perspectives are referred to as important to take up for change. To be able to include both elements in our research we used three theoretical and pragmatic frameworks consisting:

- hearts & minds intervention understanding your culture– score on 11 theme's

– Theories of change (Kotter, 2002;Schein 2004; Cozijnsen, 2014)
– Success factors in safety culture projects (Hale, Guldenmund et al, 2006)

All three frameworks will be described here in short:

2.2. Hearts & Minds understanding your culture

The program Hearts and Minds of the Energy Institute (Fleming, 2001) is intended to help the organisation to improve HSE performance to develop themselves according the safety culture ladder (see figure 1). The program also provides processes and tools to facilitate behavioural change.

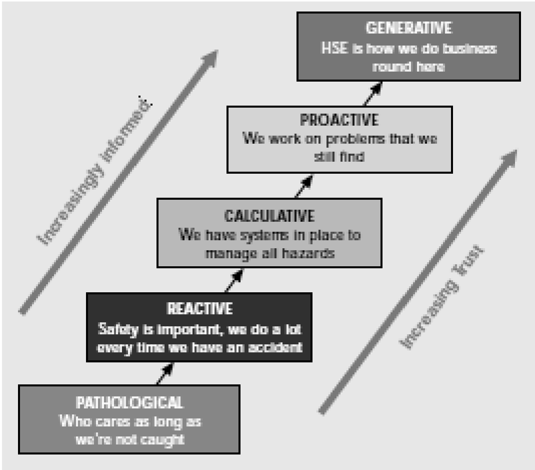

Figure 1: Safety culture ladder

Basic assumptions of the program are that for developing a safety culture the organisation has to run through five stages of development. This gradual development of the safety culture offers companies a systematic framework to work with. We have used the self-assessment tool of Hearts & Minds "Understanding your culture" as a basis for our qualitative survey at three companies, resulting in 11 questions (see table 1).

Table 1: 11 questions to better understand current safety culture (based on Understanding your culture, Energy Institute, 2008)

1.Leadership
Do you think that management is always committed to safety? How does management demonstrate this on a daily basis?
2.*Quality and quantity of procedures,*
What do you think about the quantity and quality of existing HSEQ procedures?
3.Daily HSE Behaviour
Do you always work safe? Is it always possible to work safe?
4.*Competences and safety Awareness*
What can you tell us about the hazards and risks of your work?
5.*Contractor safety*
How do you cooperate with contractors regarding to HSE?
What can be improved?
6.Reporting incidents
Do you think employees feel free to report all incidents, even unsafe behaviour?
Are all incidents analysed in a proper way?
Do employees always get feedback from their incident report?
7.Continuous improvement
Do you think the organisation is focused on continuous improvement? Why do you think that?
8.Involvement of employees
In what way are employees involved in safety initiatives?
9.Communication
Is the safety vision consistently communicated within the company?
10.Maintenance management and Management of Change
What do you think of the quality of maintenance within the company?
Are HSE issues always considered in case of change?
11.Risk management (H,S & E)
Are all risks sufficiently known and tackled?

2.3. Theories of organizational change

Change management literature stresses some important elements to take into account for making successful organizational changes. For example Schein (2004), Kotter (2002) and Cozijnsen (2014) emphasize that for successful change, organizations should have large enough motivation, explained as an ambition or a crisis. Furthermore, all authors state the importance to get a grip on the flow to manage and organise organisational change. Moreover, to be aware in this process of the effect when trying to change people's behaviour. Cozijnsen (2014) developed a model of change to help organizations to find out whether they are fit to take up organisational changes. The model has integrated knowledge of a variety of change management disciplines and literature, and includes four building blocks: 1. organisation context; 2. Concepts for improvement; 3.behaviour; 4. Strategies, methods and interventions, and seven pillars for successful change. Each pillar helps to frame the risk into a factor of success. For example the risk profile of the organisation context might be an inhibitor, which includes risk factors as lack of trust, urgency or chance capacity. Nonetheless each process for changing safety culture starts with a question, an ambition, a situation (actuality) or a crisis.

2.4. Success factors safety culture projects

From effect studies from safety culture projects we can possibly learn what were drives and arguments to start these projects. Unfortunately little of those studies are available. Based on an evaluation study of the results of 20 companies in The Netherlands who started in the period 2003-2008 activities to improve their safety culture, Hale and Guldenmund et al(2010) concluded that for effective change four success factors are of importance. That is:

1. Active and supportive role of higher management
2. Strengthen dialogue between shop floor and (operational) management
3. Training and motivation management and board members
4. Systematic approach

Especially factors 1-3 for successful changes seems to pinpoint underlying drives and arguments which make changes apparently to a success. These factors are all also an important part of the Hearts and Minds program.

2.5. Topic lists

Based on literature as described above, we derived two topic lists on motives and perspectives how companies intend to invest in safety culture. For all three companies, we collected survey and workshop data. We used this data to complete our topic list for motives (see table 2) and perspectives (see table 3).

Table 2: Topic list of motives

Motives	What is the essential why? Crisis, ambition?	Problem driven (Zwetsloot & Dijkman, 2010) Our safety performance lags behind of our concurrent Too much loss of productivity due to incidents and disturbances A serious accident General bad project preparation (do first, instead of think first) Insufficient report of incidents, near misses and deviations Overruling of procedures and rules Labour inspection enforces to better performance on safety Ambition driven (zero accidents, resilience) Zero vision: prevent all kinds of accidents as business principle Strengthen the resilience of the organisation Image improvement Improvement of organisational culture and collaboration in the network economy

Table 3: Topic list of perspectives and preconditions (derives from Hearts & Minds UYC and literature)

<table>
<tr><td rowspan="8">Wat are perspectives to meet problems and ambitions, and how?

Goal setting, give a push to organizational movement, strengthen dialogue</td><td>Leadership
Commitment to safety</td><td>1.Demonstration of safety leadership
In all daily decisions at all levels and communicate those decisions in a consequent way</td></tr>
<tr><td>HSEQ procedures
Quantity and quality</td><td>2.increase compliance of rules and procedures
3.develop a congruent set of rules and procedures</td></tr>
<tr><td>Daily HSE behaviour
Always work safe?</td><td>4.safety should be the first priority, rules over production
5.more compliance behaviour at all levels</td></tr>
<tr><td>Competence and safety awareness
Hazards and risks?</td><td>6.trust employees to make the right risk assessments
7.improving visible leading by example</td></tr>
<tr><td>Contractor safety
Cooperation with contractors in HSE</td><td>8.better align purchasers and planners with safety
9.more attention to multi languages at the shop floor</td></tr>
<tr><td>Reporting incidents
Employees feel free and motivated to report?</td><td>10.increase reporting
11. consequent follow up and feedback on reports
12. ensure blame free investigations</td></tr>
<tr><td>Continuous improvement
Focus on improvement?</td><td>13.follow up and learn from incidents
14.reframe focus towards lagging indicators instead of leading indicators</td></tr>
<tr><td>Involvement of employees
In what way employees are involved in safety initiatives?</td><td>15. increase of involvement of employees at shop floor
16. use practical knowledge of employees</td></tr>
<tr><td></td><td>Communication
Is safety vision consequently communicated?</td><td>17. develop a consistent safety vision
18.training of communication skills, improve dialogue and interaction</td></tr>
<tr><td></td><td>Maintenance management
What is quality of maintenance?</td><td>19.Increase supervision and interaction
20.Overdue of maintenance is a serious safety issue
21.Implementation of new technics and materials can be improved</td></tr>
<tr><td></td><td>Risk Management
Are all risks sufficient known and tackled?</td><td>22.do not let systems overtake safety; personal contact should be the driver for attitude and behaviour for safety</td></tr>
<tr><td rowspan="6">Preconditions</td><td rowspan="6">Motivation and capacities (Theories of chance: Kotter, Cozijnsen and success factors from success factors safety culture projects (Hale, Guldenmund):</td><td>23.Large enough motivation (ambition or crises)</td></tr>
<tr><td>24.Change capacities</td></tr>
<tr><td>25.Aware of effect of behavioural changes</td></tr>
<tr><td>26.Active and supportive role of (higher) management</td></tr>
<tr><td>27.Strengthen dialogue between shop floor and (operational) management</td></tr>
<tr><td>28.Training and motivation management and board members</td></tr>
</table>

3. RESULTS AND DISCUSSION

3.1. Results 'what drives the wish to change'?

First, we scored data of three companies (company A: oil and gas industry; company B: energy company C: ship yard) to the topic list of motives to get an overview on the essential why the company intends to start with safety.

Table 4 shows the motives (essential why) of the three companies. Although our first impression was that all companies tend to have more problem driven motives than ambition driven motives towards safety culture, it turned out that company A. expressed to have a clear ambition towards zero accidents. Ambition driven motives seem to be less common for company B and C. All three companies scored on the problem of overruling procedures and rules. Remarkable is that all companies shared the ambition driven motive of image improvement.

Table 4: Scores of three companies to topic list of motives

			Company		
			A	B	C
Motives	What is the essential why? Crisis, ambition?	Problem driven (Zwetsloot & Dijkman, 2010)			
		Our safety performance lags behind of our concurrent			x
		Too much loss of productivity due to incidents and disturbances		x	x
		A serious accident			x
		General bad project preparation (do first, instead of think first)		x	x
		Insufficient report of incidents, near misses and deviations		x	x
		Overruling of procedures and rules	x	x	x
		Labour inspection enforces to better performance on safety			
		Ambition driven (zero accidents, resilience)			
		Zero vision: prevent all kinds of accidents as business principle	x		
		Strengthen the resilience of the organisation			
		Image improvement	x	x	x
		Improvement of organisational culture and collaboration in the network economy			

Table 5 shows the perspectives of the three companies. These scores show that perspectives to change within all companies are specifically found in leadership, increase of HSEQ compliance and procedures, issues with contractor safety and involvement of employees. This latter perspective of involvement of employees shows that there is apparently a need and an interest to better align employees to safety activities. Although, based upon these cores, perspectives for such an alignment might differ, is this for better reporting, increase compliance behaviour, to set up communication and dialogue, or perhaps other perspectives? Looking at preconditions, company C is driven from an ambition or a crisis to start with safety culture. Clearly this is an important situation, shown by the supportive and active role of company's (higher) management.

Table 5: Scores of three companies to topic list of perspectives and preconditions

			Company		
			A.	B.	C.
Wat are perspectives to meet problems and ambitions, and how? Goal setting, give a push to organizational movement, strengthen dialogue	**Leadership** Commitment to safety	1.Demonstration of safety leadership In all daily decisions at all levels and communicate those decisions in a consequent way	x	x	x
	HSEQ procedures Quantity and quality	2.increase compliance of rules and procedures	x	x	x
		3.develop a congruent set of rules and procedures	x	x	x
	Daily HSE behaviour Always work safe?	4.safety should be the first priority, and therefore rules over production	x		
		5.more compliance behaviour at all levels	x	x	x
	Competence and safety awareness Hazards and risks?	6.trust employees to make the right risk assessments		x	
		7.improving visible leading by example	x	x	
	Contractor safety Cooperation with contractors in HSE	8.better align purchasers and planners with safety	x	x	x
		9.more attention to multi languages at the shop floor			x
	Reporting incidents Employees feel free and motivated to report?	10.increase reporting		x	x
		11. consequent follow up and feedback on reports		x	
		12. ensure blame free investigations			
	Continuous improvement Focus on improvement?	13.follow up and learn from incidents		x	x
		14.reframe focus towards lagging indicators instead of leading indicators	x		
	Involvement of employees In what way employees are involved in safety initiatives?	15. increase of involvement of employees at shop floor	x	x	x
		16. use practical knowledge of employees			x
	Communication Is safety vision consequently communicated?	17. develop a consistent safety vision			x
		18.training of communication skills, improve dialogue and interaction	x		x
	Maintenance management What is quality of maintenance?	19.Increase supervision and interaction			x
		20.Overdue of maintenance is a serious safety issue	x		x
		21.Implementation of new technics and materials can be improved		x	
	Risk Management Are all risks sufficient known and tackled?	22.do not let systems overtake safety; personal contact should be the driver for attitude and behaviour for safety	x	x	
Preconditions	**Motivation and capacities** (Theories of chance: Kotter, Cozijnsen and success factors from success factors safety culture projects (Hale, Guldenmund):	23.Large enough motivation (ambition or crises)			x
		24.Change capacities			
		25.Aware of effect of behavioural changes			x
		26.Active and supportive role of (higher) management			x
		27.Strengthen dialogue between shop floor and (operational) management			
		28.Training and motivation management and board members			

3.2. Discussion

To ensure sustainable safety at work, companies increasingly intent to create a safety culture. Doing so, improving safety culture requires (behavioural) change within the company. For this, companies should not only have insights into what has to be changed, but also how this change can be induced. In practice, inducing change often appears to be difficult (see Schein 2004). Sustainable change requires an active involvement of a variety of stakeholders. These stakeholders should understand why the change is worthwhile for the company. Moreover, they should give meaning to the change themselves (Scharmer, 2007, Van der Zouwen, 2011, Van Scheppingen, 2014). In other words: stakeholders should understand the 'essential why' of improving safety culture and understand what the perspectives are to induce the change. Effect studies often state the relevance of drives, motives and perspectives to start a safety culture program. Unfortunately, these motives and perspectives are rarely specified. This paper aims to contribute to this lacking knowledge by making explicit what are the motives and perspectives of companies to improve their safety culture.

Based on the findings – and in line with Guldenmund (2010), who stated that 'safety culture had become a term used by people all around the globe to explain everything relating to safety failure that cannot be explained in another way'-, the motives to improve safety culture are mostly related to problem solving and reducing safety risks. Risk reduction, of course, is – and will be- a main focus of safety professionals. Creating a sense of urgency to prevent hazards is, therefore, often remarked as step 1 in a safety culture program. With this we come up to the issue of different risk perceptions. Different stakeholders - needed to induce the full change and embed a safety culture- may (will!) have different risk perspectives. It is not likely that all stakeholders will give the same meaning to safety and/or risks and feel the same sense of urgency when safety hazards are made clear. This raises the question whether safety professionals should invest (all) their effort in convincing other stakeholders of the urgency to strengthen a safety culture. Another possibly relevant strategy is searching for shared motives and creating common ground. Working on shared motives is expected to mobilize energy within the organization to make a next step in change (Van der Zouwen, 2011; Van Scheppingen, 2014). It is interesting to address the question what motives serve (parallel) interests of all relevant stakeholders. We presume that the ambition/developmental motives of organizations are specifically relevant for this. Especially to align with strategic management can be fruitful, after all their ambition to ensure the existence of the company might include also safety ambitions. Further research however is needed to examine our presumption.

Strengthening safety culture is not a rational and linear process that can be implemented. Organizational and safety culture is something that a company is, rather than something a company has (Cooper, 2000). Making a next step in cultural development is therefore seen as a collective and continuously learning process (Schein, 2004). This research provides some insights in supporting such a collective learning process and strengthening a safety culture. Making motives explicit within the company is seen as an important step to cultural change. With this, stakeholders are enabled to develop their own meaning to the change. In health science, a participatory value case methodology was found to be a useful method to collaboratively making shared motives explicit (Van Scheppingen et al 2013). It seems relevant to investigate if such a method will be useful regarding safety culture.

To promote safety culture, it is meaningful to reflect from time to time to the current situation and the way ahead (Zwetsloot & Dijkman, 2010). The recognized motives and perspectives in this paper can be used to support this reflective, developmental process. First, the motives and perspectives can be used as (shared) aim for which companies strive. Second, the motives and perspective can be used as indicators for periodically monitoring within the company. Third, they can be used to investigate and discuss the similarities and differences among the stakeholders when regarding safety culture.

Maybe the main contribution of the recognized motives and perspectives, however, is that they can be used to facilitate a substantive dialogue about the 'essential why' and perspective of strengthening a safety culture. To be used in training, workshops, strategic dialogue or regular work meetings or tool box meeting, this seem useful and complementary to other approaches to enhance safety culture.

4. CONCLUSIONS

Our main conclusion is that cultural change in organizations, including safety culture, may benefit from motives and perspectives to be explicit and shared within the company. Sharing such motives and perspectives among stakeholders and searching for parallel interests are expected to mobilize energy and motivation to make a next step in safety culture.

More specific, our research showed that most motives for starting up activities on safety culture are problem driven, and not so much ambition driven. Those ambitions of organisations, perhaps hidden in several divisions, are of value to dig up. Safety culture could then be more a shared concern, embedded in company's strategy and not so much the only concern of safety professionals.

Making motives and perspectives explicit contributes not only to better understand why there is a need to change organisations' safety culture, but also unravels several perceptions on risks and safety within the organisation. Although we are aware that we have based our research on data of three companies, we are convinced that this research opens new possibilities to look into organisations' safety culture. The findings of this research are presumed to be useful in developing sustainable safety culture programs and interventions.

5. REFERENCES

Cooper, M.D. (2000). Towards a model of safety culture. *Safety Science*. 2000;36 111-136

Cozijnsen,A.J. (2014) De 7 V's van verandermanagement. Veranderrisico's omzetten in slaagfactoren. *Uitgave van Persons Benelux, Amsterdam*

De Witte, M. Jonker, J. (2014). De kunst van veranderen. Bewegen naar de kern. The art of change. Movement to the heart. *Deventer, Kluwer* 2014.

Guldenmund, F.W. (2000) Misunderstanding safety culture and its relationship to safety management. *Risk Analysis,* Vol.30, No.10, 2000

Guldenmund, F.W. (2000). The nature of safety culture: a review of theory and research. *Safety Science.* 2000; 34(1-3):215–257

Hale, A, Gudenmund, F.W., Oh J. et al (2010). Veiligheidsverbetering:wat werkt en wanneer. In: *Tijdschrift voor toegepaste Arbowetenschap.* Nr.2 50-56

Hollnagel,,E. (2006) Reslience:the challenge of the unstable. In: Resilience engineering: *Concepts and precepts / [ed] Erik Hollnagel, David D. Woods, Nancy Leveson, Aldershot, UK: Ashgate, 2006, 1, -397*

Hudson, P. (2007). Implementing a safety culture in a major multi-national. *Safety Science* 2007:42: 697-722

Kotter, J.P. (2002). The heart of change. Real-life stories of how people change their organizations *Harvard Business review press.*

Parker, D. Lawrie, M. Hudson, P. (2006). A framework for understanding the development of organizational safety culture. *Safety Science* 2006:44:551-562

Scharmer, C.O. (2007) Theory U- leading for the future as it emerges. The social technology of presencing. *Cambridge MA: SOL*; 2007.534p

Schein, E. (2002). A conceptual model for managed cultural change. In: E. Schein. *Organizational Culture and Leadership (3rd edition). Jossey-Bass.*

Van der Zouwen, A. (2011). Building an evidence based practical guide to large scale interventions. Towards sustainable change with the whole system*. Doctoral Thesis, Tilburg University.*

Van Scheppingen, A.R. et al (2012). A value case methodology to enable a transition towards generative health management: A case study from the Netherlands. J. of *Human Resource Costing and Accounting* 2012; 16 (4)

Van Scheppingen A.R. (2014). Fostering self-regulation in health in organisations. *Gildeprint, Enschede. The Netherlands. ISBN 9789461087430.* Doctoral Thesis, VU University Amsterdam.

Zwetsloot, G.I.J.M, Leka S. Corporate culture, health and well-being In: Leka S, Houdmondt J, editors. *A text book for occupational health psychology. Chicester: Wiley-Blackwell*; 2010. P. 250–68.

Zwetsloot,G.I.J.M, Dijkman,A.J. (2010). *Arbo Informatieblad 56. Werken aan een veiligheids- en gezondheidscultuur. Uitgeverij SDU.* pp.22-41.

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Safety management in multilingual teams and the role of leadership

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Abstract

Existing approaches to stimulate safe behaviour mostly fail to devote explicit attention to the diversity of employers on the workfloor. Especially the group of workers that performs risky and low skilled work appears to be more diverse in terms of age, language, culture, religion, gender, and also health status. In this study we focus on the improvement of safety performance in multilingual i.e. multicultural organisations. Due to globalisation trends the need for approaches that pay attention to language issues and aspects of cultural background for the prevention of accidents has grown. One of such tools could be the managing role of the leader in such diverse teams as is already shown by the positive effects of a Safety Specific Transformational Leader (SSTL) on Safety Performance on operational workfloors. The open and safety specific style of communication of this type of leaders has been shown to foster safety on the workfloor. However, none of these studies made a comparison between multilingual and monolingual work teams regarding the effectiveness of this SSTL communication style. One could suggest that in multilingual teams a “walking and talking around” manager is not that profitable as in monolingual teams; in what way he manager has to communicate with his colleagues speaking different languages in order to be convincing about safety performance? To explore the safety performance in multicultural teams and the role of leadership, we defined the following research questions: (a) do multilingual organisations differ in safety performance from monolingual organisations? (b) what is the impact of leadership to safety performance, and does this differ between monolingual and multilingual organisations? (c) What do our findings mean for potential approaches in managing safety of multilingual organisations?

Based on a questionnaire study in 17 companies in the warehouse sector in the Netherlands (total number of participants was 260, from which 154 from multilingual organisations), we have analysed the following variables: company safety awareness, personal safety awareness, general safety risks, safety-specific transformational leadership. Pearson correlations, a t-test, linear regression analyses and an interaction term were conducted to test the relations and differences between the relationships. At last the results will be discussed with a selection of the companies in an interactive panel.

Our first analyses indicate that employees in multicultural/lingual organisations show a lower safety awareness on company level, more safety risks and a lower score on transformational leadership. Also, it shows that transformational leadership is positively related to safety awareness and negatively to safety risks.

The results of explorative multivariate regression analyses indicate that there is a positive relation between leadership and safety awareness on a company level and a stronger relationship between leadership and safety awareness in monocultural/lingual organisations compared to multicultural/lingual organizations.

The results of this study show that the safety performance within multicultural/lingual organisations is lower than the safety performance of monocultural/lingual organisations. Also we found that there is more transformational leadership in mono cultural/lingual teams, and also that the relationship between leadership and safety is stronger in the monolingual teams.

Keywords: safety culture; multiculturalism, communication, leadership, warehousing.

1. INTRODUCTION

Due to globalisation trends there is a growing need for ways to improve safety and health in multicultural/multilingual work settings. Over the past few years, the workforce has changed, with a growing number of migrants in the labor force (EU-OSHA, 2013). Migrant workers are often employed in low-skilled, low-paid jobs with dangerous working conditions that local workers would not accept. Moreover, several studies have revealed that migrant workers are more often involved in occupational accidents than national workers (EU-OSHA, 2013). The European Foundation for the Improvement of Living and Working Conditions (Eurofound, 2007) has published several national reports concerning migrant workers, which highlight that migrant workers are more exposed to risky situations than local workers, for example in Spain, Italy and Austria. Based on the results of the Netherlands Working Conditions Survey, conducted among approximately 25 000 workers, Van den Bossche et al. (2006) showed that non-Western migrants are significantly more often involved in accidents resulting in physical or mental injury. Possible reasons for this range from more practical ‘communicational problems in understanding the instructions’ to the ‘confrontation with unfamiliar local working procedures’ (EU-OSHA, 2013). Lindhout (2009) for example found that language issues were related to safety issues but also indicated that other factors, such as cultural diversity may play an underlying role in safety (Lindhout, 2009). Evidently, organizational communication, be it in the form of language or cross-cultural communication styles or the complexity of intercultural communication, plays an important role in occupational safety. Guldenmund and colleagues (2010) refer to the serious consequences of diversity in relation to safety knowledge, values about work and communication. In their study, it is shown that migrants are more vulnerable to safety incidents owing to aspects such as obedience (e.g. they are more reluctant to raise safety issues), language barriers, and eagerness to earn money quickly. For example, in the Netherlands it is expected that half of the migrants from Mid-and East European countries will enter via an employment agency (Ministry of Social Affairs and Employment in the Netherlands, 2011). Their more flexible (insecure) and so more vulnerable labour position will probably make the workers more reluctant to come up with safety issues.

Communication issues and risk perception have been mentioned as causes of accidents by the Dutch Ministry of Social Affairs and Employment (Guldenmund et al., 2010). De Vries and colleagues (2007) argue that language problems and cultural differences often cause problems with respect to understanding safety regulations. Employees often do not understand the safety regulations and/or its importance, and will probably as a result, act less committed to them. In addition, unfamiliarity with local standards can account for accidents (Van Hooff et al., 2009). This study shows that the higher risk may be partly explained by the characteristics of the low-skilled jobs. Van Hooff and colleagues (2009) conclude that both the characteristics of migrants (e.g. language comprehension, knowledge and understanding of local habits and risk perception) and those of their working environment (temporary work, unskilled and risky work) mean that occupational safety is at risk.

In a study for the Dutch Ministry of Social Affairs and Employment, Guldenmund and colleagues (2012) investigated possible factors affecting occupational accidents among migrant workers in three European countries (Denmark, the Netherlands and the United Kingdom). Guldenmund and colleagues (2012, p. 7) conclude that the vulnerability of migrant workers might best be explained on situational (instead of cultural) grounds. Migrants might, for example, encounter difficulties in receiving and/or fully understanding safety instructions owing to language and/or literacy problems. Moreover, they often settle for poor and unsafe working conditions as their primary concern is to make money to avoid going home empty handed.
So, next to language issues and cultural issues, also characteristics of the migrants (knowledge of the local habits, illiteracy), characteristics of the job (unskilled or risky work) and situations circumstances will possibly affect safety in multicultural/multilingual teams. Whether cultural aspects, like background differences and differences in risk perception are undoubtedly influential in the potential occurrence of occupational accidents, on the workfloor it is still believed that multilingualism on the work floor accounts for the largest part of situations in which accidents occur. Although companies are aware of the difficulties that a workforce with different cultural backgrounds and languages can bring, when examining occupational safety policies these cultural background characteristics are hardly considered (Bukman et al., 2010; cf. Vickers et al., 2003). In existing safety programs the attention to the diversity of cultural backgrounds of employees on the work floor is lacking. Safety managers do renew existing safety guides and create interventions and/or programs to improve the adaptability to the variety of workers, in terms of safety, but merely translating procedures, to avoid language barriers, is insufficient. For example using pictograms is seen as an effective and practical way of decreasing language related uncertainties, but in most times they are unable to give an ‘action perspective’; let alone the perception of pictograms by workers with different cultural backgrounds. Taking into account the multiple type of factors that may cause unsafety in

multicultural teams, it is argued by Starren et al. (2013) that “there is a need for the improvement of personal competencies, and especially leadership competencies, to deal with constantly changing language and culture situations at work.”
In this present study we will look at the managing role of the leader in such diverse teams. Regarding to leadership style, it is already shown form literature that there are positive effects from specific leadership on Safety Performance on operational workfloors. Prior research has found that transformational leadership is a management method/style with specific communication styles (Barling, Weber & Kelloway, 1996) that could improve the procedures in multicultural (multilingual) teams related to safety (EU-OSHA, 2013). The open and safety specific style of communication of this type of leaders has been shown to foster safety on the workfloor. Moreover this style of leadership competencies can be trained and developed.
In the studies of Barling et al. (2002), De Koster et al. (2011) and Kelloway et al. (2006), the crucial aspects for Safety-Specific Transformational Leadership (SSTL) have been defined. This type of leadership is characterized by the following aspects:

- “Idealized influence”: refers to acting as a role model for safety behaviour;
- “Inspirational motivation”: means communicating a safety vision that encourages employees to behave accordingly;
- “Intellectual stimulation”: makes employees think of “new ways of doing work” to improve safety, and;
- a transformational leader with “Individualized consideration”: shows active interest and care for the personal safety of employees and individually supports them to.

The above SSTL characteristics show the aspects of an effective communicative style in order to behave and convince as a safety specific leader.
However, none of these earlier studies made a comparison between multicultural and monocultural work teams regarding the effectiveness of this transformational communication style. One could suggest that it will work in multicultural/multilingual setting too. But one could also suggest that in these kind of teams the typical “walking and talking around” -characteristic of the transformational style manager is not that profitable, because of the language barriers. The question is in what way he manager has to communicate with his colleagues speaking different languages and coming from different backgrounds, in order to be convincing about safety performance?
In this present study we conduct a quantitative study on leadership style in monolingual and multilingual warehouses in the Netherlands, and its effect on the risk of occupational accidents. We choose for the warehousing because of the relatively high risk activities, the prevalence of multicultural teams, and because De Koster has used the warehouse setting for his earlier findings. To explore the safety performance in multicultural teams and the role of leadership, we defined the following research questions:
(a) do multilingual organisations differ in safety performance from monolingual organisations?
(b) what is the impact of leadership to safety performance, and does this differ between monolingual and multilingual organisations?
(c) What do our findings mean for potential approaches and tools in managing safety of multilingual organisations?

2. MATERIALS AND METHOD

2.1 Sample

Based on a questionnaire study in 17 companies in the warehouse sector in the Netherlands (total number of participants was 260, from which 154 were multilingual organisations). The companies were randomly selected and categorised as being MULT (9)/MONO (8) based on our criteria of how many languages were spoken on the workfloor . The sectors ranged from the logistics sector to food supply warehouses. Most warehouses used in this study were located around the city of Nijmegen, and/or the eastern part of the Netherlands (for example, JUMBO, KRUIVAT, DHL).

2.2 Procedure

The self-reported questionnaire data were collected in 2013 by means of random company visits to warehouses. Dutch warehouses were contacted via email or telephone and provided with a written or oral introduction that the research was about different leadership styles in multicultural teams and asked whether the workforce had a certain degree of internationality or multilingualism or not. After confirmation of the amount of different languages spoken on the workfloor, we labeled the company as monolingual if there was only one general worklanguage, if there were more then two languages spoken om the workfloor we labeled the company by definition as multilingual. In companies where only two languages were spoken we analysed the percentage of multilingualism (if more then 50 % of the employees indicated in the questionnaire that he/she spoke two language at the workfloor then the company w was considered as being multilingual). Respondents were asked to fill in a paper questionnaire provided by the researcher in person. Respondents could select between Dutch, English, German and Polish questionnaires. The questionnaire included 50 questions and a short instruction that the research is on different leadership styles, that all data will be treated anonymously, only serving the purpose of the research, and information on how to answer the questions. It took respondents about 5 minutes to fill in the survey. As the researchers were present during the answering procedure, respondents were allowed to ask if they had difficulties understanding the questionnaire. The respondents were informed of the purpose and procedures of the study, the participation was voluntary, and strict confidentiality was guaranteed regarding individual responses outside the research team. All respondents were men between 19 and 51.

2.3 Measures

Multi/monolingualism The first four questions were combined to multilingualism/monolingualism and focused respectively on the native language, language knowledge, language(s) spoken on the work floor by oneself, and language(s) spoken on the work floor by others. These introductory questions all had six answer possibilities, namely: 1 = Dutch, 2 = English, 3 = German, 4 = Polish, 5 = Romanian and 6 = ‘Other(s), namely __’.

Safety Awareness (SA) SA was measured with a scale developed by Barling et al. (2002). The scale measures an individual’s own awareness of safety issues and consists of seven items on a seven-point scale ranging from 1 (disagree strongly) to 7 (agree strongly). We modified three items slightly to be applicable to a warehouse situation. An example item is: “I know how to inform management about any potential hazards I notice on the job”.

The reliability of (individual) safety awareness consisting out of 5 items was adequate: α = .70. However, in order to ensure the reliability of the questions, item 7, regarding dangerous situations on the work floor (e.g. fire) has been withheld from the study. Apparently, the question was not formulated clearly. The reliability of company safety awareness consisting of 6 items was good: α = .89. Example “I work in a company where the possibility of accidents causing a threat to the environment is low”.

Safety performance The reliability of safety performance consisting of 7 items was good: α = .91. Example “In the past 12 months I came in contact with fluids, gasses or high voltage that were unintentionally released”.

Safety-specific transformational leadership (SSTL): The remaining questions, 23 to 33 focused on safety-specific transformational leadership (SSTL). We measured SSTL using Barling et al.’s (2002) 10-item scale; see also de Koster et al. (2006), Kelloway et al. (2011). Barling and colleagues based this scale on the MLQ, an instrument used to measure general transformational leadership (Bass and Avolio, 1990). Like Barling et al. (2002), we used a seven-point scale response format per item ranging from 1 (disagree strongly) to 7 (agree strongly). An example of an item includes, 'My direct manager talks about his/her values and beliefs of the importance of safety'. The reliability of safety-specific transformational leadership consisting out of 11 items was good: α = .92.

First Pearson correlations were calculated between the variables. T-test and lineair regression analyses were applied to investigate research question 1 and 2a. An interaction term was calculated and added to the regression analyses to test whether the impact of SSTL differs between mono and multilingual companies.

3. RESULTS

First step in our analyses was to find out whether multilingual organisations do differ in safety performance and awareness and in their (perceived) Safety Leadership from monolingual organisations? Descriptive statistics and intercorrelations among the study variables for the sample as a whole are presented in Table 1. The correlations analyses show that company safety awareness correlates significantly with personal safety awareness and safety performance in general. Personal safety awareness does not correlate with safety performance. Transformational leadership correlates significantly with all the safety performance indicators for mono- and multicultural teams taken together. Due to a high intercorrelation between company safety awareness and personal safety awareness, personal safety awareness is excluded from further analyses (!).

Table 1: Intercorrelations among language of the company (MULTI/MONO) company safety awareness, personal safety awareness, safety performance and safety-specific transformational leadership (N=254).

Variable name	1.	2.	3.	4.	M (SD)	α
1. Company safety awareness	-	.67**	.24**	.55**	5.14 (1.28)	.70
2. Personal safety awareness		-	.01	.52**	5.83 (1.32)	.89
3. Safety performance (high score is low risk-)			-	.17*	5.42 (1.93)	.91
4. Safety-specific transformational leadership				-	5.29 (1.37)	.91

**p < .05. **p < .01.*

Question A: Do multilingual organisations differ in safety awareness, safety performance and SSTL from monolingual organisations? Table 2 shows the results of the T-test in which monolingual and multilingual companies are compared. Monolingual companies show a significantly higher score on company safety awareness, safety performance and transformational leadership.

Table 2: T-test , comparison of monolingual and multilingual companies on included measures

Variable name	Monol/ Multi	N	M	SD	T	Df	Sig.
Company safety awareness	Monl	104	5.51	1.20	3.79	254	.00
	Multi	152	4.91	1.27			
Personal safety awareness	Mono	104	5.91	1.24	.88	254	.38
	Multi	152	5.76	1.37			
Safety performance	Mono	106	6.01	1.61	4.16	256	.00
	Multi	152	5.03	2.01			
Safety-specific Transformational leadership	Mono	104	5.53	1.26	2.48	256	.01
	Multi	154	5.11	1.41			

Monolingual companies do significantly differ from multilingual companies on company safety awareness and safety performance even when controlled for SSTL (see table 3).: Monolingual companies show a higher company safety awareness and safety performance. However, monolingual companies do not differ significantly from multilingual companies on SSTL when controlled for company safety awareness and safety performance (see table 4).

(B) 1. What is the impact of safety specific leadership on safety awareness and performance? Table 3 shows the regression analyses with safety performance and company safety awareness as dependent variables. The analyses show that transformational leadership is significanty related to company safety awareness but is not significantly related to safety performance when controlled for company safety awareness. This is an indication that safety awareness partly mediates the relationship between SSTL and safety performance. Since we also found a significant relationship between between company safety awareness and safety performance not controlled for SSTL (not depicted) and no difference between MULTI/MONO) in relationship between performance and awareness.

Table 3: Regression analysis for safety performance and company safety awareness, standardized Beta coefficients (N=254).

	Company safety awareness				**Safety perfor-mance**		
	Step 1	**Step 2**	**Step 3**		**Step 1**	**Step 2**	**Step 3**
MONO=0, MULTI=1)	-.14*	-.11*	-.10	MONO=0 MULTI=1	-.22**	-.20*	-.20*
Safety-specific transformational leadership	.53**	.51**	.53**	Safety-specific transformational leadership	.14**	.05	.05
Safety performance	-	.12*	.11*	Company safety awareness		.16*	.16*
MONO/MULTI*Leadership		-	-.14**	MONO/MULTI*Leadership			-.01
R2 adjusted	.32	.33	.34	R2 adjusted	.07	.09	.08

$^*p < .05$. $^{**}p < .01$.

Table 4: Regression analysis for transformational leadership, standardized Beta coefficients (N=254)

Variables	**Step 1**	**Step 2**	**Step 3**
MONO=0 MULTI-1	-.16**	-.04	-.03
Company safety awareness		.54**	.53**
Safety performance			.04
R2 adjusted	.02	.30	.30

$^*p < .05$. $^{**}p < .01$.

(B) 2. The next question was whether the relationship between leadership and company safety awareness and performance differs between monolingual and multilingual companies. For this question an interaction term was calculated of SSTL and company language (MULTI/MONO) and added in the third step of the analysis. The interaction term is significant for the outcome measure company safety awareness but not for safety performance (see table 3). In order to get a better insight in the direction of the relationship two separate analyses are performed for monolingual and multilingual companies (see table 5). The relationship between transformational leadership and company safety awareness is stronger for monolingual companies in comparison to multilingual companies.

Table 5: Regression analysis for company safety awareness separately for monolingual, (N=102) and multilingual (N=152)companies standardized Beta coefficients

	Monolingual	**Multilingual**
Safety performance	0.02	0.16**
Safety-specific transformational leadership	0.71**	0.42**
R2 adjusted	.49	.21

$^*p < .05$. $^{**}p < .01$.

(C) Third Research Question is on the meaning of our findings for potential approaches and tools in managing safety of multilingual organisations?
This research question will be based on discussions of the outcomes with a selection of the involved companies to make recommendations on how to improve safety performance in multicultural organisations. The involvement of the companies self is important since culture is a very complex phenomenon which makes it very important to look at the contextvariables as well before drawing conclusions.

4. CONCLUSIONS AND DISCUSSION

In sum, the multivariate analyses show that multilingual companies do differ in the degree of company safety awareness and safety performance from monolingual companies (monolingual companies have a higher degree of safety awareness and safety performance), but do not differ in the degree of transformational leadership style when controlled for company safety awareness and safety performance.

Transformational leadership has a positive relationship with company safety awareness and there is an indication that company safety awareness mediates the relationship between SSTL and safety performance. The relationship between SSTL and company safety awareness is stronger in monolingual companies. These results add to prior research on the influence of safety-specific transformational leadership an important leadership styles on occupational safety (Barling de Koster et al, xx) . As no other emprirical research is carried out before on this reltaionshp beween SSTL and Safety on the operational workfloor within multicultural workfloors, is has always been suggested that “SSTL is likely to become even more important as work teams with high levels of cultural difference become more common.” (OSH 2013, p xx). Our results clearly show that safety specific transformational leadership is not enough because SSTL is a much weaker predictor for maintaining safety in multincultural companies then it is for monocultural companies. One of the reasons of why a SSTL is less effective in a multlingual company could be that the diversity in culture and language among he workers in a multinational team makes it very complex to create a shared safety climate. Starren and colleagues (2012) did present a framework and a research agenda that may guide the current understanding of national culture and occupational safety and identify promising areas for research that advance the field. In their paper they looked at the safety climate as one of the predictors of knowledge and motivation regarding safety and thus safe behaviour. It is to be expected that individual perceptions of the safety climate will vary in a culturally diverse work team. Enhancing a constructive safety climate in a diverse workforce requires special attention. Therefore, multicultural and multilingual work teams should pay special attention to developing a shared vision on the safety climate. This requires an inclusive organisation, and it is the role of good leadership to develop such a shared vision. As the combinations of cultural differences, individual differences and regulations are endless, it is important to train in competences that increase leaders’, as well as team members’, in intercultural effectiveness. Recognizing intercultural differences and their predictive role on the degree of safety awareness and safety climate as well as the crucial role leadership plays in predicting occupational safety climate, performance and awareness, may provide the basis for a multi-level organizational communication training and development of safety programmes in multicultural and multilingual workplaces.

One of the problems n developing multi-level organizational communication training, is the underestimationthe “power of language” of the managers but also of the colleague-employees in the process of creating a safe and healthy work environment. Non-English speaking employees, more so than the managers and English speaking co-workers, strongly think that (lack of) language is influencing the way they are treated within the company (Paul, 2012). Safety specific transformational managers need not only to be able to demonstrate genuine, public and continuing commitment to safety. They must also ensure openness and trust in the workplace, and the absence of a blame culture. Managers must be ready to make use of safety expertise, as well as to listen to the views of their own workers and recognise their knowledge and understanding of the practicalities of OSH in the workplace . The first challenge in future research for finding more effective ways in providing safety in multicultural and multilingual companies is to investigate how these managers can create a shared vision of safety climate without speaking the language of their employees?

5. REFERENCES

Barling, J., Kelloway, E.K. & Loughlin, C. (2002). Development and Test of a Model Linking Safety- Specific Transformational Leadership and Occupational Safety. Journal of Applied Psychology, 87(2), 488-496.

Bukman, M., Tijsmans, N. & Visee, H. (2010). Best Practices Arbeidsveiligheid Buitenlandse Werknemers. Regioplan Beleidsonderzoek (1900). Verkregen op 11 maart 2014 van http://www.evo.nl/site/bewustveilig-onderzoeken-publicaties/$FILE/SZW_best-practices-arbeidsveiligheid-buitenlandse-werknemers.pdf

Christian, M.S., Bradley, J.C., Wallace, J.C. & Burke, M.J. (2009). Workplace safety: a meta-analysis of the roles of person and situation factors. Journal of Applied Psychology, 94 (5), 1103–1127.

Claes, M-T. & Gerritsen, M. (2007). Culturele waarden en communicatie in internationaal perspectief. 2e druk. Bussum: Coutinho.

Culpepper, R.A., Austin, S.F. & Watts, L. (1999). Measuring cultural dimensions at the individual level: an examination of the Dorman and Howell (1988) scale and Robertson and Hoffman (1999) scale. Academy of Strategic and Organizational Leadership Journal, 3(1), 22-34.

Hofstede, G. & Hofstede, G.J. (n.d.) VSM 2013. Geraadpleegd op 16 juni 2014 via: http://www.geerthofstede.eu/vsm2013
Hooff, M. van, Smulders, P., & Vroome, E. de (2009). Onderzoeksnotitie: Verklaren werkomstandigheden de gezondheidsverschillen tussen autochtone en allochtone werknemers? *Tijdschrift voor Arbeidsvraagstukken, 25*, 147-155.
House, R.J., Hanges, P.J., Javidan, M., Dorman, P.W. & Gupta, V. (2004). Culture, Leadership and Organizations: The GLOBE Study of 62 Societies. Thousand Oaks, CA: Sage Publications (Eds.).
Koster, R.B.M. de, Stam, D., & Balk, B.M. (2011). Accidents happen: the influence of safety-specific transformational leadership, safety consciousness, and hazard reducing systems on warehouse accidents. *Journal of operations management, 29*, 753-765.
Mohamed, S., Ali, T.H., & Tam, W.Y.V. (2009) National culture and safe work behaviour of construction workers in Pakistan. Safety Science (47), 29–35.
Nisbett, R.E. & Miyamoto, Y. (2005). The influence of culture: holistic versus analytic perception. Trends in Cognitive Sciences, 9, 467-473.
Paul, J. (2013). Improving communication with foreign speakers on the shop floor. *Safety Science, 52*, 65-72.
Reniers, G. & Gidron, Y. (2013). Do cultural dimensions predict prevalence of fatal work injuries in Europa? Safety Science, 58, 76-80.
Sage, J. (2007). *Managing Organizations in a Global Economy. An Intercultural Perspective*. Mason, Ohio: Cengage Learning.
Starren, A., Hornikx, J., & Luijters, K. (2013). Occupational safety in multicultural teams and organizations: A research agenda. *Safety Science, 52*(2), 43-49.
Starren, A., Luijters, K., Drupsteen, L., Vilkevicius, G. & Eeckelaert, L. (2013). Diverse cultures at work: ensuring safety and health through leadership and participation. European Agency for Safety and Health at Work. Luxembourg: Publications Office of the European Union. doi: 10.2802/ 14394.
Taras, V., Rowney, J. & Steel, P. (2009). Half a century of measuring culture: Review of approaches, challenges, and limitations based on the analysis of 121 instruments for quantifying culture. Journal of International Management. 15, 357-373.
Veiligheidsuitkomsten (2009). Occupational Safety and Health Impact Assessment. (OSHIA), TNO, Rijswijk.

Evaluation of the relationship between biosecurity and physical and organizational structure of a dental clinic in a public school of Curitiba-PR-Brazil

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Abstract

This research aimed to evaluate the physical structure of a dental clinic in a public school in the city of Curitiba and its impact on biosecurity. As a methodology, a descriptive research in October 2014 was carried out by means of direct observation of architecture and furniture according to which advocates the RDC 50/02, rule of Health Surveillance Agency (ANVISA) and system Investment Support Project Development in Health (SOMASUS). Was conducted photographic record for risk analysis, documenting possible sources and existing control measures. As for the physical structure of the building architecture standards were followed in relation to the design, pipes, countertops, sinks and sterilization materials. However, inadequacies were found: waiting room with wooden floors, irregular footers, an office without protection against the incidence of sunlight; taps that had no device to dispense contact with hands, brushing room with tiles and inadequate painting. The existing furniture was well distributed and in accordance with the regulatory standard. The study enabled us to identify the potential risks of contamination of this sector, especially in relation to the built environment (architecture). There is no effective security to control cross-contamination because of inadequate infrastructure present, requiring reforms in physical spaces and adaptations in the dental clinic.

Keywords: contamination; biosecurity; occupational hazards

1. INTRODUCTION

Biosafety can be understood as a set of educational and regulatory actions aimed at accident prevention in healthcare (Santos, Santos & Arnaud, 2011; Vasconcelos *et al,* 2009). It is necessary that the spaces and practices meet the indispensable requirements to minimize occupational hazards.

The architectural programming of healthcare environments is topic of growing concern as its construction, dimensioning, organization of furniture and equipment, so that professionals can attend more adequately and satisfactorily their patients (Assoni & Almeida, 2013).

The physical infrastructure is based on building techniques and architectural solutions of Engineering in relation to the functional conduits and flow of services, in order to minimize the risks or prevent them, contributing to the quality of care provided (Brasil, 2002).

In this sense, the National Health Surveillance Agency (ANVISA), follows medical advances, making available to health care services a series of equipment and architectural solutions, making it efficient to curative and preventive action of diseases in Healthcare Care Facilities environments – EAS (Rodrigues, 2008).

Thus, it is understood that the physical infrastructure relies on technical basis, assuming the combination of functional behaviors and architectural and engineering solutions, in order to contribute effectively to the quality of health assistance in the workplace (Camargo, Medrado & Pereira, 2014).

Therefore, the present study aims to evaluate the physical and organizational structure of a dental clinic of a public school in the city of Curitiba and its impacts on biosecurity.

2. MATERIALS AND METHOD

This was descriptive research, through direct structured observation of architecture and photographic record of a dental clinic of a public school in the city of Curitiba, held in October 2014.

For the observation, were evaluated criteria regarding physical structure and furniture. And this was structured from two Brazilian legislation: the Collegiate Board Resolution (RDC) of the National Health Surveillance Agency (ANVISA) number 50/2002 (Brazil, 2002), Regulatory Standard 32 and the Support System Regulation to Investment Projects Development in Health (SOMASUS) (Brazil, 2011).
As support for analysis and documentation of the risks, the photographic record was performed (SAMSUNG Digimax i6 camera, with 8.1 megapixel resolution and 4x optical zoom).
The research followed the ethical aspects, not being identified the name of the school investigated.

3. RESULTS AND DISCUSSION

Following the rules of the RDC/ANVISA No. 50/2002, the individual dental offices must have, obligatorily:
a) Sizing: minimum area of 9 m2. May dispense the Material Sterilization Central (CME) and have, in the same environment, a countertop with sink and sterilization equipment. The two investigated offices present 22 m2, countertop, sink and autoclave for sterilization of materials and instruments. The sterilization regulation control is performed by a ribbon that accompanies all the instruments to be sterilized where it reads the sterilization and its effectiveness; being the date of the last preventive maintenance of biosafety equipment the day 08/22/2014. Sterilization occurs at 132 degrees, for 4 to 6 minutes.
b) Finishing materials: materials for cladding of walls, floors and ceilings of critical areas and semi-critical environments must be resistant to washing and the use of disinfectants, monolithic surfaces and absorption rate not exceeding 4%, without slots and apparent structural shapes. The walls and ceilings of the clinic investigated (figure 1), presented smooth surfaces, light-colored, without structural shapes with resistant painting to cleaning and disinfection processes.
c) Partitions: the use of removable partitions in the critical areas is not allowed. The offices analyzed are separated by masonry wall, showing no partitions.

Figure 1 – dental office

d) Tubing: the critical and semi-critical areas, should be no apparent tubing in the walls and ceilings. The studied clinic does not have apparent tubing.
e) Baseboards and floors: the execution of the joint between the baseboard and the floor should be such that allows complete cleaning of the formed corner. Baseboards were observed not aligned with the wall and the floor which made difficult the local cleaning process. Furthermore, the floor of the waiting area is old and with wood floor in clubs (many loose, damaged and having protrusions), which prevents it from being classified as washable, impermeable and light color as is required (figure 2).

Figure 2 – waiting room footers

f) Ceilings: The ceilings in critical areas should be continuous, being forbidden the use of removable false linings, the kind that interferes with the cleaning of the environments. The construction of offices presents slab ceiling having no wood or plaster linings.
g) Blinds and curtains: for protection from the sun and reduction of dust accumulation, the use of protective films in glasses or soluble facade louvers is the most recommended. The clinic uses washable blinds, however one of the offices did not present this protection (figure 3).
h) Lighting: is performed by natural and artificial means. However, in one of the rooms there is no protection against the sun in the afternoon, causing complaints..

Figure 3 – Windows with no protection against sunlight

i) Brushing room: we found damaged baseboards; taps without commands that dispense contact with hands; tiled walls to the middle height and with inadequate painting presenting infiltration (figures 4, 5 and 6).

Figure 4 – wall with tile up to middle height

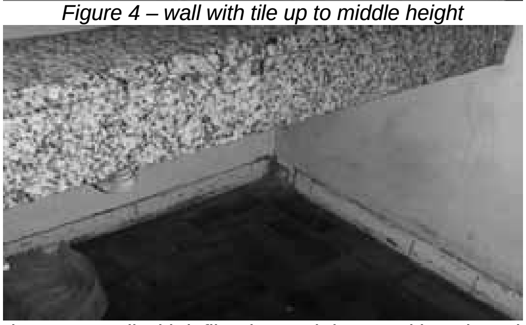

Figure 5 – wall with infiltration and damaged baseboards

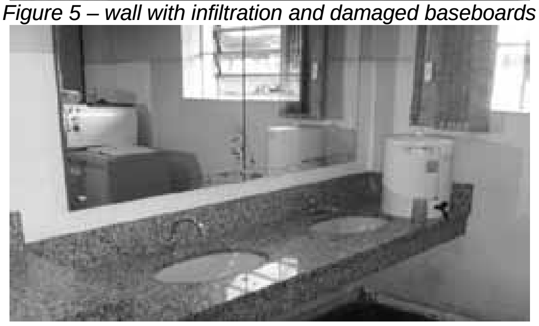

Figure 6 – taps that do not dispense contact with hands

j) Furniture: the dental offices have dental set, dental x-ray machine, cupboard, cylindrical bucket for debris with pedal, rotating chair/owl, chairs, office type table with drawers, swivel chair with arm, all well distributed in an area of 22 square meters. The cleaning of the equipment is made with soap and water and disinfection with alcohol 70 (figure 7).

Figure 7 – dental room furniture

The procedures regarding the working routine of dentists and their offices occur satisfactorily, due to the organization and planning of the flow of services. The irregularities of the physical structure found had already been plotted by the department of works of the institution according to request for improvements in the environment made by the head of the health section of the school and with reform timetable scheduled for January 2015.

Because it could not be traced separately from medical sciences and due to the specific particularities of services, Odontology seeks the prevention of cross-contamination in ambulatory care and the reduction or elimination of these risks (Lima *et al*, 2012; Vasconcelos *et al*, 2009). In the face of contamination of the a dental environment, the Biosafety presents itself as a functional and operational process. Thus, needs to be evaluated for its efficiency and quality for the prevention and cross- contamination reduction, very important for reduction of occupational hazards in dental practice (Lima *et al*, 2012).

The conducted study enabled the identification of the potential risks of contamination of this sector, especially in relation to the built environment, due to the impossibility of adequate sanitation.

The dental clinic investigated has offices whose area size exceeds the recommended minimum. However, it does not fully meet the standards established by the Brazilian legislation as the physical infrastructure.

The dental chairs are positioned facing the natural light (windows) which on the one hand optimizes the use of this type of lighting as well as the use of appropriate artificial lighting. Because natural lighting makes it possible to reduce shadows and obfuscation on the work field, thus minimizing eye fatigue (Pernambuco, 2001; Dias, Orenha & Sundefeld, 2007). On the other hand, creates a need as the placement of blinds of washable material in one of the dental offices, thereby avoiding the main complaint related to obscuring by the incidence of sunrays during the morning hours.

The wash basins of dental rooms do not present adequate infrastructure for hand hygiene to occur properly, being proposed following the regulatory standard of safety and health at work in health facilities NR-32 (Ministry of Labour and Employment, 2011), according to which all washbasins and sinks must have taps and liquid soap dispenser with commands that dispense hands contact (Aranha, 2014).

The Sanitation of the equipments and surfaces is made with alcohol 70, following the regulatory standard, because cleaning and disinfection of such surfaces is fundamental factor for the reduction and incidence of infections, where can be used Povidini Iodine spray or alcohol 70 in spray (ANVISA) (Brazil, 2002).

On the issue of ventilation this was considered appropriate, because it has good exchange of fresh air, external escapes and acclimatized, by the presence of air conditioner with regular and periodic exchange of filters) (Brazil, 2002). According to the study by Santos *et al* (2011), the air-conditioning equipment installation must be accompanied by ventilation system and/or complementary exhaustion, thereby ensuring the renewal of outside air necessary in these environments.

The sterilization of instruments in the autoclave is by self-vacuum sterilization was also considered adequate, since its use is the preconized to bring many advantages to the used time, promoting sterilization at a temperature of 132 degrees Celsius in two atmospheres of

pressure, in four minutes (Noro & Ribeiro, 2012). The autoclave is an effective mean for sterilization and not enough to have a good equipment, periodic maintenance is necessary and control with biological tests (Assoni & Almeida, 2013), as well as follow the technical specifications regarding the use to avoid shocks and burns (Silva *et al*, 2015).
The arrangement of the furniture is in accordance with the guideline of SOMASUS (Brazil, 2011) and NR 32 (Ministry of Labour and Employment, 2011), containing all the equipment and furniture needed by individual offices. Failure to meet the rules can lead to physical wear and consequently damage to the worker health. According to Mallone and Dellinger (2011), the furniture organization in the dental office should forebode the comfort and support to the patient and professionals. Dias *et al* (2007) also agree with this description, stating that the correct planning of the workspace prevents the development of occupational diseases. Besides, Barreto *et al* (2011), regarding safety and health at work, reports that the proper placement of equipment and furniture provides reduction of cross-contamination risks. With regard to this issue, Draganov *et al* (2011) state that for the safety and comfort of the patient, the sizing, flows and measures of environments must be observed.
Regarding the floor of the waiting room that is wood, it should be replaced with ceramic floors, washable, light-colored, resistant to cleaning. On the issue tiles of brushing room, they should be replaced by clear tiles to the ceiling, with minimal indentations, as well as the elimination of infiltration of the wall and proper painting. Is also necessary the exchange for new taps, which dispense the contact of the hands when the closing of water. The baseboards should be reformed so that they are aligned with the wall, thereby facilitating efficient cleaning and sanitizing. These adequacies are necessary to make the place into compliance with which forebode the RDC no.50 / 02 (Brazil, 2002) and the NR 32 (Ministry of Labour and Employment, 2011).
Also in relation to the existence of taps that require manual activation, Queluz (2005) writes in his paper that the absence of this mechanism makes the work inadequate to the biosafety standards, exposing the entire team of professionals to health risks.
Although the results of the present study have revealed a good professional conduct in relation to biosecurity protocols, there is much to be conquered, particularly with reforms in physical spaces and adaptations in the dental clinic architecture for effective control of biosafety.

4. CONCLUSIONS

The clinics analyzed, in infrastructure criteria, are in disagreement with Brazilian standards. The fact of being in accordance to the flow of aseptic procedures, follow safety standards, health at work and have the appropriate furniture, does not guarantee the effective security of cross-contamination control. This occurs because the infrastructure presents itself inadequate, necessitating reforms that facilitate the elimination of contamination risks, preserve the health of workers and, especially, of patients to be assisted.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] Santos M G C dos; Santos R C dos; and Arnaud R R. "Avaliação das Normas de Biossegurança nas Clínicas Odontológicas da Universidade Federal da Paraíba." *Revista Brasileira de Ciências da Saúde* 14.3 (2011).

[2] Vasconcelos, Márcia Maria Vendiciano Barbosa, et al. "Avaliação das normas de biossegurança nas clínicas odonto-lógicas da UFPE Evaluation of biosecutrity norms in UFPE dental clinics." *Odontol. clín.-cient* 8.2 (2009): 151-156.

[3]Assoni, Letícia Carolina Paraboli,and Rogeria Marial Alves Almeida. "Teste de Aderência de Candida Albicans em instrumentais odontológicos de aço inoxidável com corrosão e materiais termossensíveis: teste de limpeza/desinfecção química. "Caderno de Estudos Tecnológicos 1.1 (2013).

[4] BRASIL. Ministério da da Saúde. Agência Nacional de Vigilância Sanitária. Resolução-RDC n. 50, de 21 de fevereiro de 2002. Dispõe sobre o Regulamento Técnico para planejamento, programação, elaboração e avaliação de projetos físicos de estabelecimentos assistenciais de saúde. Disponível em: http:/www.anvisa.gov.br/ legis/resol/2002/50_02rdc.pdf. Acesso em 25 de outubro de 2014.

[5] RODRIGUES, N. T. Vistoria arquitetônica em estabelecimentos de saúde: um roteiro de análise. Salvador: Nuno Tavares, 2008. 144f.: il. Monografia (Especialização) – Programa de Pós-Graduação em Arquitetura. Universidade Federal da Bahia. Faculdade de Arquitetura, 2008. Disponível em Acesso em 10.03.2014

[6] BRASIL. Ministério da Saúde. Secretaria Executiva. Departamento de Economia da Saúde e Desenvolvimento. Programação Arquitetônica de Unidades Funcionais de Saúde. Brasília: Ministério da saúde, 2011.

[7] Lima FRN, Melo AUC, Ribeiro CF, Neves ACC, Brandt WC, Silva-Concílio LR. Avaliação das condutas de biossegurança em consultórios odontológicos da rede pública e privada. Clipeodonto 2012;4(1):2-6.

[8] NR 32 – SEGURANÇA E SAÚDE NO TRABALHO EM SERVIÇOS DE SAÚDE. Disponível em: www.http://portal.mte.gov.br/data/files/8A7C816A350AC8820135161931EE29A3/NR32%20%28atualizada%202011%29.pdf. Acesso em 30 de novembro de 2014.

[9] Aranha T. B. "Análise dos riscos ocupacionais dos laboratórios do Departamento de Odontologia em uma instituição pública de ensino superior na cidade de Campina Grande-PB." (2014).

[10] BRASIL.Ministério da Saúde. Agência Nacional de Vigilância Sanitária. Resolução-RDC n. 50, de 21 de fevereiro de 2002. Dispõe sobre o regulamento Técnico para planejamento, programação, elaboração e avaliação de projetos físicos de estabelecimentos assistencais de saúde. Disponível em: http:/anvisa.gov.br/legis/resol/2002/50_02rdc.pdf. Acesso em 25 de outubro de 2014.

[11] Noro, Luiz Roberto Agusto, and José Stênio Ribeiro. "A vigilância sanitária e as condições de atendimento odontológico em unidades de saúde municipais de Fortaleza, Ceará- doi:10.5020/18061230.2005.p.17." Revista Brasileira em Promoção da Saúde 18.1(2012):17-23.

[12] Barreto ACB, Vasconcellos CPP, Girão CMS, Rocha MNNP, Mota OML, Pereira SLS. Environmental contamination by aerossol during treatment using ultrasonic devices. Braz J Periodontal. 2011;21(2):79-84.

[13] Carmargo, Estela Maris Zanlorenzi, and Eva Orlani Souza Medrado."Avaliação da estrutura física dos consultórios odontológicos, em Boa Vista-RR, à luz da RDCANVISA nº 50/2002." *Caderno de Ciências Biológicas e da Saúde* 4 (2014).

[14]Pernambuco (Estado), Secretaria Estadual de Saúde, Divisão Estadual de Saúde Bucal de Pernambuco. Manual de Biossegurança no Atendimento Odontológico. [Internet]. Recife; 2001. [citado 2012 abril 20].

[15] Dias MC, Orenha ES, Sundefeld MLM M. Avaliação da distribuição e organização de móveis e equipamentos na área de tratamento dos estabelecimentos de assistência odontológica. Cienc Odontol Bras. 2007;10(2):40-46.

[16]Silva, Eliana Napoleão Conzendey, et al. "Mapeamento de Riscos como Ferramenta para Ações de Prevenção em Saúde do Trabalhador: Estudo de Caso em Consultório Odontológico." *Revista UNIANDRADE* 16.1 (2015): 45-57.

[17] Dias MC, Orenha ES, Sundefeld MLM M. Avaliação da distribuição e organização de móveis e equipamentos na área de tratamento dos estabelecimentos de assistência odontológica. Cienc Odontol Bras. 2007;10(2):40-46.

[18] Queluz DP. Perfil dos profissionais auxiliares da odontologia e suas implicações no mercado de trabalho. Rev Odonto Ciência. 2005; 20(49):270-80.

[19] Draganov PB, Sanna MC. Ateliê de projetos físicos: estratégia para aprendizagem de administração de recursos físicos em enfermagem. Rev Gaúcha Enferm., Porto Alegre (RS) 2011 set;32(3):620-4.

Worker healthcare as a tool at safety on work: anti-smoking treatment analysis in police corporation

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Abstract

Police work has many hazards, and in order to minimize many of them, particularly those relating to personal accidents that endanger the integrity of this worker, it is necessary to maintain a good cardio-respiratory condition. Many factors may affect this condition, and among them we highlight sedentary lifestyle and smoking. About the smoking, focus of this study, epidemiological studies in Brazil have shown that respiratory diseases have been occupying an important place in the main causes of hospitalization in the Unified Health System. It is estimated that 50% of smokers will develop chronic bronchitis and even those who do not yet have clinical symptoms already have functional and morphological changes in the lungs. So it is relevant to adopt worker's healthcare policies that focus on reducing the prevalence of smoking. However, despite the various techniques described in literature, there is no consensus on the best strategy to achieve this goal. So, this article aims to investigate effectiveness of non-pharmacological treatment strategy, known as Neural Stimulation (NS) in a Brazilian military corporation in southern Brazil. For this purpose has been performed an exploratory and descriptive research with 27 workers who were smokers and were willing to quit smoking. The technique of NS was first presented to all police through speeches conducted by a group of volunteers from a non-governmental organization (NGO). After raising awareness through lectures, the group that agreed stop smoking went through a course that taught the technique that should be applied on a daily basis. For monitoring the effect of treatment researchers adopted a monoximeter to evaluate treatment six steps. The equipment measures the CO concentration in parts per million (ppm) on a scale ranging from 1ppm (non-smoker) to 20ppm (heavy smoker). When arriving to the course on the first day the worker has been evaluated (average of 9,3ppm), ranking the group on the penultimate level of light smokers; during the course after smoking his "last cigarette" (average of 11.1ppm); after the first week of self-treatment (average of 3,3ppm); after the second week of self-treatment (average of 3.0ppm); after three months from the starting of self-treatment (average of 6,6ppm) and after six months of starting self-treatment (average of 6,5ppm - first level of light smokers). At the end of the study, none of the military stopped smoking, although there was a reduction of two levels in the monitoring range. This result showed a tendency to decrease or cessation of smoking during the two weeks in which volunteers of NGO and researchers were in the corporation. Direct stimulating and supporting during the beginning of self-treatment appears to have presented a positive result. However, with the gaps between meetings, there has been hard to maintain the motivation to quit smoking, as demonstrated by reports where only one of the military have performed the technique of NS every day as recommended. Therefore, so for that strategies like this one can be adopted in other companies, it is suggested to keep a support group until the end of the recommended time for smoking cessation.

Keywords: non-pharmacological treatment; monoximeter; neural stimulation; NGO.

1. INTRODUCTION

Smoking is associated with mortality of about six million people a year and continues to represent the leading cause of preventable deaths in the world, being considered a worldwide epidemic (Organización Mundial de la Salud, 2011).

The World Health Organization (OMS) recognizes that a basic requirement for the reduction of tobacco use is that each person is made aware of the damage of this use for health: its addictive nature and the potential to cause numerous and varied diseases, including premature deaths, for both direct consumers and for those exposed to its smoke (World Health Organization, 2011).

Additionally, the population, in general, has the fundamental right of assistance to quit smoking, being a humanitarian commitment and a legal obligation of member countries. OMS also stimulates that countries develop and conduct data collection on the use and tobacco control policy implementation, which can be used in general health surveys or as part of researches in the area. Brazil was one of the countries that have signed the Framework Convention on Tobacco Control (CQCT) (Organización Mundial de la Salud, 2011).
This convention provides, among other actions, controlling the use of tobacco by the population and, therefore, has as commitment to establish effective measures that promote cessation of use of this substance and the appropriate treatment for its dependence, leaving to the country, prepare and implement effective programs with these objectives (Organización Mundial de la Salud, 2011).
Brazil has developed strong and comprehensive actions in relation to tobacco control, giving the country international recognition of leadership in this area, even being the second largest exporter and producer of tobacco in the world (American Cancer Society, 2003).
Therefore, evaluate possible methods to combat smoking in the country seems to be a fundamental task and the research group Quality of Life, Health and Labour, of the Federal Technological University of Paraná (QVSAT-UTFPR), chose to monitor and evaluate the initiative not - pharmacological to combat smoking proposed by a non-governmental organization (NOG), that got, from one of the public security systems of a Brazilian state, the permission to operate with their servers.

2. MATERIALS AND METHOD

The cited NOG offers a comprehensive program of possible improvement of the quality of life of the servers involved in the project. This program was initially constituted of a series of courses, repeated every week, for six months, aimed at creating the opportunity for all employees to have access to it. A part of the course focused on the "treatment for tobacco dependence" as recommended by the non-pharmacological methodology of neural stimulation (NS), and the servers who smoked were invited to participate in treatment. The NS is a treatment technique made with hands, resting the fingertips on specific points of the human body as the top of the head and regions of the spine, for a few minutes (Mãos sem Fronteiras, s/d). To participate in this survey, the participants were presented to their goals, advantages, disadvantages, the form of participation and informed that they could abandon the research at any time without any personal injury. In case of acceptance, the participants signed the Clarified and Free Consent Term (TCLE) before the start of data collection.
In this regard, a group of investigated was monitored and tested. The application of these tests included: the filling of an instrument on the participant's profile; an individual field diary and measurement of the amount of carbon monoxide (CO) expired by the investigated, device through BabyCO Meter carbon monoxide measuring equipment, CareFusion brand, Cat No. BC01, STK-36 -. battery hand gear, often used, among other applications, in varying programs and anti-smoking treatment clinics aiming to verify and quantify the progress of clients. The equipment measures the CO concentration in parts per million (ppm) on a scale ranging from 1 ppm (non-smoker) to 20ppm (heavy smoker) (CareFusion, 2010).
As to monitoring and evaluation of treatment, the study participants were approached by the research team six times: initial evaluation; during treatment proposed by the NGO (two weeks), which have been evaluated three times; after this period of treatment and considering the Smoker's Minimum Approach Protocol (Prefeitura Municipal de Curitiba, 2007), the participants were evaluated at the end of the third month, counting from the day of start of the treatment performed. This period is considered as relevant, because it represents the most likely months to relapse and also to be estimated as a period of improvement in lung function (Boletim Brasileiro de Avaliação de Tecnologias em Saúde, 2005). The accompaniment and evaluation were terminated at the end of the sixth month, after the beginning treatment, verifying the final situation in which it was at the time. This minimum time of five to six months for verification of effectiveness of the treatment was determined by comparative studies of anti-smoking treatments of the Brazilian Bulletin of Technology Assessment in Health (2005) and by the wording of the Cochrane Library, which, according Presman et al. (2005), adopts as a success criterion the abstinence for the minimum period of six months.
Among the possible results were considered four options to be investigated: the fully quit smoking; reduce consumption; not quit smoking; or increase the consumption; and the proposed approach helped in the understanding of the main difficulties for obtaining the first result.

Data collection using the carbon monoxide measuring equipment (a three seconds puff on the device) was as follows:
1st At the beginning of the second day of QV course , taught by the NGO, after the signing of the TCLE;
2nd On the same day, at the end of the course, when the smoker, supposedly, smoked his last cigarette after NS treatment conducted by volunteers of the NGO in smokers;
3rd After the first week of NS treatment performed by study participants themselves;
4th After the second week of NS treatment conducted by study participants themselves;
5th After at least three months of starting treatment;
6th After at least six months of starting treatment.
In each one of these six moments of gathering the research team used an individual field diary of the participants where were noted all their grievances, perceived changes, explanations provided by the participants about what happened during the week or the months that followed, seeking elucidate, from the qualitative point of view, the numerical results obtained through the use of carbon monoxide measuring equipment.
Additionally, there was a specific space in this diary to write down day by day, during the first two weeks of treatment, if the study participant performed or not self NS treatment proposed and taught by the NGO during the course previously taught.

3. RESULTS AND DISCUSSION

Between the months of July and October 2012, were administered 10 QV courses, with the participation of 500 servers. Of this total of servers, 27 declared themselves willing to quit smoking and decided to perform the non-pharmacological treatment proposed by the NGO. There were 25 men and two women (sample).
As the research universe is composed of servers of a police corporation was considered absolutely normal that the sample had presented 93.6% of men (25) and 7.4% of women (two). This situation only reflected the reality found on site, an environment that actually work more men than women.
The average age presented was 39 years, having 31 years the youngest and 50 years the oldest, and started smoking, on average, at age 16 (median 16 and trend 17).
The group showed variations in the level of education: 13 subjects were graduated, 11 had completed high school, two had only primary education and one of them was postgraduate.
The main reason that led them to smoke was follow friends (16), followed by curiosity (eight) and for fun (seven).
On average, they smoke 16 cigarettes a day, with the first being consumed before the first time after waking up (56 minutes on average). Only five of them (18.5%) had never tried to quit smoking.
The main symptoms they feel when they stop are restlessness (23) and nervousness (18) and return to smoking mainly due to stress (13) or by seeing someone else smoking (11).
Eight report having problems due to smoking as shortness of breath, cough, weight loss, pain or inflammation in the throat and laryngitis and 24 of them (89% of the sample), believe that smoking is definitely harmful to health.
On average, the first day the worker has been evaluated (average of 9,3ppm), ranking the group on the penultimate level of light smokers; during the course after smoking his "last cigarette" (average of 11.1ppm); after the first week of self-treatment (average of 3,3ppm); after the second week of self-treatment (average of 3.0ppm); after three months from the starting of self-treatment (average of 6,6ppm) and after six months of starting self-treatment (average of 6,5ppm) - first level of light smokers.
This result showed a tendency to decrease or cessation of the smoking habit during the two weeks in which participants were sought by the researchers who collected the data and, at the same time, were accompanied by volunteers from the NGO, who accompanied the last day of the first week and the last day of the second week of proposed treatment, talking to the participants and performing on them the NS technique.
Until the holding of the fifth data collection - after three months, were 17 dropouts (16 men and one woman), being that 12 of them have already given up on the first day because have not returned any time. Figure 1 presents the numerical result obtained by blowing three seconds on the carbon monoxide measuring equipment in each one of the seven participants who presented himself from the first to the penultimate stage of collection of the study, the fifth collection.

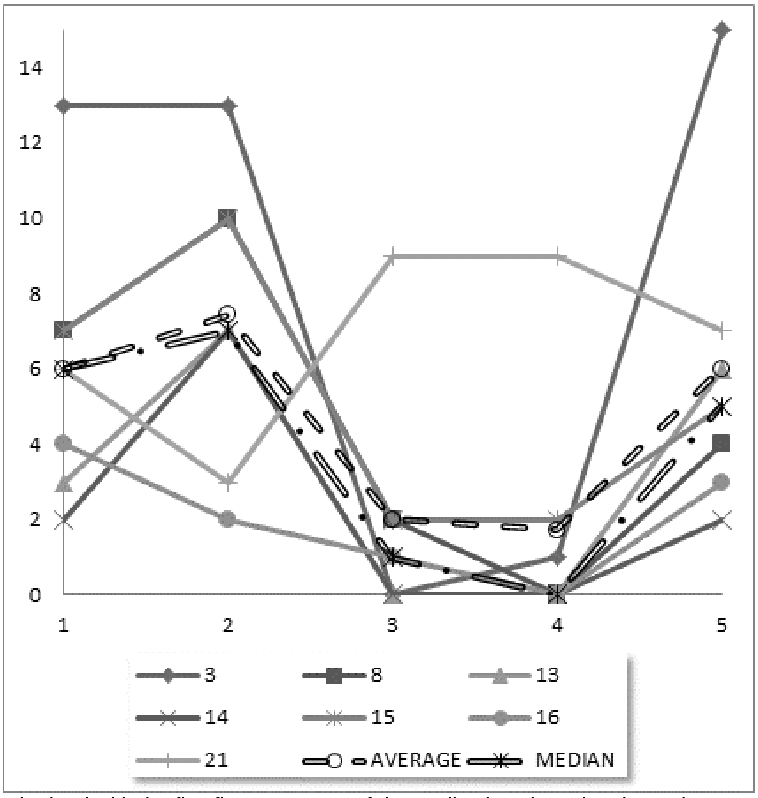

Figure1 - Results obtained with the five first measures of data collections by using the carbon monoxide measuring equipment.
Source: Stadnik et al. (2013, p. 1138

Study participants until the sixth data gathering - after six months of treatment, four individuals. That is, of the 27 smokers who started the non-pharmacological treatment proposed by the NGO, only four participated in all data gathering performed, the other 23 did not attend to one or more of the different stages of the research process. Figure 2 shows the numerical result obtained by blowing three seconds on the carbon monoxide measuring equipment in each one of the four participants who presented himself for this step of the study: the sixth collection.

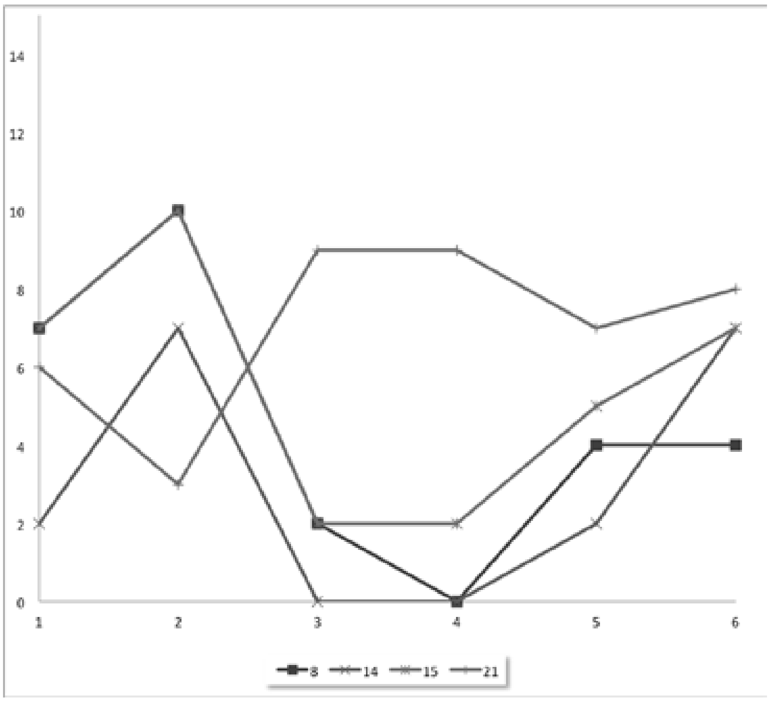

Figure 2 - Results obtained with the measures of the six data gathering by using the carbon monoxide measuring equipment.

Each line in grayscale of the graphics exposed (Fig 1 and Fig 2) represents one of the participants who presented themselves to the stages of data collection. The Figure 1 graphic shows the seven participants who presented themselves for the fifth data collection and the Figure 2 graphic shows the four participants who presented themselves for the sixth and final data collection. These participants are identified by numbers that correspond to their entry into the study. It also appears in these two figures (graphics) a horizontal line, that represents the data collections, which were five in Figure 1 and six in Fig 2, and a vertical line, with numbers ranging from 0 to 14, indicating the amount found by making use of the carbon monoxide measuring equipment in evaluation of CO expired by study participants at the time of collection.

In Figure 1, additionally, it can be observed two dotted black lines, one to identify the mean and the other the median, resulting from the comparison of the numerical data of the first five data gathering using the carbon monoxide measuring equipment.

We choose not to perform the same analysis with the graph that showed the four participants, when the inclusion of the sixth collection (Fig 2), as we consider unnecessary, since it was possible to show only with the first figure what we got with this analysis of mean and median: a trend of reduced values in steps 3 and 4. The mean was slightly higher than the median because of one of the participants (number 15 in Fig 1 and 2) that presented higher results exactly during the two weeks (steps 3 and 4) in which the participants received attention of the two treatment control groups: the investigation team, which conducted the measurements via carbon monoxide measuring equipment and notes in individual field diary and; the group of volunteers of the NGO who performed the treatment by the NS technique.

We infer that this decrease precisely in the weeks that the participants were strongly accompanied by both groups may have aided the participants in a reduction of cigarette consumption, by social support. On the other hand, one of the participants, inversely to the behavior of others, increased his consumption precisely during these two weeks. We observed that this subject was one of the women. According to Perkins[11], who performed a specific study on the incidence of smoking on women, the main symptoms of abstinence syndrome are more frequent in this social group. However, this study presented here revealed no major data. This done, we believe that we can not confirm this information, just present it as a possibility.

In a note in the field diary, we see that this participant, particularly, was going through a change in her work sector and considered her new role very stressful. Moreover, referring to other notes of the field diary of other participants, we found that this was a very common complaint in the studied group. Workers really perform a normally very stressful function, public safety.

In this regard, Shiffman et al (1993) described that most of the relapses related to a period of abstinence from smoking are related, especially, to situations of psychological stress and the presence of smokers in the the environment.

In the case of the study presented here, were observed reports of smokers who wanted to leave the addiction, but who has, for example, a spouse who is a smoker or friends who are smokers as well. According to the participants, this situation hinders the success of treatment.

In Figure 2 it can be observed the four individuals (Ind.) who participated the six phases of data collection. Will be detailed some of the events that have passed with each of them in Table 1, from the notes of the field diary.

Table 1 - Details of the four participants who presented themselves for all stages of data collection.

Ind.	Age	Genre	NS practiced?	Final summary notes in the field diary:	Final situation:
8	35	Male	No.	Even quit smoking until early January (treatment began in October), but in the holidays changed the routine and returned to sporadically smoking.	Decreased consumption.
14	30	Male	No.	Stayed 40 days without smoking at the beginning and then returned with the same intensity.	Does not quit smoking.
15	31	Male	Partially.	Managed to stay a few days without smoking but spouse smokes and does not intend to leave the addiction. Considered that this situation hindered his success in the program.	Does not quit smoking.
21	48	Fem.	Yes.	NS technique practiced, but did not find co-workers to follow her development in the technique learned. Felt fine with the treatments and liked to participate. Considers her professional work very stressful.	Does not quit smoking.

The non-pharmacological tobacco control technique used by the NGO here cited is the NS and it was considered that this type of treatment offered approaches other activities recognized by the Brazilian public health system (National Health System - SUS) as Integrative and Complementary Health Practice and comprises, according to the Decree # 971 the universe of approaches denominated by the WHO as Traditional and Complementary/Alternative Medicine - TCM/AM, such as acupuncture, homeopathy, herbal medicine, hydrotherapy and cryotherapy. These therapies involve approaches that seek to stimulate the natural mechanisms of prevention and health recovery, with emphasis on welcoming listening, developing the therapeutic relationship and the integration of the human being with the environment and society. Other points shared by various approaches covered in this field are the broader view of the health / disease process and the global promotion of human care, especially self-care (Brasil, 2006).

According to studies found in the database of the Cochrane Library (White, Rampes & Campbell, 2006; Bise, Burnand, Mueller, et al., 2005), methods such as acupuncture, hypnotherapy, laser therapy, electro-stimulation and evaluation of biomedical risk (expired CO measurement and spirometry) are methods for which there is still no scientific evidence showing that these methods increase the smoking cessation rate, preventing their recommendation based on current knowledge.

Epidemiological studies in Brazil have shown that respiratory diseases have been occupying an important place in the main causes of hospitalization in the Unified Health System (SUS) and that the prevalence of chronic bronchitis, wheezing and breathlessness are more common in smokers, with a prevalence rate in direct proportion to the number of cigarettes smoked. It is estimated that 50% of smokers will develop chronic bronchitis and even those who do not yet have clinical symptoms already have functional and morphological changes in the lungs. From the point of view of workers' health, studies have also pointed out that smoking cessation improves respiratory symptoms as much as the decline in lung function and bronchial hyper responsiveness. So it is relevant to adopt worker's healthcare policies that focus on reducing the prevalence of smoking. (Reichert *et al*, 2008). However, despite the various techniques described in literature, there is no consensus on the best strategy to achieve this goal.

4. CONCLUSIONS

We chose to investigate a non-pharmacological technique that began to be used in Brazil in the past ten years, Neural Stimulation. We conclude that we have not studied sufficiently to perform validation of such treatment. None of the participants truly stopped smoking after to the first three months of treatment. Of the seven participants who were present at all stages of data collection, only one showed a considerable decrease and the participant claimed to have stopped smoking (participant no. 8 in the Fig. 1). However, only one of the participants performed the self-treatment regularly as indicated by the technique. Additionally, the participant (a woman) who was more disciplined in relation to treatment was one that had the highest measurements by monoximeter during the two weeks of following-up (measurements 3 and 4).

On the other hand, experience reports coming from the NGO group of volunteers present successful cases regarding smoking cessation, hence our interest in researching the technique. Although it seems promising still requires further studies for their understanding and validation.

We consider an important aspect to be pointed out the issue of psychosocial support; we observed that during the time in which participants were followed directly by the volunteers of the NGO the results were better.

Also, it is important to clarify that the use of monoximeter may have caused some positive or negative influence. There were no clinical studies proving its effectiveness in the treatment of smokers. (Boletim Brasileiro de Avaliação de Tecnologias em Saúde, 2005)

In this research the monoximeter was only used as a tool of measurement to monitor and evaluate the treatment carried out by the volunteers of the NGO, however, we believe that this tool can also influence the participants, some participants were motivated to check your measurements, others were intimidated or annoyed by the results or with the number of times they were searched for this action.

Based on the importance of worker healthcare to guarantee their safety in the workplace, it is suggested to keep a support group until the end of the recommended time for smoking cessation and, besides the utilization of monoximeter, cardiorespiratory fitness tests would be applied so that participants can clearly quantify the benefits of to kick the habit.

5. ACKNOWLEDGMENTS

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6. REFERENCES

American Cancer Society (2003). Luther Terry Awards Leadership on Tobacco Control. Helsinki.

Bise R., Burnand B., Mueller Y., Cornuz J. (2005) Biomedical risk assessment as an aid for smoking cessation. Cochrane Database Syst Rev (4):CD004705.

Brasil (2006). Anexo Portaria nº 971, de 03 de maio de 2006. Aprova a Política Nacional de Práticas Integrativas e Complementares (PNPIC) no Sistema Único de Saúde.

Boletim Brasileiro de Avaliação de Tecnologias em Saúde (2005). Estratégias clínicas para cessação do tabagismo. Brasília-DF, Agência Nacional de Vigilância Sanitária - Anvisa.

CareFusion (2010). BabyCO Meter Operating Manual. U.K: CareFusion, 2010.

Organización Mundial de la Salud (2005). Convenio Marco de la OMS para el Control del Tabaco. Geneva, The WHO Document Production Services.

Organización Mundial de la Salud (2011). Informe OMS sobre la epidemia mundial de tabaquismo, 2011: advertencia sobre los peligros del tabaco. Resumen. Ginebra, Servicio de Producción de Documentos de la OMS.

Perkins, K. A. (2001). Smoking cessation in women. Special considerations. CNS Drugs 15(5):391-411.

Prefeitura Municipal de Curitiba (2007). Como ajudar seu paciente a deixar de fumar: Protocolo de orientações para o profissional de saúde na abordagem mínima do fumante. Curitiba, Secretaria Municipal de Comunicação Social.

Presman S., Carneiro E. & Gigliotti A. (2005). Tratamentos não-farmacológicos para o tabagismo. Rev Psiq Clín 32(5):267-275.

Mãos sem Fronteiras (s/d). Apostila do curso de estimulação neural MSF. Curitiba.

Reichert J., Araújo A. J., Cantarino M. C., et al. (2008). Diretrizes para cessação do tabagismo. J Bras Pneumol 34(10):845-880.

Shifman S, Read L, Matese J et al. (1993). Prevenção de recaída em ex-fumantes: uma abordagem de automanejo. In: Marllart GA, Gordon JR. Prevenção de Recaída: estratégia de manutenção no tratamento de comportamentos Adictivos. Artmed, Porto Alegre.

Stadnik, A. M. W., Ulbricht, L., Sarturi, M. F., Meirelles, D. & Maldaner, M. (2013). Monitoring and Evaluation of Non-pharmacological Anti-smoking Treatment by Monoximetry: The First Three Months. L.M. Roa Romero (ed.), XIII Mediterranean Conference on Medical and Biological Engineering and Computing 2013, 1136 IFMBE Proceedings 41, DOI: 10.1007/978-3-319-00846-2_281, © Springer International Publishing Switzerland 2014

White A. R., Rampes H. & Campbell, J. L. (2006) Acupuncture and related interventions for smoking cessation. Cochrane Database Syst Rev (1):CD000009. 104.

World Health Organization (2011). WHO report on the global tobacco epidemic, 2011: warning about the dangers of tobacco. Geneva, WHO Press.

Changes in the patterns of the hazardous protective suits: a necessary measure to prevent accidents

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Abstract

In recent years there has been an important increase in the number of interventions in Madrid, involving medical emergency workers, associated with chemical and biological risk. In those interventions, the safety of the workers depends, among other things, on the integrity of the protective suit. Several accidents within workers attending ebola- infected patients stood out the significance of a correct selection of the protection equipment. During learning courses, practices and real interventions, we have observed some tears in the perineal zone seams, which led us to study the factors influencing on those dangerous fails. The main findings of this study were obtained by performing a cross- sectional study: the sample underwent a stress test regarding their physical features (flex cracking resistance, tensile strength and puncture resistance). The convenience sample consisted of 45 members of a civil protection and emergency medical service agency, who had basic training in wearing CBRN suits for hazardous risks. All of them completed a four tests circuit: bending over to pick up an object from the floor, getting on a 60cm. high object, walking 100m. and crossing twice a narrow pass. One third of the coveralls got broken at the seams. Within them, 75% had tears situated at the perineal zone, while one third of the tears happened in overalls whose size was bigger than that recommended by the manufacturer. The average waist measurement of the people, who tore the coverall at the perineal seams, is 113.6 cm, would use XL-size according to manufacturer specification and was using XXL while performing the test. The study has revealed a lack of toughness of the fabric at the seams, mainly at the perineal zone. The tears were produced even when using bigger than recommended sized coveralls. Bearing in mind the deficiencies found we studied how to improve workers safety and concluded that he pattern design should start adapting to the new anthropometric measures of the current population and with variation between men and women. As sizes are getting increased, waist and hips circumferences of the protective suit should be increased at a higher rate than the other measures or include elastic elements. The perineal zone of the protective suites must be reinforced, especially at the seams.The measures to choose the correct size, in the manufacturer specifications, must include the waist circumference. Damages in lower limbs appear with a higher prevalence in women as they have a lower average height, thus causing bags which are at greater risk of being punctured. To get a better adjustment to the various anthropometric measures it would be advisable to implement tightening elements to better fit the suit to the worker phenotype, particularly in the back and under the buttocks. All these measures are aimed at obtaining a further adaptation of the suits to the actual worker constitution, thus minimizing the risk of accidents.

Keywords: CBRN coverall, Fabric toughness, Tears in seams, Puncture resistance, Chemical risk, Emergency response teams.

1. INTRODUCTION

The cases in which protective equipment against CBRN (Chemical, biological, radiological and nuclear) risks are used in SAMUR Civil Protection (Emergency Medical Service and Civil Protection of the City of Madrid), are steadily increasing. In those cases the integrity of the suit is the primary measure of worker protection, meaning that suit integrity is a key element in the prevention of occupational risks for those workers. Additionally, several Ebola cases were treated in Spain in 2014, where a nurse suffered an accident, having contact with the patient and contracting the disease. This fact has produced a great concern among health workers both in Spain and in other infected countries.

Our study aims to assess the relation between the suits anthropometric measures and the breaks produced in those suits when the subjects pass a stress test regarding the suits physical characteristics.

The costumes used in this analysis are used by SAMUR Civil Protection at CBRN risks, usually in the following cases:

- First aid in cases with suspected serious infectious diseases (ex. Ebola); always asking for teams with a higher level of protection and avoiding, while working with this suit, contact with the fluids of the patient, due of its limited resistance to liquids.
- Pepper-spray attacks, protecting those involved in the decontamination of the patient.
- In massive chemical contamination (leakage, explosion, ...) or biohazard (anthrax) (see Figure 1), it is used in areas where the risk of contact with agents is low or very low during patients decontamination or, after complete decontamination, for people checking proper decontamination and/or delivering clothes (see Figure 2). They can also be used when decontamination area is far from the incident area, to indicate and help people access to decontamination (see Figure 3).

Figure 1 –Intervention in embassy for possible anthrax attack.

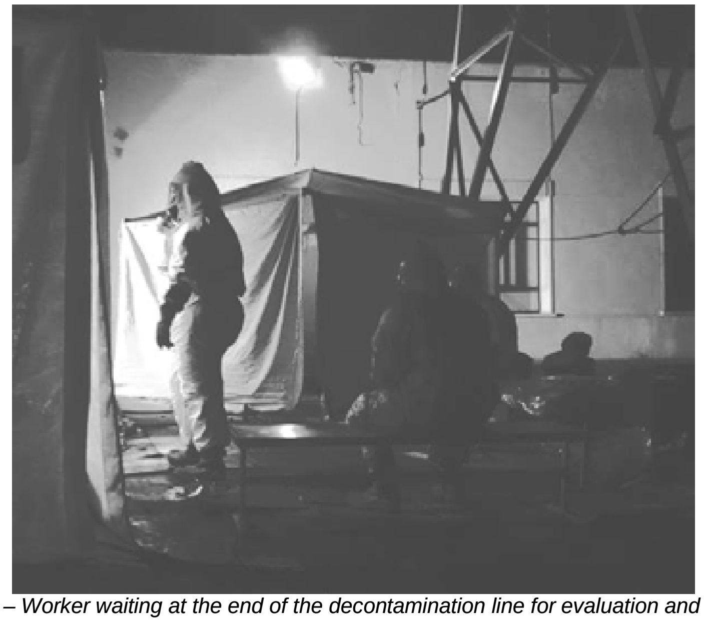

Figure 2 – Worker waiting at the end of the decontamination line for evaluation and clothing.

Figure 3 – Indication of the decontamination for personnel that came into contact with a possible Ebola-infected patient.

• In accidents or attacks with acid or base (eg gender-based violence in which an individual throw acid to the partner's face or body, or accidents in which a person comes into contact with the acid). It is used for administering Diphoterine® (neutralizing) to the patient (see Figure 4).

Figure 4 – Helping a woman attacked with acid.

• Death certification of several days corpses or entering in people with Diogenes syndrome houses.

Figure 5 – Entering in the home of a patient with Diogenes syndrome and large amount of accumulated garbage.

Apart from hazardous risks that make essential the use of protective suits (Giménez-Mediavilla 2012), the working environment for emergency services teams might have hook and sharp elements (collapsing buildings, needles, street furniture, vegetation,...) threatening the suit integrity.
Additionally during learning courses, practices and real interventions, we have observed some tears in the perineal zone seams, which led us to study the factors influencing on those dangerous fails.
According to Schwope, 1989, we tested protective suits with hood, made with a microporous membrane and classified as Category III protective equipment with limited protection against particles (type 5) and limited liquid splashes or sprays (type 6) (see Figure 6).

Figure 6 – Analyzed suits.

1.1. Applicable regulations

Based on the general principles of prevention (art. 6 Directive 89/391/EEC - OSH "Framework Directive" of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work), the first and most important objective is to avoid risks, but if these risks cannot be avoided, other measures such as the use of personal protective equipment (PPS) shall be adopted.
In general, the use of PPE as a preventive measure is the last election as collective protection measures should take precedence over PPE use, but this is not the case in situations of emergency, where the lack of time makes the use of PPE prioritized, or in those situations in where the installation of collective protection is impossible. This situation is often produced within emergency medical services work e.g. going to help one or more patients presenting biological or chemical hazard.
PPE must be provided by the employer (art. 9 89/391 EC), employers are required to provide workers and their clothes with appropriate protective equipment (Art. 16.3 of ILO Convention 155, 7/22/81).
According to the European directives, PPE should provide effective protection, should not cause unnecessary discomfort, should take into account the anatomical and physiological conditions of the worker and must fit the wearer (article 1.3.1 European Directive 89/686 approximation of the laws of the Member States relating to Personal Protection Equipment). Besides, article 4 of the European Directive 89/656 / EEC (use of Personal Protective Equipment by workers at work) indicates that PPE must fit the wearer correctly after any necessary adjustment. Moreover these

rules it indicates that protective clothing against chemical hazard should be also considered as PPE.

According to the above listed regulations, we conclude that the suits analyzed in this study, as being used as Personal Protective Equipment should mandatorily be adapted to the anthropometric conditions of workers using them.

In emergency situations as well as in other jobs where they collective action cannot be established, PPS act as the main barrier to avoid contact with contaminants. That is why ensuring the integrity of the suits is very important to prevent accidents.

2. STUDY OVERVIEW

The main findings of this study were obtained by performing a cross-sectional study: the sample underwent a stress test regarding their physical features (flex cracking resistance, tensile strength and puncture resistance) (Schwope, 1989). The convenience sample consisted of 45 members of SAMUR-PC-Madrid (civil protection and emergency medical service agency), who had basic training in wearing CBRN suits for hazardous risks, being 62.2% of them members of HazMat teams. They wore a XXL-coverall (the biggest size). The suit was sealed in wrists with the gloves and in calves with the boots. All of them completed a four tests circuit: bending over to pick up an object from the floor, getting on a 60cm. high object, walking 100m. and crossing twice a narrow pass (about 10cm. bigger than the intervenient) with sharp elements (in one side of the pass there were 15 mm. sharp elements linearly aligned between 0.30 and 1.50 meters from the ground and, in the other side, 6 mm. sharp elements randomly distributed and connected by a wire) (see Figure 7).

Figure 7 – crossing a narrow pass.

The average morphology of the participants was: a male, 31 years old, measuring: height 171.73cm. (SD=9.42, 95%CI=169-174.5), chest circumference 98.8cm. (P25=88, P50=98, P75=108.5) and waist circumference 90.16 cm. (P25=76, P50=84, P75=103) and L-size according to manufacturer specifications (DuPont 2010, Indutex 2011).

2.1. Study results

33.33% (16) of the coveralls got broken at the seams (see Table 1). Within them, 75% (12) of the tears were situated at the perinneal zone, while 66.66% (16) of the tears happened in overalls whose size was bigger than that recommended by the manufacturer.

Table 1 – Tears at seams.

	Axilla	Groing	Perineum	Total
Men	2	1	9	26
Women	1	0	3	19

The average waist measurement of the people, who tore the coverall at the perineal seams, is 113.6 (SD=14.8, 95%CI=104.87-122.37) and the average person would use XL-size according to manufacturer specification and was using XXL while performing the test.

The study has revealed a lack of toughness of the fabric at the seams (which are the most critical areas), mainly at the perineal zone (with higher prevalence in men). The tears were produced even when using bigger than recommended sized coveralls (the recommendations are based on height and chest circumference).

According to recent studies, the average waist circumference of Spanish people is increasing. This fact augments the multidirectional tension in the perineal zone, thus subjecting the fabric and seams to an increased effort compared to which they were subjected several years ago, when these suits were designed.

55.56% (25) of the suits presents orifices (see table 2), within them 52% (13, 7 men and 6 women) were situated in the back, 48% (12, 9 women and 3 men) in the lower limbs, 32% (8, 5 men and 3 women) in the abdomen and 36% (9, 5 men and 4 women) in the thorax. The average height for the 12 people whose suit presented orifices in the lower limbs was 167.25cm. (P25=160, P50=165, P75=169.5) and their average manufacturer recommended size was M.

Table 2 – Snags.

	Upper limbs	Lower limbs	Thorax	Back	Abdomen	Total
Men	0	3	5	7	5	26
Women	1	9	4	6	3	19

The study shows two noticeable differences between the damaged zones: one depending on the difference between recommended by the manufacturer and used size and the other depending on the participant gender (lower limbs in women and abdomen in men).

An additional problem is that, due to their location, some of the tears were not detected when they occurred.

3. PROPOSALS FOR IMPROVEMENTS TO THE PROTECTIVE SUITS DESIGN

Bearing in mind the deficiencies described in section 2 we propose the inclusion of elastic elements in the seam of the perineal area. The union between the elastic elements and the suit can be made in two ways, by sewing the elastic strips to the suit or attaching elastic strips by using adhesive strips (avoiding any loss of strength caused by the new seams). The elastic tape used gives the protective suit amplitude of 2 cm (5-7 cm) in the middle of the piece of the perineal area. Being conscious that this test has been done with a very limited sample, we believe that the change is significant enough to recommend to manufacturers the addition of elastic elements at the maximum stress seams thus improving safety for occasional workers in CBRN hazard environments, and preserving in those areas the impermeability and tightness required to the whole suit.

Seeking for solutions to prevent breakage by snags, we suggest adapting the costume to the worker as recommended by the standards of Occupational Hazards. All the following proposed elements increase the tight fit of the suit to the worker morphology.

The first option is to expand the elastic band at the waist (see Figure 8), currently located in the back area of the waist, to the whole waist circumference (see Figures 8 and 9). This option improves the fit of the suit to the worker in the waist area, but due to over sizing there are some remaining areas susceptible to snag with sharp objects at the top and bottom areas of the elastic area. Another potential problem of this option lies in its manufacturing cost.

Figure 8 – Waist elastic enlarged area.

Figure 9 – Suit with elastic all around.

Other tested option consists in incorporating a tape of the same material as the rest of the suit to be used as a belt, (see Figure 10). Initially the suggestion of the same material is due to its low cost and the easiness to be removed when undressing. We consider that the cost of this solution would be the middle of the proposed, since it would be enough to include a strip of fabric, similar to the suit, in the bagging process.

Figure 10 – Suit with belt.

Finally adhesive tapes can be placed in waist and hip zone. Those tapes could be placed by the manufacturer together with the suit or could be just placed over it while dressing, adjusting the suit to the worker. They never should be placed so tight that the suit might be broken because of them. By placing adhesive tapes at strategic points, a better adjustment to the worker morphology is achieved (see Figure 11). If the tapes are not supplied an indication could be incorporated to the user manual, thus being the cheapest solution for manufacturers and is also the solution in which a better fit is achieved. Moreover, if the adhesive strips are placed in front backwards it will be difficult to have hooks problems.

Figure 21 – Tapes placed in waist and hip zone.

We consider that with this contribution to the of protective clothing manufacturing, workers will be safer as it will be less likely to have accidental exposure to chemical and biological risks.

4. CONCLUSIONS

The pattern design should start adapting to the new anthropometric measures of the current population and with variation between men and women. As sizes are getting increased, waist and hips circumferences of the protective suit should be increased at a higher rate than the other measures or elastic elements should be included.

The perineal zone of the protective suites must be reinforced, especially at the seams.

The measures to choose the correct size, witthin the manufacturer specifications, must include the waist circumference. Damages in lower limbs appear with a higher prevalence in women as they have a lower average height, thus causing bags which are at greater risk of being punctured. To get a better adjustment to the various anthropometric measures it would be advisable to implement tightening elements to better fit the suit to the worker phenotype, particularly in the back and under the buttocks.

All these measures are aimed at obtaining a further adaptation of the suits to the actual worker constitution, thus minimizing the risk of accidents.

Several inexpensive improvements have been tested and a remarkable advance in suit performance has been found. The most advisable improvement consists in placing adhesive straps in waist and hip zones adapting the suit to the worker and avoiding loose and decreasing the risk of snagging. There have also been placed elastic bands that have prevented the break in the perineal area in 100% of the tested individuals. We recommend the implementation of these measures among PPE users.

5. REFERENCES

Authors. (2015). ------ In *Actas del 27 Congreso Nacional en Urgencias y Emergencias SEMES* (pp. ---).

DuPont. (2010). Classic and classic colour model CHF5: Instructions for use. *DuPont Personal Protective Equipment*, Retrieved March 5, 2015, from http://www.dpp-europe.com/IMG/pdf/IFU_Tyvek_Classic-5.pdf

Giménez-Mediavilla, J.J., M.C. Castillo-Ruiz de Apodaca, D. González-Rodríguez (2012). *Actuación sanitaria en incidentes NRBQ*, Madrid: Acindes.

Indutex (2011). Propguard: Instructions for use.

Schwope, A.D., T.R. Carroll, J.O. Stull, M.D. Royer (1989). The selection and measurement of physical properties for characterization of chemical protective clothing materials. In Perkins, Stull (Ed.) *Chemical protective clothing performance in chemical emergency response*, ASTM-STP 1037, Philadelphia: American Society for Testing and Materials.

Developments in the safety science sector and in the field of safety management between the 1970s and 1979, the year of the near disaster on three mile island, a literature review

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Content

1. SUMMARY

Objective: What influence has research conducted by general management schools and safety research had upon the causes of accidents and disasters in relation to the managing of safety between 1970 and 1979?
Method: The study was confined to original articles and documents, written in English or Dutch from the period under consideration. For the Netherlands, the professional journal *De Veiligheid* (Safety) was consulted.
Results and conclusions: Dominant management approaches started with 1) classical management starting from the 19th century incorporating as a main component scientific management from the early 20th century. The interwar period saw the rise of 2) behavioural management which was based on behaviourism, this was followed by 3) quantitative management from the Second World War onwards. After the war it was 4) modern management that became important. A company was seen as an open system, interacting with an external environment with external stakeholders. These management schools of thought were not exclusive, but existed side by side in the period under consideration.
Early in the 20th century, it was the U.S. 'Safety First' movement that marked the starting point of this knowledge development in the sphere of safety managing, with cost reduction and production efficiency as the key drivers. Psychological models and metaphors were used to explain accidents resulting from ‘unsafe acts’. Safety was managed by training and targeting reckless workers, all in line with scientific management. Supported by behavioural management, this approach remained dominant for many years until long after World War II.
Influenced by quantitative management, potential and actual disasters occurring after the war led to two approaches; loss prevention (up-scaling in the process industry) and reliability

engineering (inherently dangerous processes in the aerospace and nuclear sectors). The distinction between process safety and occupational safety became clear after the war when the two evolved as relatively independent domains.
In occupational safety in the 1970s human error was thought to be symptomatic of mismanagement. The term ‘safety management’ was introduced to scientific safety literature alongside concepts such as loosely and tightly coupled processes, organizational culture, disaster incubation and the notion of mechanisms blinding organizations to portents of disaster scenarios. Loss prevention remained technically oriented. Until 1979 there was no clear link with safety management. Reliability engineering that was based on systems theory did have such a connection with the MORT technique that served as a management audit. The Netherlands mainly followed Anglo-Saxon developments. In the late 1970s, following international safety symposia in The Hague and Delft, independent research finally began in the Netherlands.

2. INTRODUCTION

This article is one in a series on knowledge development of the safety domain. Previous publications in Safety Science examined periods extending from the late 19th century until the 1970s (Swuste et al., 2010, 2014). According to the authors, these reviews should provide historical insight into the development of the scientific safety domain. They demonstrate how era-linked knowledge on the causes of accidents is and why ideas can emerge, disappear or lay dormant for some time. In this contribution the rate of knowledge development for managing safety at company level is mapped out. The terms safety management and safety management system were only introduced in the 1970s.
The authors base their assumptions on the idea that the managing of safety development, as reflected in the literature, is fed both by knowledge about the causes of severe accidents (severe or otherwise), and by more general ideas on the managing of companies and their production. However, the authors do not suggest that these relations will clearly emerge during the period under discussion.
All the articles published before the early 1970s are briefly summarized but the post-1970s discussion will be more extensive. In conjunction with these publications the questions below were crucial:

1. What are the general management schools, theories and models for accident causation that have been developed over the years?
2. What has been the influence of such developments on safety management knowledge?
3. What was the context within which this development took place?
4. What are the consequences of this for the field of professional safety in the Netherlands?

3. MATERIALS AND METHODS

The questions posed and answers given in this study are based on extensive literature research involving documents and scientific articles, both in English and Dutch. The research was mainly limited to developments seen in the safety domain in the United States, the United Kingdom and the Netherlands. Original references and sources were accessed via the Delft University of Technology library and through internet. The national professional journal for safety specialists *De Veiligheid* (Safety Journal) was studied to discover more about the various consequences for the Dutch professional field of safety.
The period under study has been divided into five subsections including: general management schools, safety theories and occupational safety models, process safety theories and models, knowledge development related to managing safety and finally, the development in the Netherlands. General management schools are based on the common format of management literature that distinguishes between the classic, the behavioural, quantitative and modern management (Pindur et al., 1995).
The relationship between general management trends, safety theories and models, and safety management is not completely obvious. General management developments are based on market developments and production efficiency, while the other two aspects originate from developments in occupational and process safety. The discussion and conclusion section will provide a suitable synthesis between these topics.
In this article the developments seen in safety legislation are only cursorily discussed. Although legislation remains the primary consideration in many companies, including in the introduction of

safety management and such systems, and even though legislation can have a pivotal role in knowledge development, it is still predominantly based upon previously acquired knowledge.
Tables 2 and 3 at the end of this article will present an overview of the knowledge development observed in safety theories, models, metaphors, safety management and general management approaches from the 19th century onwards. The tables will also integrate information from two previous articles (Swuste et al., 2010, 2014).

4. GENERAL MANAGEMENT APPROACHES

This chapter will start with a short description of different management schools, already starting in the 19th century onwards, because these schools still had their influence in the period under consideration.

4.1Classical management and behavioural management

The classical management school began in the late 19th century and placed top company managers in the centre of decision-making, which at that time was a revolutionary concept. The classical management trend has two fundamental movements – scientific management and general administrative management. Scientific management centres on ways of improving industrial and labour productivity by redesigning tasks and working methods. By contrast administrative management theory examines organizations as total entities and focuses on ways of making them more effective and efficient (Pindur et al., 1995). The Americans Fredrick Taylor and Frank and Lillian Gilbreth were well-known pioneers of scientific management. The Franco-Turkish Henri Fayol and the German Max Weber were pioneers of administrative management. With the exception of Weber, these authors had engineering backgrounds and it was these technological backgrounds that were to determine the characteristics of the related management schools. An organization was seen as a mechanical entity and every person in the organization was expected to judge and act rationally. This view was reflected in the publication 'The Principles of Scientific Management' by Taylor (1911). In the early 20th century business flourished in America, there was plenty of money, but labour remained the limiting factor. In the late 19th century Taylor experimented with different working methods at the Midvale Steel Company where he worked in Philadelphia, Pennsylvania. In particular, he found that it was the participation of employees in production decisions that led to production increase, as long as there was evidence of a standardized workflow. Complex processes were divided into simple sub-processes. The ideal scenario was to cultivate an atmosphere in which employees would not have to think about work. Taylor maintained that employers and employees had similar goals. After all, higher production increased profits for employers and led to higher wages for employees. The approach constituted a first attempt at influencing the behaviour of employees through reward systems. However, in most organizations the management was barely aware of what the work actually entailed and could not therefore guide the system. According to Taylor this was the biggest obstacle to efficient production. His approach was based on:

- observations, measurements, registration;
- selection and training of workers;
- the development of standards and regulations;
- close cooperation between management and employees.

Later on this was to culminate in the renowned' time and motion studies', initiated by Frank and Lillian Gilbreth (1917). Classic management was characterized by the use of 'scientific methods' in management. In this respect scientific involved introducing empiricism, together with measuring, monitoring and recording, all of which marked the start of the planning, organizing, influencing and controlling of production. What limited this approach was the assumption that employees and employers are economically-driven beings. Workers were mainly seen as a means to achieving management ends.
Prior to World War II it was the rise of industrial psychology that was to introduce a new movement to management approaches, that of behavioural management, in which human behaviour, motivation and leadership were the key features. This management movement was inspired by the then modern behaviourism, an empirical approach within psychology, which based human behavioural explanations on the incentives offered, conditioning and the context in which behaviour occurred. The 'human relations movement' was simply a part of this movement. Well-known pioneers were the Americans Elton Mayo and Fritz Roethlisberger who, in the late 1920s and early 1930s, investigated the behaviour of workers at the Western Electric

Company Hawthorne, situated just outside Chicago, Illinois. Productivity was thought to be determined much more by psychological factors, group dynamics at work and by the attention received from supervisors and management, and much less by the economic benefits or physical working conditions. Another pioneer was the American psychologist Abraham Maslow. He published his hierarchy of needs in 1943, a theory of psychological health founded more profoundly on the fulfilling of innate human needs and culminating in self-actualization forming the basis for most motivation of human behaviour. The main problem with the behavioural management school of thought was the complexity of human behaviour. Behaviour and changes in behaviour are simply too difficult to predict. Human motivation thus seemed to play no significant role. The psychoanalytical movement led by Freud (1911), although arguably one of the first attempts to understand the background to human error, did not create any response in the safety domain. All that remains of his approach is the 'slip', an act that occurs without any planning. In the 'behaviourist climate' of that time no value was attached to the drivers of behaviour.

4.2 Qualitative management and modern management

During and just after World War II seven manuals on safety, damage prevention and the managing of security were published in the United States (Heinrich, 1941, 1950; Armstrong et al., 1945, 1953 Heinrich and Crannis, 1959, Blake, 1963 Bird and Germain, 1966). In that period in the United Kingdom only one publication appeared (Association of British Chemical Manufacturers, 1964). All these publications were produced against the background of two management schools: quantitative management and modern management.

Quantitative management started before World War II and was based upon the mathematical and statistical approaches adopted for military problems. After the war, these techniques started being applied in the private sector. The approach, which was originally known as 'operational research', supported management decisions during the planning phase and in the monitoring of projects (Moore, 1968). Quantified and mathematical models, amounted to both its strength and its weakness because when making decisions not all the relevant input is quantifiable.

After World War II modern management emerged. This trend focused on management processes. There management was seen as a decision-making and information-processing activity in which managers had to plan, organize, manage and supervise. The view of an organisation as an open system was also important. Companies were no longer seen as a closed system, as in previous times, but were perceived to interact within a commercial environment and with external stakeholders. The Americans Deming (1982) and Juran (Juran, 1951; Juran and Barish, 1955) were its pioneers. Immediately after the Second World War they played an important role in rebuilding the Japanese industry. Their focus was on quality control; it was a focus that had shifted from finished products to production. Employees and customers played a major role in quality control.

Later on it was stressed that the production and market environment, as well as stakeholders, are sector specific or even company specific. Universal management techniques did not seem to be obvious thereby leading to the design of management systems for individual organizations (Schein, 1972). Another trend came from Mintzberg (1979), who did not emphasize the uniqueness of companies, but postulated rather that there is a consistent pattern in the response of companies to external influences. This pattern was determined by the structure of the organization and by subsequent decision-making processes.

5. OCCUPATIONAL SAFETY

5.1 Safety theories and models, and 'accident prone conditions'

The main centre for safety science research in the 1970s was the United Kingdom and there were a number of breakthroughs. The multi-causality concept was introduced in relation to accidents. 'People, not things are causing accidents'. In fact it still resembled the 'accident proneness theory' (for an overview see Swuste et al., 2010), but unsafe acts and unsafe conditions were, by then, more clearly being explained as symptoms of faulty management and not as causes of accidents (Petersen, 1971). The term 'accident prone conditions' emerged in the United States, in sharp contrast to 'accident prone workers' (Pfeifer et al., 1974). Therefore unsafe acts were placed in a context.

In the United Kingdom, the research done on occupational accidents was predominantly conducted by psychologists and ergonomists, working at Aston University, Birmingham. Unlike previous accident models and theories, which were based upon hazards, or reflex reaction during process disturbances, the focus was on the information that was available to workers just before an accident took place (Hale and Hale, 1970; Dunn, 1972). During accidents, information flows could be disturbed; there could be information overload physical limitations preventing adequate responses, or evidence of a worker having chosen the wrong action strategy. Ergonomists developed the ergonomics of information as well as the type, design and quality of information offered to employees at their workplace and the classification of errors that could result from this (Singleton, 1971, 1972).

In general, ergonomics was increasingly influential in the safety domain. According to the task dynamics theory developed by the Dutchman Winsemius (see for more information Swuste et al., 2014), the ergonomic design and redesign of machines and workplaces was a direction in which solutions could be sought. The theory of task dynamics or task momentum was also reflected in a large prospective study on accidents in the metal, assembly and distribution sectors. What made this study remarkable was the fact that safety research had hitherto only relied on retrospective study design or had been based on case studies. The study also showed the general disinterest of safety management in the companies being studied. A director could find safety important, but generally it remained something on paper with no further consequences for business operations (Powell et al., 1971). Similar conclusions were also drawn during an extensive literature review of 80 years of publications on accidents. In addition to the extensive analysis of the accident proneness literature, the survey pointed to conflicts at company level between safety and production, to process disturbances being risk factors for accidents and to the relatively low effectiveness of safety training for employees (Hale and Hale, 1972).

In the United States attention was being given to a topic which later on in the Netherlands was to become known as the 'humanization of labour'. Short-cycle work on conveyor belts was described as monotonous and demotivating. In the literature, a comparison was drawn with Modern Times, Charlie Chaplin's 1936 movie (Swain, 1973) (Figure 1). Higher wages, strict employee selection, training and motivational programs, punishment none of these measures had any demonstrable effects or, if they did, they were only short-lived.

Figure 1, 'Modern Times', movie by Charley Chaplin

The suggested solutions were: to seek job enrichment, to match tasks to humans and to give workers greater autonomy over the organization of their work (Pfeifer et al, 1974; Cohen et al., 1975). The need for active involvement on the part of top management of companies was also emphasized. That would not only save time and money but would display demonstrable care for the welfare of employees. The concept of 'workers' welfare' which originated in the United Kingdom was introduced to the United States (Ellis, 1975; Cohen, 1977; Cleveland et al., 1979; Nye, 2013). Finally, the defective scientific evaluation of safety initiatives was criticized as were the generally accepted determinants of safety. Cohen complained about the extensive literature on safety training, which lacked evaluative research (Cohen et al., 1979). For similar reasons Ellis (1975) was hesitant about the effects that safety legislation, inspections, statistics and government standards had on safety in companies.

6. PROCESS SAFETY

6.1 The system approach and increased complexity

It was after World War II that large-scale industrial processes first began. It was a development that was to result in the process safety movement of the early 60s, an important movement within the safety domain which became known as 'Loss Prevention'. Due to the upscaling of production processes in the chemical industry, the control of these processes became more complex thus resulting in fires, explosions and the emission of toxic substances. All of this was to have far-reaching effects beyond the premises of plants. There was growing public anxiety concerning the possibility of large-scale accidents and various forms of pollution (Carson, 1962).

Publications on loss prevention appeared in both the United States and the United Kingdom (Association of British Chemical Manufacturers, 1964; Fawcett, 1965a, 1965b). As with safety techniques, the engineering approach was dominant. The focus was no longer on unsafe actions but rather on 'loss of containment' control; on keeping chemicals inside the pipes. In both countries methods and techniques were developed to improve equipment and process reliability. In part these techniques originated from the process industry (Hazard and Operability Study - HAZOP) but they also came from the military sector (Failure Mode and Effects Analysis - FMEA and Fault Tree Analysis - FTA error or tree). An extensive discussion of these methods is to be found in a previous publication (Swuste et al., 2014).

6.2 Major industrial accidents and process safety

In the 1970s certain sociological studies were published that dealt with the complexity of production processes (Reeves and Turner, 1972), their organisation but also their internal codes, rituals and socialization processes (Turner, 1971). In three medium-sized to large companies a relationship was established between the organization of the work, the technology of the production process and the control that management had over production. In the early 70s of the last century, the automation of production in the manufacturing sector was relatively limited and production was mainly organised as batch-wise processes. These processes possessed a high degree of complexity due to the numerous sub-products and thus also the many process steps, which made any production planning virtually impossible. Foremen and middle managers had to resolve production and planning problems in an ad hoc fashion. This was no different in the case of safety-related issues.

The describing of socialization processes in companies came as a direct result of extensive sociological study. Through informal interviews and observations researchers had been able to put themselves in the shoes of companies, while pinpointing their organizational characteristics by means of what was termed the 'grounded theory' approach. These studies were relevant to occupational safety but especially to process safety. A sociological approach does not focus on the individual behaviour of employees. Instead it investigates and describes how production companies are functioning and how decision-making works. Such an approach was also followed in the United States but different conclusions were drawn. In the British study, batch-wise production was seen as an obstacle, due to its increased complexity. Batch-wise production was, by definition, loosely coupled. Loosely coupling is a technical term and refers to the presence of a buffer, or of space between production steps, as well as a degree of variability between these steps. In the US study it was precisely the benefits of a loosely coupled production system that were investigated, its flexibility, the capacity to respond to local needs, to restore faults in production, and the reduced vulnerability compared to tightly coupled production systems (Weick, 1976).

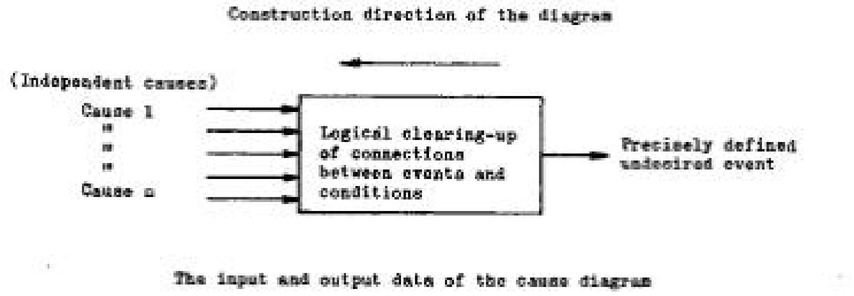
In the 1970s a number of major accidents and disasters occurred in the process and nuclear industries that received much media attention and created fear amongst the general public. In the Nypro, Flixborough, North Lincolnshire disaster of July 1st 1974 in the United Kingdom at the caprolactam plant, 28 workers were killed and 89 people were wounded, including 53 civilians. DSM owned 55% of Nypro. A year later, on November 7th, 1975 the naphtha cracker II exploded at the DSM Beek plant in Limburg. Fourteen workers were killed and 109 were wounded. Again a year later, on July 9th, 1976 a reactor exploded at the Icmesa Chemical Company in Meda, near Seveso, Italy. A gas cloud escaped with the highly toxic TCDD (2,3,7,8-tetrachlorodibenzodioxin). This disaster culminated in the mass slaughter of animals in the region. No direct fatalities or injuries were reported but there was a high rate of spontaneous abortions in pregnant women exposed to the toxin. On March 28th, 1979 a malfunctioning of the secondary cooling system at the Three Mile Island nuclear power plant, near Harrisburg, Pennsylvania, in the United States triggered the increased risk of 'meltdown'. During this near-disaster radioactive gases were discharged into the atmosphere. This incident, which the media classified as a ‘disaster’, led to no immediate injuries or deaths or later, to any demonstrable adverse effects on public health in the Harrisburg area. These four events are just a few examples of the number of disasters occurring during this period which led to serious doubts about safety. The reference book by Lees (1980) provides an extensive overview of the situation.

Public resistance to industrial disasters, took off in the 1960s. This led to extensive media coverage. The chemical and nuclear industries had an image problem and action groups published articles in Nature, one of the most important scientific platforms (Anonymous, 1977). Such bad control of industrial activities on the part of companies was no longer acceptable. In the case of Three Mile Island, this was reinforced by the ‘China Syndrome’ movie, which was released twelve days before the near-disaster occurred. Starring Jack Lemmon and Jane Fonda, it told the story of safety problems at a nuclear power plant. The title was a metaphor for a meltdown at a plant. If such a thing were to happen it was predicted that the repercussions would reach China.

Disasters and accidents drew people’s attention to process safety and two trends emerged: reliability engineering and loss prevention. Reliability engineering originated from military, nuclear and aerospace domains (Barlow and Proschan, 1975; WASH-1400, Rasmussen, 1975) and loss prevention came from the processing industry (Lees, 1980). These two movements, together with Rowe’s 1977 reference book ‘An anatomy of risk’, introduced the concept of risk in the safety domain. More information on this is provided in the article by Oostendorp et al., 2013.

The disasters at Flixborough and DSM Beek, but also the 1978 BLEVE (boiling liquid vapour explosion) involving an LPG tanker at the Los Alfaques campsite in Spain Tarragona, were decisive in the field of loss prevention. These events generated a stream of publications both in professional and scientific journals. The devastating effects of vapour cloud explosions were poorly understood, as became clear from official reports of these disasters and in the relevant literature (Parker, 1975 Ficq, 1976; Sadee et al., 1976). Much research was initiated to understand the dangers and spreading of these gas clouds (see e.g. Nettleton, 1976 and 1976/1977). On industrial sites, offices and control rooms were either situated in the vicinity of process installations or were dotted around the plants thus leading to devastating effects for workers if disasters occurred at such locations. The official Flixborough report published by the Department of Employment (1975) was surprisingly mild about the company’s quality of the management. According to the report the management had been safety conscious, there were no indications that production had taken precedence over safety. However, the understaffing of the technical support facilities was mentioned. Other reports and articles drew very different conclusions. Attention was drawn to the very low standard of safety management, to the way in which production prevailed over safety and to the inadequacy of the local authorities’ licensing thus allowing large volumes of flammable substances to be stored on site. (See also Lees, 1980; Carsen and Mumford, 1979; Harvey, 1979). Trevor Kletz (1976) from Imperial Chemical Industries (ICI) was the greatest critic. He denounced the way in which, in the process industries, management had a fascination for accident rates as a gauge of safety. To his mind ‘loss of containment’ incidence and analyses of near accidents were more important. According to the author, such data reflected, in line with the loss prevention approach, the reliability of plant components and therefore presented a more realistic picture of the safety of any process.

‘First time safe’ was the reliability engineering motto. It challenged the customary 'fly-fix-fly' routine. The Apollo I fire of 1967, which killed three astronauts, made people realize that the consequences of the old motto were unacceptable for complex systems. System safety that adhered to the life cycle approach, hazard analysis and fault tree analysis techniques formed the basis to this philosophy, along with the calculating or estimating of the chances and probabilities of system errors occurring. The assumption was that 'what could happen, would happen when the time was ripe’. Reliability engineering was promoted through series of seminars, organized by the United States and held in the UK, Germany, the Netherlands, Switzerland and Denmark. A schematic overview of this is given in Figure 2 which shows a model that was developed for the Danish Atomic Energy Commission to systematically investigate the chances of failure in the nuclear reactor industry sector (Nielsen, 1971; Nielsen et al., 1975).



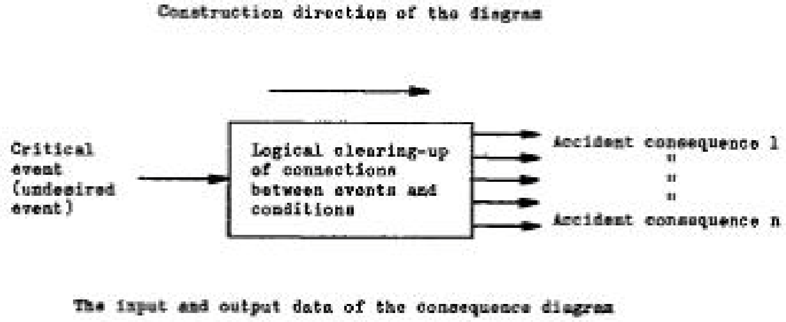


Figure 2, the cause and consequences diagram (Nielsen, 1971)

The model consists of two fault trees surrounding an unwanted event and thus constituting an early presentation of the later bowtie. The adverse event was defined in the same way as in a fault tree or in the functional failure of a system or component. The system approach, previously advocated by ergonomists in the safety domain, recognizably returned and is apparent in the graphical presentation given in Figure 2. Technical solutions to safety problems were preferred, because they were relatively easy to define.

In 1976, the results of another descriptive sociological study into companies and organizations were published. This time the study involved companies and organizations from outside the process industry sector and described: the slag of a colliery tip on a mountainside in Aberfan, Wales which slid down into the village in 1996; the collision of an express train carrying exceptional freight in Hixon, Staffordshire (1968); and the fire at a resort in Douglas, Isle of Man (1974). These accidents caused dozens of deaths (Turner, 1976). The main question that was asked was this: ‘what had gone wrong in these organizations’. It was assumed that no single human error could be accountable for such accidents so the causes had to be sought in the complex and diverging chains of events and decisions made within those organizations. Despite the wide differences in the types of accidents, it was only with great difficulty that the organizations seemed to recognise and appreciate the deviant signals. Big accidents proved virtually impossible to predict. Like much safety research, this study, had the benefit of 'hindsight'. In retrospect, the disturbances confronting workers seemed fairly clear and well defined. At the time of the respective accidents though that was sometimes quite different. Problems, for example during production, could be quite diverse, not understood or ignored, so making the early signs of major accidents very vague for workers. Stage II of the model in Figure 3, known as the ‘incubation period’ addresses this very point.

The Sequence of Events Associated with a Failure of Foresight	
Stage I	**Notionally normal starting point:** (a) Initial culturally accepted beliefs about the world and its hazards (b) Associated precautionary norms set out in laws, codes of practice, mores, and folkways.
Stage II	**Incubation period:** the accumulation of an unnoticed set of events which are at odds with the accepted beliefs about hazards and the norms for their avoidance.
Stage III	**Precipitating event:** forces itself to the attention and transforms general perceptions of Stage II.
Stage IV	**Onset:** the immediate consequences of the collapse of cultural precautions become apparent.
Stage V	**Rescue and salvage — first stage adjustment:** the immediate postcollapse situation is recognized in ad hoc adjustments which permit the work of rescue and salvage to be started.
Stage VI	**Full cultural readjustment:** an inquiry or assessment is carried out, and beliefs and precautionary norms are adjusted to fit the newly gained understanding of the world.

Figure 3, the stages of major accidents (Turner, 1976)

In a later publication, the term ‘man-made disasters' was used for the first time (Turner, 1978), and the study was extended to include 84 reports of major accidents in civil aviation, water heaters, trains, ships and mines.

7 SAFETY MANAGEMENT

7.1The managing of safety, the safety ladder and the control of damage

After World War II the first publications on the managing of occupational safety began to appear. In fact it was only 20 years later that the term ‘safety management’ was introduced. In the 1950 edition of his reference book Heinrich discussed certain fundamentals of accident prevention which he graphically represented as a ladder; a metaphor for a management system. A comprehensive article on Heinrich’s publications was published by Gulijk and several co-authors in 2015. The Heinrich approach ascribed an exemplary role to the manager in realizing safe and efficient production. It was a message that had been underscored in the first edition of a publication by Armstrong and his co-authors some five years before (Armstrong et al., 1945).

'Damage Control', in the work of Bird and later also Germain, adhered to Heinrich's tradition of the domino metaphor in which unsafe acts were seen as the primary cause of accidents. It was just extent of the consequences that had widened, from injury to accidents, near-accidents and the incurring of damage (Figure 4).

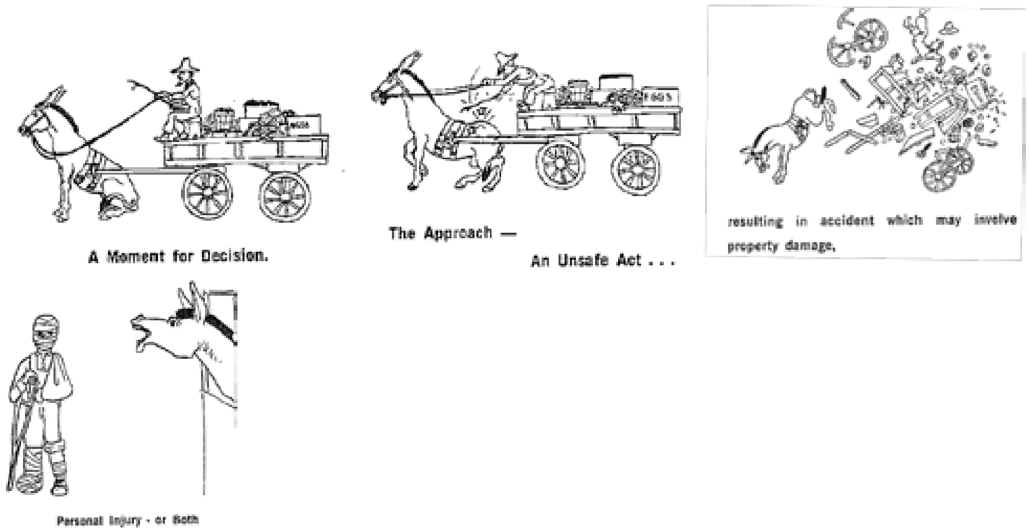


Figure 4, damage control (Bird and Germain, 1966)

Both authors worked at the Lukens Steel Co. in Coatesville, Pennsylvania, where they investigated 90,000 accidents involving injury between 1959 and 1965. Until then damage to objects had not been covered by any US safety literature. Working on the 1: 29: 300 distribution of the accident mechanism (see Table 2 at the end of this article), it was pointed out that a large proportion of the accidents without injury and the near misses could actually have caused considerable damage. This led to the 'damage iceberg' with its different ratios, as illustrated in Figure 5. According to the authors, the costs connected with these accidents were considerably higher than the costs of the accidents themselves. Furthermore, this investigation revealed to the management a range of unsafe acts, which also contributed to non-damage accidents. The damage control program required an accurate strategy of accident and damage reporting, work preparation, auditing and cost calculations. The books by Bird and by Bird and Germain gave extensive examples of the kinds of forms used for these reports (Bird and Germain, 1966; Bird, 1974).

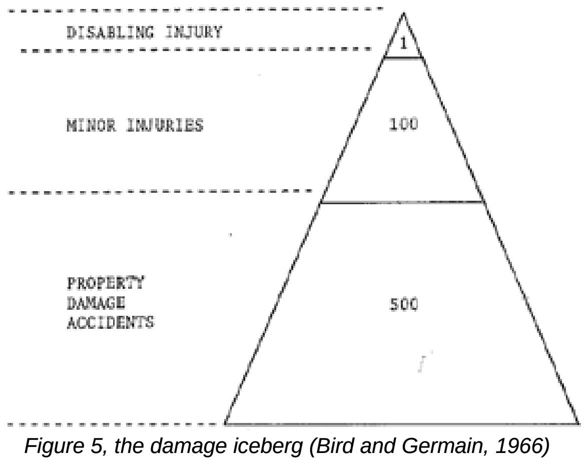


Figure 5, the damage iceberg (Bird and Germain, 1966)

7.2 Occupational and process safety management systems and auditing

In the United Kingdom it was the government that took the initiative concerning the consequences of safety and management within companies. The well-known Robens report started off by reflecting on the role of the government (Robens, 1972). This led, in 1972, to the establishment of the Health and Safety Commission (HSC). One year later the Health and Safety Executive (HSE) was made responsible for safety- related research and for the monitoring of safety in companies. In the United States, several safety reference books on safety management were published in the 1970s (Petersen, 1971, 1975, 1978; Bird, 1974; Bird and Loftus, 1976). Petersen coined the term 'safety management' in the title of his books. Finally a significant contribution was made to accident sequences and management by

Johnson, (1973a). That led to an accident management model in the nuclear industry in the form of the Management Oversight and Risk Tree (MORT) technique (Johnson, 1973b).
The Robens Committee (1972) started with the fairly broad remit of evaluating the quality of legal provisions for occupational and process safety. The results were shocking. Occupational mortality and morbidity were alarmingly high in the United Kingdom and alongside accidents the incidence of new occupational diseases, like bladder cancer and asbestos-related cancers also emerged. The impact of safety legislation started being seriously questioned when, for instance, in the United States a few years later (Ellis, 1975) the question 'What is wrong with the system?' was asked. That became the title of the first chapter of the related report and the answer was clear. There were nine groups of laws with as many controlling bodies, spread over five different ministries. It took an average of 15 years to amend any law. The laws were impossible to implement, too many, too detailed and too poorly structured. There were far too many technical and descriptive regulations, while human and organizational factors remained desperately underexplored. The remedy was relatively simple. The committee suggested delegating the technical control of hazards to those who created them, in other words to industry. Businesses would have to take the initiative, leaving the issue of safety mainly to private parties. The Committee also proposed establishing a single organization with responsibility for research and monitoring. That organization became the HSC and the HSE. The HSC produced two reports on 'major hazards' (HSC, 1976 and 1979), in the immediate aftermath of the Flixborough disaster. These reports provided an inventory of all the British companies using toxic and very toxic gases as well as flammable liquids, and any unstable, highly reactive materials that were subject to legislation once the quantities exceeded certain limits. The reports gave overviews of explosions in almost every continent and stressed, as also mentioned in the Robens report, the importance of the role of top company management in matters of safety. Companies had to demonstrate that their management systems had an impact on safety, and hazard and risk analyses became mandatory. This focus on management was also present at the HSE, which conducted research into the conditions for occupational safety improvements.
A humanitarian approach to working conditions was also promoted in the UK, whilst noting that surprisingly few managers had had any form of safety training (HSE, 1976). Curiously, none of the reports adopted the term safety management, in contrast to the American textbooks of the day.
Models of accidents and their prevention in manuals both by Bird and Petersen looked very similar. Both authors were indebted to Heinrich's domino model. Bird used a modified version of the dominoes and drew a distinction between the root and direct causes (see Figures 6 and 7).

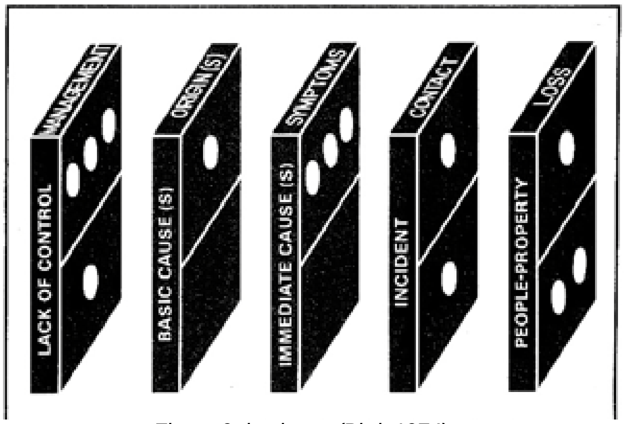


Figure 6 dominoes (Bird, 1974)

Root causes were personal and work-related causes. Personal factors were skills, motivation and mental or physical problems. Work factors were the different standards for tasks, design, maintenance, inadequate purchases, or simply wear and tear. The direct causes resembled the factors published by Heinrich in 1941 (Figure 7).Instead of 'social environment' and 'fault of person': the first two dominoes of Heinrich's, Bird's first domino pointed to a lack of management control in the company in question. This resulted in a safety program consisting of regular inspections, task analyses, safety procedures and training, as well as personal contacts with employees that functioned badly.

UNSAFE CONDITIONS

1. Inadequate guards or protection
2. Defective tools, equipment, substances
3. Congestion
4. Inadequate warning system
5. Fire and explosion hazards
6. Substandard housekeeping
7. Hazardous atmospheric conditions: gases, dusts, fumes, vapors
8. Excessive noise
9. Radiation exposures
10. Inadequate illumination or ventilation

UNSAFE PRACTICES

1. Operating without authority
2. Failure to warn or secure
3. Operating at improper speed
4. Making safety devices inoperable
5. Using defective equipment
6. Using equipment improperly
7. Failure to use personal protective equipment
8. Improper loading or placement
9. Improper lifting
10. Taking improper position
11. Servicing equipment in motion
12. Horseplay
13. Drinking or drugs

Figure 7, immediate causes of accidents (Bird, 1974)

The manual by Bird and later by Bird and Loftus took the reader by the hand and was written in a very practical and hands-on way, including extensive chapters on psychological insight into behaviour and the motivation of employees. This latter subject was also covered by Petersen's reference books. These authors rejected the early 20th century 'Safety First' movement (US Steel, 1913). To their minds safety had to be integral to the business and part of work procedure. This was articulated in the 3rd point of Figure 8. Again, both Bird and Petersen provided many examples of the kinds of forms that could be used for accident investigation reports in relation to safety inspections and other initiatives. Combinations of these topics turned into a first draft for a safety audit. Petersen introduced SCRAPE, a systematic model for measuring the safety efforts of foremen, such as safety inspection rounds, safety training and meetings, and accident investigation (Petersen, 1971). These activities were point scores and the management could award a weekly score to each leader on the basis of a record of the activity forms. A second system was the Technic of Operations Review (TOR), which enabled people to detect deficiencies in the organization after an accident, a near-accident or damage. An example of this is given in Figure 9. The reference book by Petersen of 1975 provided an extensive report of the psychological and management models that existed on motivation, behaviour and different ways of managing a safety program.

NEW PRINCIPLES OF SAFETY MANAGEMENT

1. An unsafe act, an unsafe condition, an accident: all these are symptoms of something wrong in the management system.
2. Certain sets of circumstances can be predicted to produce severe injuries. These circumstances can be identified and controlled:

Unusual, nonroutine	High energy sources
Nonproductive activities	Certain construction situations

3. Safety should be managed like any other company function. Management should direct the safety effect by setting achievable goals, by planning, organizing, and controlling to achieve them.
4. The key to effective line safety performance is management procedures that fix accountability.
5. The function of safety is to locate and define the operational errors that allow accidents to occur. This function can be carried out in two ways: (1) by asking why—searching for root causes of accidents, and (2) by asking whether or not certain known effective controls are being utilized.

Figure 8 Safety management (Petersen, 1971)

This was called the safety climate program and it distinguished between:

- The overzealous style; personal protective equipment should be worn, machines must be shielded so that they are difficult to reach but operable, there are severe penalties for the violation of procedures and there is an endless stream of safety films, talks and meetings. There is evidence of an overexposure to safety;
- The rewarding style; the company initiates safety competitions and rewards individual employees for their safety performance. The rewards are small. Employees can see that the company takes safety seriously;
- The lively style; the company organizes safety competitions between factories or departments. Big billboards at the entrance to the company record the number of accident-free days. These companies teach employees that safety is an integral part of the job;
- The negligent style; safety in such companies only becomes important after a serious accident has occurred. Employees see that the company is not interested

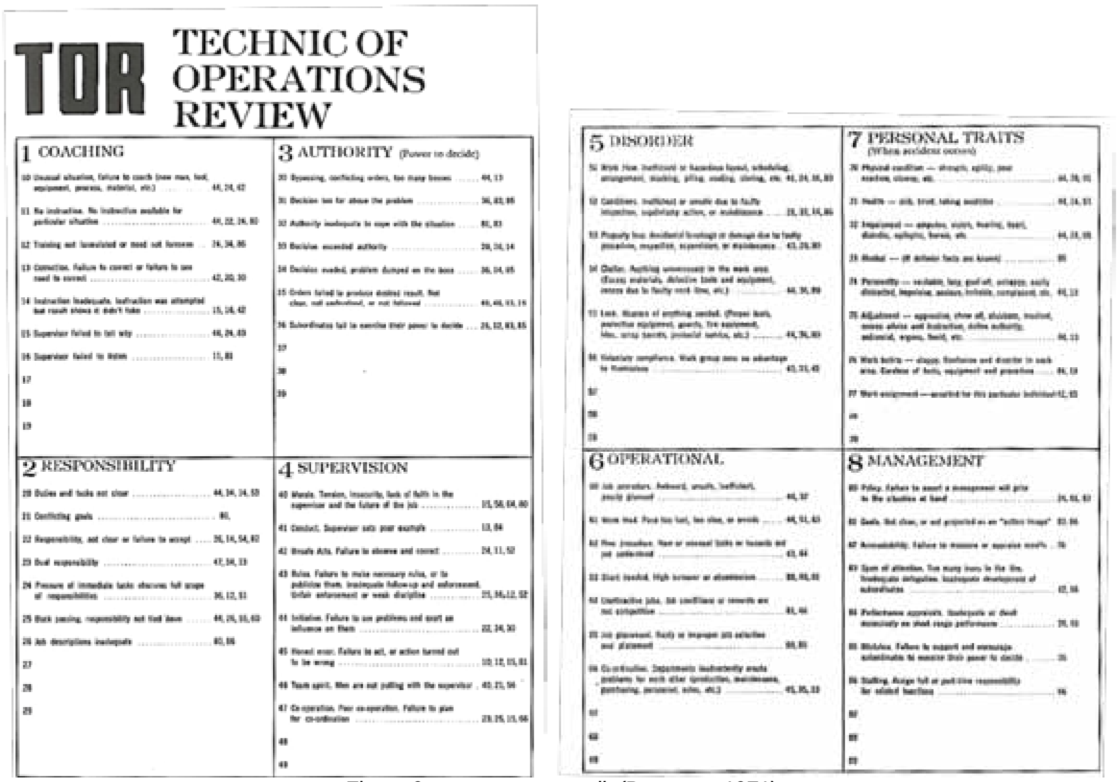


Figure 9, management audit (Petersen, 1971)

In this approach the role of management was not essentially different from that of the 1950s. Cost control and production efficiency remained central. It was just the welfare of workers that received extra emphasis. A combination of a safety analysis of each task, task-specific training and ongoing safety observations, otherwise known as the JSA JIT SO system (job safety analysis, job instruction training, safety observations) gave companies a high degree of labour autonomy. From then on, the safety of a company or plant was seen as a measure of the quality of the supervision and safety observations. Just as stated by Heinrich, the foreman was central. If a foreman could not organize safety, his control of costs and the general product quality and production level would also be doubted. The responsibility for safety was placed fairly and squarely on the shoulders of middle and lower management. At the same time, the system approach was directly related to training and design. If an industrial system failed that meant that those operating the system had been insufficiently well trained to deal with the design of the system (Johnson, 1970; Cleveland et al., 1979). This was reflected in the accident definition, in which the ‘energy transfer' and 'barrier' concepts referred directly to the models of Gibson (1961), and Haddon and his co-authors (1964):

> *An accident is the result of a complex series of events, related to energy transfer, failing barriers, and control systems, causing faults, errors, unsafe acts, and unsafe conditions and changes in process and organisational conditions* (Johnson, 1970).

Johnson (1973a) presented an integrated management model for occupational and process-related accidents. Accidents were multi-causal and resulted from a relatively long sequence of changes and errors; the accident scenario. Any components of the industrial process could be part of this sequence; management, design, the environment, machinery, equipment, supervision and employees. Before accidents occurred, scenarios were often already partly in place because of certain interaction and changes in both process and organizational conditions. Examples of such non-routine conditions are shown in Figure 9, Paragraph 5 and they simply added to the complexity of the accident which, only in retrospect, could be seen as having led to the disaster scenario (Figure 10).

This concept of accident causation led to the MORT technique. It was developed by the United States Atomic Energy Commission, the aim being to establish a perfect safety management system, by combining accident models with quality systems. MORT was also useful as an in-depth analysis technique for system failure. MORT comprised a number of fault trees, starting from the functional failure of a system. The use of these kinds of error trees had been previously represented by Nielsen who had made a logical connection between causes and consequences (Figure 11).

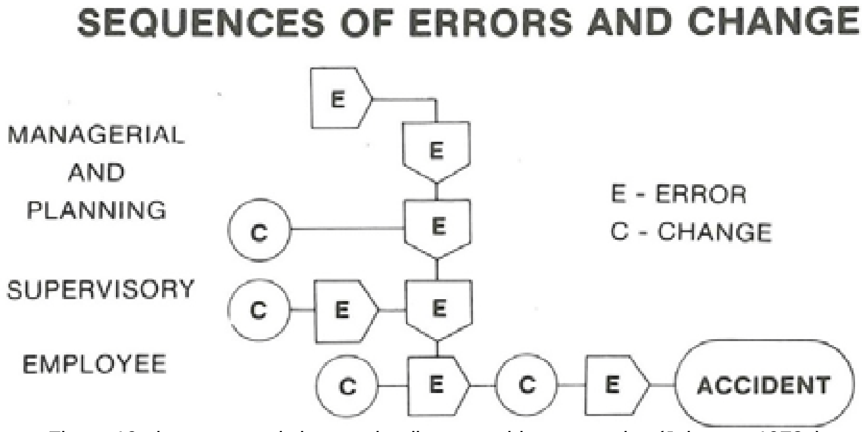


Figure 10, the errors and changes leading to accident scenarios (Johnson, 1973a)

The top event in MORT is an accident or damage. Directly below the top event there are four different fault trees that are used to analyse the event: 1) assumed risks, 2) the Haddon (1963) energy model, 3) a feedback and control system, and 4) the system life cycle (Figure 14).

Figure 11, the bowtie precursor (Nielsen, 1971; Johnson, 1973b)

If Petersen was the first to use the term 'safety management' then the United States Atomic Energy Commission report represented the first time when the descriptor 'safety management system' was used. Like a fault tree, MORT was not based on systematic research but rather on a logical description of the functions required for an organization to manage its risks effectively. The report concluded that the overall safety programs seen in companies were far from optimal, as was the literature on safety tools for major accidents. The programs were poorly defined and the information collected was flawed, thus saddling middle managers and workers with blame in the event of damage or accidents. In this respect, the situation did not seem to be very different from that of the beginning of the century. Management had, according to the report, the legal and moral obligation to guarantee production safety. First an answer needed to be given to questions regarding the predominant probable accident and disaster scenarios, and the likely consequences of these scenarios. The next question was whether the risks were controlled, what residual risks were present and what arguments were used to reject the measures taken to reduce risk. Finally, there was the question of the quality of the company's safety program, was it as effective as it was designed to be?

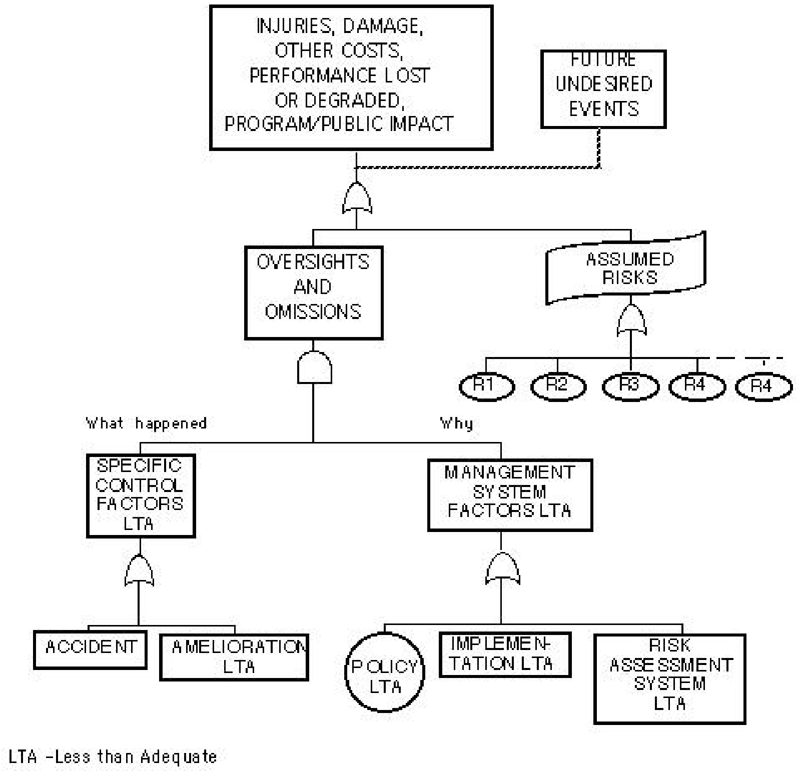


Figure 12, MORT (Johnson, 1973b)

The report also gave a characterization of five safety program quality levels and linked that to the risk of a major accident or disaster (see Table 1). The origin of the probabilities presented was not given. The only thing mentioned was that companies had sufficient data to justify an order of magnitude difference between the successive levels. Nuclear energy sector reactors fell into the fifth level.

safety program level	**disaster probability**
sub-minimal, less than minimal compliance with regulations,	1×10^{-3}
minimal, minimal compliance with enforced regulations,	5×10^{-4}
manuals, applications of manuals and standards,	1×10^{-4}
advanced, advanced programming, exemplified by leading industries,	1×10^{-5}
systems, system safety,	1×10^{-6}

Table 1, the quality of safety programs and disaster probability (Johnson, 1973b)

8 DEVELOPMENTS IN THE NETHERLANDS

By the 1970s, the focus in the Dutch professional journal *De Veiligheid* on accident proneness theory, and Heinrich's notions of lack of safety, which had become dominant from the 1930s onwards, had somewhat diminished. Other developments originating from the safety science domain and mainly from the United States and the United Kingdom were discussed. Two international symposia on safety were also organized in the Netherlands. The first was the Loss Prevention Symposium in The Hague and Delft, organized by the Royal Institute of Engineers (KIVI) and the Royal Dutch Chemical Society (KNCV), which ended just a day before the Flixborough disaster (Buschmann, 1974). This Symposia was the very first of a successful series of Loss Prevention Symposia, organised every three year throughout Europe. The second symposium was organized by what was then the Technical High school of Delft, the Foundation for Road Safety Research (SWOV), the Safety Institute (VI) and the Directorate General of Labour (DGA). This Delft symposium discussed academic education and the research continuing into safety (THD, 1978). In the same year, the organization psychologist Hofstede (1978) published an article in which he denounced systems thinking. Also in 1979, a new journal *Riskobulletin* (Risk Bulletin) appeared, edited by the Adviesgroep Veiligheid en Gezondheid in de Industrie (the Advisory Group for Safety and Health in Industry). This Group included members of the Union of Scientific Workers, which had been created in reaction to the Vietnam War, and the Association of Scientific Researchers, which had been created after the World War II atomic attack on Nagasaki and Hiroshima. Science shops, present at almost all Dutch universities and supporting the knowledge-related questions posed by workers, environmental and community groups, were also connected to this Advisory Group.

The major disasters that had received considerable media attention were discussed in the professional journal *De Veiligheid* (Groothuizen, 1976; Versteeg, 1979). There was extensive coverage of the theories and models expounded by Winsemius (1951), task dynamics (Anonymous, 1974; Andriessen, 1974 Wijk, 1977), prevention strategies and Haddon's hazard-barrier-target model (Cooper, 1973; Bergsma, 1974), loss control management proposed by Bird and the reference books of Petersen (Pope, 1976 Bird, 1978; Fletcher, 1978; Wright, 1978; Leij, 1978, 1979). The Netherlands also received its first book on safety management (Zwam, 1978). The reviewing of Petersen's safety manual marked the introduction of the term safety management to the Netherlands and at certain fixed intervals the control of process deviations and organizational change were viewed as sources of prevention (Dop, 1977 Radandt, 1979). It is interesting to note that neither MORT nor developments within the nuclear sector were addressed in the journal. This was different when it came to the topic of the 'humanization of labour' which addressed the negative effects of extensive division of labour and the separation of management and operations, 'head and hand', that had come into being in conjunction with scientific management, (Strien, 1978). Conflicts on responsibility were also evident in the working group 13 of the Dutch Society for Safety Science (NVVK). There the dilemma of company interests versus the interests of employees was addressed. The role of safety inspector was difficult to combine with the promoting of the welfare of workers, at least that was the argument (Meertens and Zwam, 1976; Kraan and Schenke, 1976; Oostrom, 1979). The debate about the ethics of the safety profession, was not unique to the NVVK. At universities, the role within society of scientists and engineers was being discussed and chemistry and science shops were the result (Zwaard, 2007).

The other topics discussed in *De Veiligheid* were systems theory together with system and process safety. These were complicated issues that met with considerable resistance from NVVK members. 'There is relatively little overlap between safety experts and system thinkers', claimed Koornneef (1979). Incidentally, this system approach had resulted in the accident model developed by Wijk (1977) which, like the one produced by Johnson and Nielsen, could be seen as a precursor to the bowtie (Figure 13).

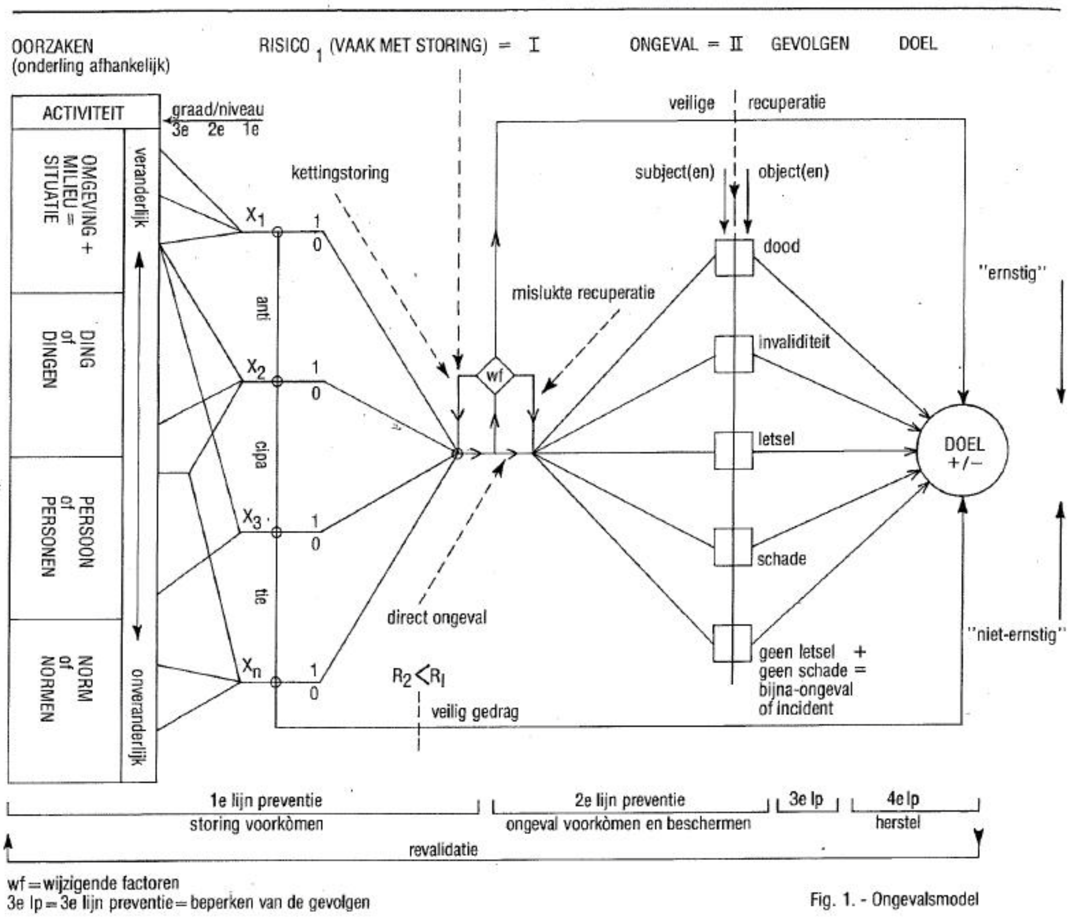


Figure 13 accident model (Wijk, 1977)

The model started with a block of 'activities'. From there, a network of lines through amending factors and disturbances ran towards the goal (accident). The tangle of lines indicates the multi-causal nature of the accident process and the interdependencies of the various factors. In its layout this model is more complex than those of Figures 2 and 11. It is highly likely that the models were developed independently of each other. The author probably knew nothing of the Danish or the United States Atomic Energy Commission models (Koornneef, 2013).

Publications on system safety, such as those of Pope, Wijk and Wansing (1976), could therefore count on criticism. The main argument was that safety science should focus on a human approach. Man was not, after all, a component of a system and did not fit into mathematical formulas and this was consistent with criticism on the failure probabilities of human behaviour alive in the United States and the United Kingdom (Rigby and Swain, 1971; Kirwan, 1994; Pasmooij, 1979). The system approach first led to the quantification, assessment and evaluation of risk, followed by all kinds of decisions made on acceptability, risk acceptance and the resultant measures and interventions or risk control. Extended argument concerning risk quantification and acceptance was published in *De Veiligheid* en *Risikobulletin*. Probability calculations were often, it was thought, based on guesswork and the uncertainty surrounding probabilities was seriously underestimated (Wetenschap en Samenleving, 1978; Reijnders, 1979) (Figure 14).

Figure 14 special issue of Science and Society, risk acceptance (W&S, 1978)

Furthermore, a comparison of the risk figures, in which non-equivalent activities were compared, made little sense. Not all risks were voluntarily taken and risk acceptance was ultimately a political issue presented as a scientific problem (Boskma, 1977 Leij and Mutgeert, 1977 Boesten 1978, 1979).

Moreover, these issues were not raised during the Delft/The Hague Loss Prevention Symposium. The problems addressed were presented as guidelines for safe design in the process industry and as studies on the hazards and risks attached to static electricity, gas and dust explosions, the transportation of hazardous materials and the reliability of system components. Oddly enough, the matter of safety management was not explicitly addressed. The University Teaching and Research Symposium in Delft was much broader. At the symposium the safety domain was not merely restricted to occupational or process safety. It was extended to include private safety, safety at home, in sport, and road safety. The presentation topics were also broader. The The Hague-Delft symposium was restricted to experts from universities, industry and government. At the Delft symposium there was also space for presentations from unions, chemistry and science shops and action groups which, alongside the technical aspects, also highlighted the social aspects of safety. The Delft symposium marked the start of the Safety Science Group, which was established at the Technical University in 1979 (Goossens, 1981). Safety Science thus became an academic discipline in the Netherlands, following earlier initiatives undertaken by the University of Wuppertal (1974), the Catholic University of Leuven (1975) and the University of Aston, Birmingham (1976).

Apart from participating in the symposium, Hofstede (1978) ventilated fierce criticism on systems thinking. The system approach with its clear goals, its input-process-output scheme, its comparison with standards and the feedback and feedforward loops was also prevalent in management literature as a model for decision structure. However, the managing of companies is primarily a social process in a socio-technical environment. Any systems approach remains flawed because there are no clear defining goals, only certain general remarks, derived from business visions. The claims, or the quality of management activities are only partially measurable or not measurable at all, which renders feedback information either usable, or not desirable.

9. DISCUSSION AND CONCLUSIONS

The development of knowledge on the accident process and the management of safety presented in this review is based upon articles and documents. This does not necessarily mean

to say that the knowledge and ideas in the academic and the professional domain were common in the period in which they were presented. Sometimes knowledge fades, sometimes it takes years or decades for ideas to be accepted. One example of this is the theory of Winsemius on task dynamics that was developed in the early 1950s but not referred to in publications until the 1970s. Much the same applied to the 'man-made disasters' of Turner dating from 1978. The preface to the second edition (Turner and Pigeon, 1997) shows that – apart from among a select group of academics – the publication went unnoticed at the time of its appearance. A summary of the knowledge developments within the safety domain and the general management trends is given in Tables 2 and 3.
The relationship between general management trends and knowledge development in the field of safety management within enterprises is not completely obvious. Here, too, the above-mentioned delaying factors could play a role. In addition, safety and general management could be perceived as two separate domains, each with their own dynamics. The first focused more on accidents and was guided by dominant explanations or models of accident processes. General management is primarily driven by market machinations and production efficiency in industrial sectors and therefore by the consequent management control in companies.
The dominant schools of management are limited. In the period under consideration four major schools emerged: classical and scientific management, behavioural management, quantitative management and modern management. These schools were not confined to a certain period of time and they could co-exist (Figure 15).

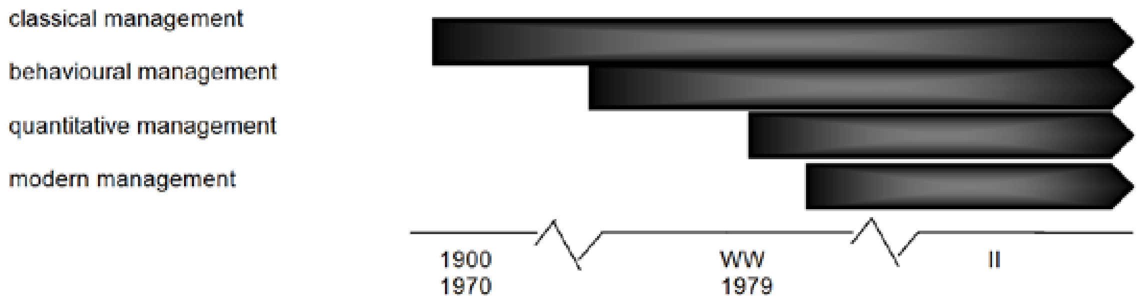


Figure 15 the leading management schools in relation to safety in Europe and the US

The focus on the managing of safety starts halfway through the 19th century in the United Kingdom, and was later to be followed by the American Safety First movement. Companies with an obvious interest in safety, like US Steel, were pioneers. Safety First prioritized safety for a company and there was no relationship with classical and scientific management. In the early days safety was a safety technique and it was the domain of the technician.
Knowledge on the managing of company safety did not become customary until the second decade of the 20th century, starting in the United States, and at first it was the preserve of large corporations and insurance companies. That knowledge was fuelled by psychological concepts. Management had to control unsafe acts by means of selection and through training; these were the standard methods of scientific management. Since the early 19th century, comprehensive labour legislation had existed in the United Kingdom which had also extended to include occupational safety and health. Safety was the domain of government committees such as the Industrial Fatigue Board and the later Industrial Health Research Board (1918-1959), which commissioned investigation on the causes of accidents. The management of safety was not a big topic in the publications of these boards or in any British literature of that period.
Before World War II the psychological models of the accident process were directly linked to the school of behavioural management. Safety techniques could quite effectively solve the 'unsafe conditions' signalled by Heinrich's dominoes. Behaviour, though, was more complex and would therefore play a greater part in the causes of accidents. It was undoubtedly the behavioural management approach which ensured that the domino metaphor remained popular until long after World War II. Dutch and American doctors and British and American ergonomists and psychologists developed theories and models of accident causation in the second half of the 20^{e} century. Their attention was focussed on process disturbances, the barrier concept and on the errors and discrepancies in the information passed on to employees. These models and theories had no detectable influence on the development of knowledge in relation to safety management, a term which had not yet been used in documents and articles. The management process linked to safety first gained clear contours in the form of the Heinrich's safety ladder

Heinrich. There seemed to be no direct line linking this to general management schools or quantitative and modern management, which emerged during and after the war. The dominoes and the safety ladder were more related to the behavioural and scientific management school.
In the 1960s an independent line of development in the area of process safety emerged in the form of loss prevention. The stress was on the operability of complex technical systems. This generated no knowledge on safety management. It merely produced the notion that safety must, by definition, be an integral part of the design and performance of processes and that empirical knowledge should support the reliability of parts of process installations.

period	theories	models, metaphors	safety management	general management
19th century		Safety technique Factory act (UK 1844), Westerouwen van Meeteren (Nl 1893), Calder (UK 1899)	Accidents are part of the job	Classical management
1900-1909	External factors; Heijermans (Nl 1905)	Road to happiness, Safety First Movement; US Steel, (US 1906)		
1910-1919	External factors Eastman (US 1910); Home Office (UK 1911) Accident proneness, Greenwood & Woods (UK 1919)	The 3Es engineering, education, enforcement; National Safety Council (US 1914)	Selection of workers, training of workers in safety philosophy safety committees; Cowee (US 1916)	Scientific management, observations, measurements, registration, selection, training of workers, standards, safety procedures, cooperation management-workers; Taylor (US 1911)
1920-1929	External factors; DeBlois (US 1926)	Hazard is energy, the probabilistic approach to accidents; DeBlois (US 1926) Costs of accidents 1:4; Heinrich (US 1927) Causes of accidents 88:10:2; Heinrich (US 1928) Accident mechanism, iceberg, 1:29:300; Heinrich (US 1929a)	Appointment safety engineer, standardisation procedures; Williams (US 1927) Safety is a condition for efficient production; American Engineering Council (US 1928) Good management is better than good tools; Heinrich (US 1929b)	
1930-1939	External factors; Vernon, (UK 1936)		Management supports safety initiatives, analyses accident causes, develops and implements solutions; DeBlois, Heinrich (US 1926, 1931)	Behavioural management, human relations, behaviour, motivation, leadership; (US 1930s)
1940-1949		Accident process, dominoes; Heinrich (US 1941) Epidemiological triangle; Haddon – Gordon; (US 1949)	Methods of accident prevention are similar to quality control; Heinrich (US 1941) Management shows leadership in safety; Armstrong et al. (US 1945)	
1950-1959	Task dynamics, man-machine interaction; Winsemius (Nl, 1951)		Managing safety as a ladder; Heinrich; (US 1950)	Quality Management; Deming, Juran (US 1951, 1982)
1960-1969	Man-machine systems;	Human factors, ergonomics, Swain		Modern management, the company as

Table 2, theories, models, metaphors and management approaches in occupational safety up till 1979

period	major accidents	theories, models, metaphors	safety management	general management
1940-1949				Quantitative, operations research, decision making based upon mathematical, statistical models
1950-1959				
1960-1969			Loss prevention; Association of British Chemical Manufacturers (UK 1964) Process safety techniques; Hazop, FMEA, FTA, (US 1960, 1962, UK 1963)	Modern management, the company as an open system, managing as a decision making and information processing activity
1970-1979	Flixborough (UK 1974) Beek (Nl 1975) Seveso (Italy 1976) Alfaques (Spain 1978) Three Mile Island (US 1979)	System safety; Johnson (US1970) Organisational culture; Turner (UK 1971) Lose, tightly coupled organisation; Reeves et al. (UK 1972) Gas cloud explosions; Nettleton (UK 1976 1976, 1977) Disasters, organisational incubation period; Turner (UK 1976 1978) Cause-effect diagram (bowtie); Nielsen (Denmark 1971) Changes, non-routine conditions causing accidents; Petersen (US 1971), Johnson (US 1973a, b)	The self-regulating system, from detailed descriptions to goal regulation; Robens report (UK 1972) MORT; Johnson (US 1973a,b) Loss control management; Bird (US, 1974), Bird and Loftus (US 1976)	Management systems are organisation specific; Schein (US 1972) Typology of organisational structures; Mintzberg (Canada 1979)

Table 3, major accidents, theories, models, metaphors and management approaches in process safety up until 1979

Loss prevention emerged against a background of strong upscaling in the process industry, increased complexity in the managing of these processes and increased public criticism.
The 1970s was a stormy period. Public opinion turned against the major industries, including the process industry, and was fuelled by a series of major accidents that received significant media attention. The rift in the departure from occupational safety, which had already been present in the previous period, only widened and the two domains gained their own dynamics.
Both in the United States and in the United Kingdom the human factor was reassessed, first in occupational safety and later in process safety. This was not seen as the cause of accidents but rather as a symptom of mismanagement. The effect of safety training in both countries was also seriously questioned. British researchers went even further. The numerous publications on

safety had been unable to prevent companies from limiting their safety focus to written statements with no further consequences for the workplaces. With the exception of reports on individual companies, serious research into the implementation and quality of safety management (systems) in various sectors had not yet been implemented.

In the 1970s British sociologists investigated the emergence of major accidents in large organizations. Concepts such as loosely and tightly coupled organizations arose, as did the concept of organizational culture, the incubation time of a disaster and the various organisational processes that blinded companies to weak signals and the omens of developing disaster scenarios. These contributions placed a very strong emphasis on safety management but only bore little or no relationship to the technical aspects of the relevant disaster scenarios. This was different in the process industry, in aerospace and in the nuclear industries. There, safety approaches developed that relied on systems theory, on the technical aspects of production processes and which had a relationship with quantitative management, the loss prevention movement and reliability engineering. Loss prevention had no clear affinity with safety management. Following the devastating effects of Flixborough, Beek and Los Alfaques, models and theories were developed to understand and control gas, vapour or dust explosions.

The present survey reveals the multidisciplinary nature of the safety domain. Technicians, engineers, doctors, psychologists, sociologists, ergonomists and safety experts have all interfered with the discipline, each presenting their own questions. In the early days there was little sign of any kind of integration of knowledge. All of that changed in the 1970's when the knowledge on safety management began to take shape, and models and concepts from different knowledge domains emerged.

With the exception of a few excursions around the start of the 20st century and the 1950's, since World War II the Netherlands always adhered rigidly to Anglo-Saxon developments. It was not until the end of the 1970s that independent research was actually conducted in our country. The Netherlands got its own Safety Science Group at the Delft University of Technology and Hofstede voiced sharp criticism of the system approach taken both to the management of companies and safety. However, in the post-1979 period this system approach only became more influential.

Many topics which dominate the discussions on safety of today are also addressed in the period covered, like for instance the integration of safety and production, management commitment, the position of middle management, the dominance of accident rates, the quality of management and the lack of attention paid to the evaluation safety of interventions. Unfortunately, one has to conclude that all those decennia of safety research did not provide any insight to control major accidents.

10. REFERENCES

American Engineering Council (1928). Safety and Production. Harper & Br New York

Andriessen J (1974). Waarom wil men veilig werken (Why one wants to work safely?) (I-III). De Veiligheid 50(6):251-258, 50(7/8):315-320, 50(9):381-384

Anoniem (1974). De ontwikkeling van veiligheids- en gezondheidsaspecten in het ontwerp en de uitvoering van machines en installaties (The development of safety and health aspects in the design and production of machines and installations). De Veiligheid 50(7/8):313

Anoniem (1977). Protecting production or workers BSSRS. Nature 270:93

Armstrong T Blake R Bloomfield J Boulet C Gimbel M Homan S Keefer W Page R (1945). Industrial Safety. Prentice Hall Inc. New York

Armstrong T Blake R Boulet C Gimbel M Homan S Keefer W (1953). Industrial Safety. Prentice Hall Inc. New York

Association of British Chemical Manufacturers (1964). Safety and Management, a guide for the Chemical Industry

Barlow R Proschan F (1975). Statistical theory of reliability and life testing. Holt Rinehart Winston Inc. New York

Bergsma J (1974). Het voorkomen voor zijn (Prevention). De Veiligheid 50(6):263-266

Bird F Germain G (1966). Damage control, a new horizon in accident prevention and cost improvement. American Management Association, The Comet Press

Bird F (1974). Management guide to loss control. Institute Press, Loganville, Georgia US

Bird F Loftus R (1976). Loss control management. International Loss Control Institute, Institute Press, Loganville, Georgia

Bird F (1978). Materiële schade (Material damage). De Veiligheid 54(5):199-201

Blake R (1956). Ratio 88:10:2. National Safety news May;19, 21, 22

Blake R (1963). Industrial Safety. Prentice Hall Inc. New York

Boesten A (1978). Risico-aanvaardbaarheid (1) (Risk acceptability). De Veiligheid 54(11):539-541

Boesten A (1979). Risico-aanvaardbaarheid (2) (Risk acceptability). De Veiligheid 55(2):87-88

Boskma P (1977). Definitie van het risicoprobleem (Definition of risk problems). De Veiligheid 53(5):237-238

Buschmann C (ed.)(1974). Loss Prevention and Safety Promotion in the Process Industries. Proceedings of the first International Loss Prevention Symposium, May 28th -30st Royal institute of Engineers (KIvI) and Royal Netherlands Chemical Society (KNCV). Elsevier, Amsterdam

Calder J (1899). The prevention of factory accidents. Longmans Grewen Co London

Carson R (1962). Silent Spring. Houghton Mifflin, Boston

Carson P Mumford C (1979). Major hazards in the chemical industry Part II their identification and control. Journal of Occupational Accidents 2:85-98
Cleveland R Cohen H Smith M Cohen A (1979). Safety Program Practice in record holding plants. DHEW-NIOSH Publications no. 79-136, NIOSH Morgantown
Cohen A Smith M Cohen H (1975). Safety Practices in high versus low accident rate companies. US Department of Health, Education, and Welfare, Centre of Disease Control, NIOSH, Cincinnati
Cohen A (1977). Factors in successful occupational safety training Journal of Safety Research 9(4):168-178
Cohen A Smith M Anger W Self (1979). Protective measures against workplace hazards. Journal of Safety Research 11(3):121-131
Cowee G (1916). Practical safety, methods and devices. Manufacturing and engineering. Van Nostrand Co, New York
DeBlois L (1926). Industrial safety organization for executives and engineer. McGraw-Hill Book Company, New York
Deming W (1982). Out of crisis, quality, productivity and competitive position. Cambridge University Press, Cambridge
Department of Employment (1975). The Flixborough disaster. Report of the Court of Inquiry. Her Majesty's Stationery Office, London
Dop G (1979). Onbetrouwbaarheid van een technisch system (The unreliability of a technical system). De Veiligheid 55(1):19-25, 55(5):249-253, 55(11):593-597, 55(12):657-662
Dunn J (1972). A safety analysis technique derived from skill analysis. Applied Ergonomics 3(1):30-36
Eastman C (1910). Work-accidents and the law. The Pittsburgh survey. Charities Publications Committee, New York
Ellis L (1975). A review of research on efforts to promote occupational safety. Journal of Safety Research 7(4):180-189
Factory Act (1844), Referred to by Hale A (1978). The Role of Government Inspectors of Factories with Particular Reference to their Training Needs. PhD Thesis, University of Aston, Birmingham.
Fawcett H (1965a). Chemical Booby traps. Safety Industrial & Engineering Chemistry 89-90 ACS Publications
Fawcett H (1965b). The literature on chemical safety Journal of Chemical Education 42(10):A815-A818, 42(11):A897-A899
Ficq C (1976). Rapport over de explosie bij DSM Beek (L), 7 november 1975. Gaswolkexplosie in Naftakraker II. . Korps Rijkspolitie Maastricht, Dienst Bewaking en Beveiliging DSM, Dienst Stoomwezen, Arbeidsinspectie
Fletcher J (1978). Total Loss Control. De Veiligheid 54(5):203-207
Freud S (1901). Psychopathology of everyday life, translated by A Brill (1914). MacMillan Co New York
Gilbreth F Gilbreth L (1917). Applied Motion studies. Sturgis and Walton, New York, NY
Gibson J (1961). The contribution of experimental psychology to the formulation of the problem or safety - a letter for basic research. Behavioural Approaches to Accident Research. Association for the Aid of Crippled Children, New York, 77-89, included in: Haddon W Suchman E, Klein D (eds.) (1964). Accident research, methods and approaches. Harper & Row, New York
Goossens L (1981). Veiligheidskunde aan de Technische Hogeschool te Delft (Safety Science at the Delft University of Technology). Tijdschrift voor Sociale Geneeskunde 59(9):312-316
Gordon J (1949). Epidemiology of accidents. American Journal of Public Health 39:504-515, included in: Haddon W Suchman E, Klein D (eds.) (1964). Accident research, methods and approaches. Harper & Row, New York
Greenwood M Wood H (1919). The incidence of industrial accidents upon individuals with special reference to multiple accidents. Industrial Fatique Board, report nr 4. Her Majesty's Stationary Office, London
Groothuizen T (1976). De explosie in Flixborough (The explosion at Flixborough). De Veiligheid 52(2):41-44
Gulijk C van Swuste P Zwaard W (2015). Heinrich's models. Journal of Risk Research (submitted)
Haddon W (1963). A note concerning accident theory and research with special reference to motor vehicule accidents. Annals of the New York Academy of Science 107:635-646
Haddon W Suchman E, Klein D (eds.) (1964). Accident research, methods and approaches. Harper & Row, New York
Haddon W (1968). The changing approach to the epidemiology, prevention, and amelioration or trauma: the transition to approaches etiologically based rather than descriptive. American Journal of Public Health 58 (8):1431-1438
Hale A Hale M (1970). Accidents in perspective. Occupational Psychology 44:115-122
Hale A Hale M (1972). A review of the Industrial Accident Research literature. Her Majesty's Stationary Office, London
Harvey B (1979). Flixborough 5 years later. The chemical engineer 349:697-698
Heijermans L (1905). Gezondheidsleer voor arbeiders. (Hygiene for workers). Brusse Rotterdam.
Heinrich H (1927). The 'incidental' cost of accidents. National Safety News (February 1927): 18-20
Heinrich H (1928). The origin of accidents. National Safety News, July p. 9-12, 55
Heinrich H (1929a). The foundation of a major injury National Safety News 19(1):9-11, 59
Heinrich H (1929b). Message to the foreman. National Safety News, December p. 23-23, 51-52
Heinrich H (1931). Industrial accident prevention, a scientific approach. McGraw-Hill Book Company, New York
Heinrich H (1941). Industrial accident prevention, a scientific approach. McGraw-Hill Book Company, New York
Heinrich H (1950). Industrial accident prevention, a scientific approach. McGraw Hill Book Company, New York
Heinrich H Cranniss E (1959). Industrial accident prevention, a scientific approach. McGraw Hill Book Company, New York
Home Office (1911). Report of the departmental committee on accidents in places under the factory and workshop act. HMSO, London
Hofstede G (1978). The poverty of management control philosophy. Academy of management review 3(3):450-461
HSC (1976). Health and Safety Commission, Advisory Committee on major hazards, first report. Her Majesty's Stationery Office, London
HSC (1979). Health and Safety Commission, Advisory Committee on major hazards, second report. Her Majesty's Stationery Office, London
HSE (1976). Health and Safety Executive, success and failure in accident prevention. Her Majesty's Stationary Office, London
Johnson W (1970). New Approaches to safety in industry. Industrial and Commercial Techniques LTD, London
Johnson W (1973a). Sequences in accident causation. Journal of Safety Research 5(2):54-57
Johnson W (1973b). The Management oversight and risk tree – MORT, including systems developed by the Idaho Operations Office and Aerojet Nuclear Company. US Atomic Energy Commission, Division of Operational Safety – SAN 821-2/UC-41
Juran J (1951). Quality control, reference book McGraw-Hill New York
Juran J Barish N (1955). Case studies in industrial management McGraw Hill Book Company New York
Kirwan B (1994). A guide to practical human reliability assessment. Taylor & Francis, Bristol

Kletz T (1976). Accident data – the need for a new look at the sort of data that are collected and analysed. Journal of Occupational Research 1:95-105
Kuiper J (1973). Veiligheid als gezondheidskundig begrip (Safety as health concept). De Veiligheid 49(12):415-422
Koornneef F (1979). Veiligheid en systeembenadering (safety and system approach). De Veiligheid 55(7/8):393-394
Koornneef (2013). persoonlijke mededeling (personal communication)
Kraan C Schenke M (1976). Spanningsvelden voor de veiligheidsfunctionaris, door werkgroep 13. (Tension for safety officers, by working group 13) De Veiligheid 52(4):143-145
Lees F (1980). Loss prevention in the process industry. Butterworth Heinemann, Oxford
Leij G van der Mutgeert B (1977). Risk analysis: industry, government and society, verslag TNO conferentie. De Veiligheid 53(4):165-168
Leij van der (1978). Veiligheid geïntegreerd in de bedrijfsvoering (Safety integrated in business). De Veiligheid 54(4):137-142
Leij van der (1979). Techniek van het veiligheidsmanagement, boekbespreking Dan Petersen (Technique of safety management. Book review Dan Petersen). De Veiligheid 55(3):129-130
Maslow A (1943). A theory of motivation. Psychological Review 50:370-392
Meertens D Zwam H van (1976). Een discussiestuk over de toekomst der veiligheidsfunctie, werkgroep 13 (A discussion paper on the future of safety functions, working group 13). De Veiligheid 52(4):113-123
Minzberg H (1979). The structuring of organisations, a synthesis of the research. Prentice-Hall. Englewood Cliffs, NJ
Moore P (1968) Basic Operational Research. Pitman Publishing, New York
National Safety Council (1914). Referred to in Greenwood E (1934). Who pays? Doubleday Doran Co Inc. New York
Nettleton M (1976/1977). Some aspects of vapour cloud explosions. Journal of Occupational Accidents 1:149-158
Nettleton M (1976). Alleviation of blast waves from large vapour clouds. Journal of Occupational Accidents 1:3-8
Nielsen D (1971). The cause/consequence diagram method as a basis for quantitative accident analysis. Danish Atomic Energy Commission, research Establishment Risø. Rapport Risø-M-1374
Nielsen D Platz O Runge B (1975). Cause consequence diagram. IEEE Transactions on Reliability R24(1):8-13
Nye D (2013). America's assembly line. The MIT Press, Cambridge MA
Oostendorp Y Zwaard W Lemkowitz S Gulijk C van Swuste P (2013). Introductie van het begrip risico binnen de veiligheidskunde in Nederland (Introduction of the concept of risk in safety science in the Netherlands). Tijdschrift voor toegepaste Arbowetenschap 26(3-4):75-91
Oosterom N (1979). Humanisering van de arbeid (Humanisation of labour). De Veiligheid 55(7/8):382-383
Parker R (1975). The Flixborough disaster, report of the court of inquiry. Department of Employment. Her Majesty's Stationary Office, London
Pasmooij C (1979). Ongunstige arbeidsomstandigheden en mens-factoren in hoog-geautomatiseerde systemen (Unfavorable working conditions and human factors in highly automated systems). De Veiligheid 55(4):161-165
Petersen D (1971). Techniques of safety management. McGraw-Hill Book Company, New York
Petersen D (1975). Safety management a human approach, a human approach. McGraw-Hill Book Company, New York
Petersen D (1978). Techniques of safety management. McGraw-Hill Book Company, New York
Pindur W Rogers S Kim P (1995). The history of management: a global perspective. Journal of management history 1(1):59-77
Pfeifer C Schaeffer M Grether C Stefanski J Tuttle T (1974). An evaluation of policy related research on effectiveness of alternative methods to reduce occupational illness and accidents. Behavioural Safety Centre, Westinghouse Electrical Co, Columbia, Maryland
Pope W (1976). Systems safety management: een nieuwe opvatting over interne management communicatie en veiligheid. De Veiligheid 52(12):487-490
Powell P Hale M Martin J Simon M (1971). 2,000 accidents, a shop floor study of their causes on 42 months' continuous observation. National Institute of Industrial Psychology, London
Radandt S (1979). Perspectieven voor de ontwikkeling van de veiligheidstechniek (Perspectives for the development of safety technique). De Veiligheid 55(11):577-578
Rasmussen N (1975). Reactor safety study. An assessment of accident risks in the US commercial nuclear power plants, WASH-1400, NUREG-75/014. Nuclear regulatory Commission, Rockville, MD, USA
Reeves T Turner B (1972). A theory of organisation and behaviour in batch production factories. Administrative Science Quarterly 17(1):81-98
Reijnders L (1979). Drie visies op veiligheid, de deugdelijke machine en de ondeugdelijke mens (Three visions on safety, the sound machine and the unsound human). Risicobulletin 1(1):5-7
Rigby L Swain A (1971). In-flight target reporting –how many is a bunch? Human factors 13(2):177-181
Robens (1972). Committee on safety and health at work (1972). Report of the Committee 1970-1972, chairman Lord Robens. Her Majesty's Stationery Office, London
Rowe W (1977). An anatomy of risk. John Wiley & Sons, New York
Sadee C Samuels D O'Brien T (1976). The characteristics of the explosion of cyclohexane at the Nypro Flixborough plant on 1st June 1974. Journal of Occupational Accidents 1:203-235
Schein E (1972). Organization Psychology. Prentice-hall. Englewood Cliffs, NJ
Singleton W (1960). An experimental investigation of speed controls for sewing machines. Ergonomics 3(4):365-375
Singleton W (1967a). Ergonomics in system design. Ergonomics 10(5):541-548
Singleton W (1967b). The system prototype and his design problems. Ergonomics 10(2):120-124
Singleton W (1969). Display design principles and procedures. Ergonomics 12(4):519-531
Singleton W (1971). The ergonomics of information presentation. Applied ergonomics 2(4):213-220
Singleton W (1972). Techniques for determining the cause of error. Applied Ergonomics 3(3):126-131
Strien P van (1978). Humanisering van de arbeid en de kwaliteit van het bestaan (Humanisation of labour and quality of live). Tijdschrift voor Sociale Geneeskunde 56:682-689
Swain A (1964). Some problems in the measurement of Human performance in man-machine systems. Human Factors 6(6):687-700
Swain A (1973). Design of industrial jobs a worker can and will do. Human factors 15(2):129-136
Swuste P Gulijk C van Zwaard W (2010). Safety metaphors and theories, a review of the occupational safety literature of the UK, UK, and The Netherlands, till the first part of the 20th century. Safety Science 48:1000-1018

Swuste P Gulijk C van Zwaard W Oostendorp Y (2014). Occupational safety theories, models and metaphors in the three decades since World War II, in the United States, Britain, and The Netherlands: a literature review. Safety Science 62:16-27
Taylor F (1911). The principles of scientific management. Harper & Brothers, New York. An unabridged republication is published by Dover publications Inc., Minola NY in 1998
THD (1978). Technische Hogeschool Delft. Universitair Onderwijs en Onderzoek in Veiligheid, Deel 1, Eindverslag (Delft Technical University. Academic research and education, part 1, final report). Symposium bureau TH Delft
Turner B (1971). Exploring the industrial subculture. The MacMillan Press LTD London
Turner B (1976). The organisational and inter-organisational development of disasters. Administrative Science Quarterly 21(3):378-397
Turner B (1978). Man-made disasters. Butterworth-Heinemann Oxford
Turner B Pidgeon N (1997). Man-made disasters. Butterworth-Heinemann Oxford
US Steel (1913). Referred to in Aldrich M (1997). Safety First. Technology, labour, and business in the building of American work safety 1870-1939. John Hopkins University Press, Baltimore, Maryland
Vernon H (1936). Accidents and their prevention. University Press, Cambridge
Versteeg J (1979). Het ongeval met de kerncentrale Three Mile Island (The accident at the Three Mile Island nuclear power plant). De Veiligheid 55(9):439-442
Wansink J (1976). Risicobeheersingsmethodiek in de veiligheid (Risk control methods in safety). De Veiligheid 52(10):377-386
Weick K (1976). Educational organisations as loosely coupled systems. Administrative Science Quarterly 21(1):1-19
Wetenschap en Samenleving (1978). Boem in Rijnmond, themanummer risicoacceptatie (Boom in Rijnmond, special issue risk acceptance). Verbond van Wetenschappelijke Onderzoekers, Bond van Wetenschappelijke Arbeiders
Westerouwen van Meeteren F (1893). Handboek der nijverheids-hygiène. (Reference book of hygiene). Elsevier, Amsterdam
Williams S (1927). The manual of industrial safety. Shaw Company, New York
Winsemius W (1951). De psychologie van het ongevalsgebeuren. (Psychology of accidents). PhD thesis, Verhandeling van het Instituut voor Preventieve Geneeskunde, Kroese, Leiden
Wijk L van (1977). Het ongevalsproces, een systeemmodel (The accident process, a systems model). De Veiligheid 53(10):433-436
Wright R (1978). Wat is loss management (1), (2) (What is loss management). De Veiligheid 54(5):209-216, 54(6):297-302
Zwaard W (2007). Kroniek van de Nederlandse veiligheid (Chronical of Dutch safety). Syntax Media, Arnhem
Zwam H van (1978). Veilig samenwerken. Veiligheid als voorwaarde van integraal ondernemingsbeleid (Safe working together. Safety a prerequisite of an integral company policy). Van Gorcum, Assen

Virtual reality ın occupational health and safety

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Keywords: Animation, Simulation, Construction, Labour Inspection

Abstract
Unfortunately, despite the technological developments, the number of occupational accidents and occupational diseases has been increasing day by day according to the raise of the number of employees across the world. The rehabilitation of the occupational health and safety conditions at workplaces is the key point to decrease the number of occupational accidents and diseases. Of course, there are lots of factors affecting the conditions of workplace and one of them is inspection system of these conditions. The labour inspection is an important mechanism to improve the occupational health and safety conditions at workplaces. So the education and the edification of assistant labour inspectors should be effective and adequate.
With technological developments late 20th century a concept of virtual reality has emerged in the world. Firstly in game sector and then in some other sectors, “Virtual Reality” has entered into every point in our lives very fastly. As an inevitable result, it will be also used for occupational health and safety systems very soon. For this reason, Labour Inspection Board of Turkey has been started to use a new simulation system. Firstly, a mine and a construction have been modeled with a 3D program. According to the law and related legislations, all of the faults and shortcomings related with these sectors are shown in the simulation.
In this study, the modeled construction will be introduced. This education system is called AROSH (Augmented Reality for Occupational Health and Safety). In this program, an excavation part of a construction has been modeled. Some of construction equipments had been imported and then the scenario was created. The entire scene rendered and a video composition created. These processes which need a huge team and lot of time, was achieved with a team of three people in a very short time with outstanding work. According to the scenario, all of the law articles about the excavation shown respectively. Thus making it easier to keep law articles in mind and gives opportunity to debate on event cases. Also a situation can be seen with lots of perspectives and can be analyzed easier.
Firstly, AROSH (Augmented Reality for Occupational Health and Safety) will be used to educate the assistant labour inspectors about inspections and legislations. In the second part of project, simulations will be use to raise the awareness of employers and employees. Also the program will be moved on a different platform and it will be interactive presentation with users. So a user can travel around the excavations and examine the equipments and analyze the situation as he/she lives in there. In case of an emergency or in case of a bad state he/she will confront what needs to be done.
As a result, a 3D program has been used to form an education program of assistant labour inspectors. Of course this program is an open program to develop. In the future, the workplace inspections will be possible when we are sitting in our office with augmented reality and so this is the first step of this dream.

1. INTRODUCTION
Unfortunately, despite the technological developments, the number of occupational accidents and occupational diseases has been increasing day by day according to the raise of the number of employees across the world. Especially occupational accidents in Turkey in recent years, made it necessary to include new methods for the promotion of occupational health and safety culture throughout the country. Labour Inspection Board has an important position for the implementation of these new methods. Although not having a direct impact on the prevention of occupational accidents, Labour Inspection Board has a key role for the improvement of workplace health and safety conditions. For these reasons, the board has been started to use a new animation and simulation system since the beginning of 2015.

2. MATERIALS AND METHODS

2.1. ANIMATION FOR EDUCATION
Animation is the process of creating the video of motion and shape change by means of the rapid display of a sequence of images that differ from previous image. Animations are excellent

tools that can be used for understanding the issues easier and more effective and to educate the people. For this reason, Labour Inspection Board prepared a work schedule for the education and the edification of assistant labour inspectors. AROSH (Augmented Reality for Occupational Health and Safety) will be used to educate the assistant labour inspectors about inspections and legislations. First of all, to increase the effectiveness and adequateness of educations, 3D animations prepared for the construction and mining sectors. By this way, assistant labour inspectors were able to see all of what is written in the legislations before they go to the inspections of workplaces. Not only the assistant labour inspectors, also the inspectors in other occupational groups also could see visually what they will be encountered in the construction and mining workplace conditions. Then prepared animations, were shown to inspectors. Of course inspectors have adequate knowledge in terms of legislation, but visuals can change inspectors' practical vision regarding the applicability of the legislations in the best sense. Animations, provides the opportunity to see the possible lack of safety precautions at workplaces without inspecting a workplace. Also it is allowing discussions to be made on issues about occupational health and safety.

3D animations composed about excavation and scaffolding subjects in construction. Excavation animation shows thirteen deficiency about occupational health and safety and the precautions for the deficiencies. To compose the animation, first of all, according to the inspections and occupational accidents statistics the most common deficiencies are identified in the excavation work and the scenario was created. After that in terms of being realistic, the equipment and the environment to be used is determined and they began to be created with vector lines as shown in the Figure 1.

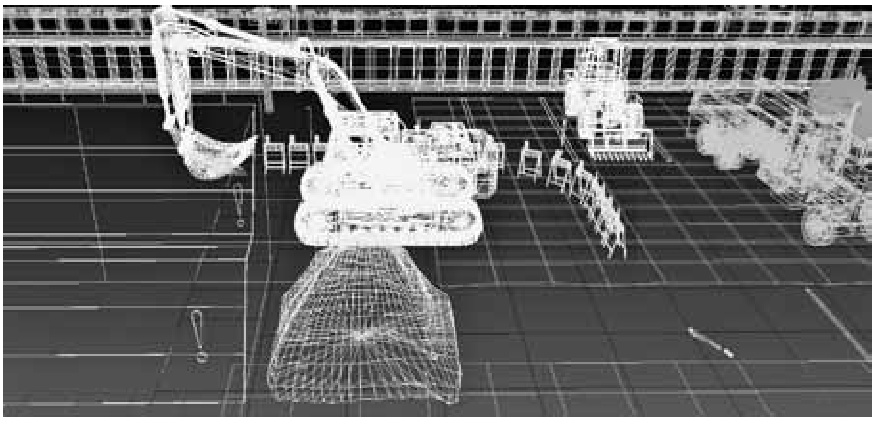


Figure 1 – The environment and the construction equipments created with vector lines

Afterwards, the materials of the drawn equipments and environmental factors have been identified. During the determination of the properties of materials, it had been paid attention the materials to be more realistic. Assigned material properties and equipments as shown in the Figure 2 were analyzed detailly in the program.

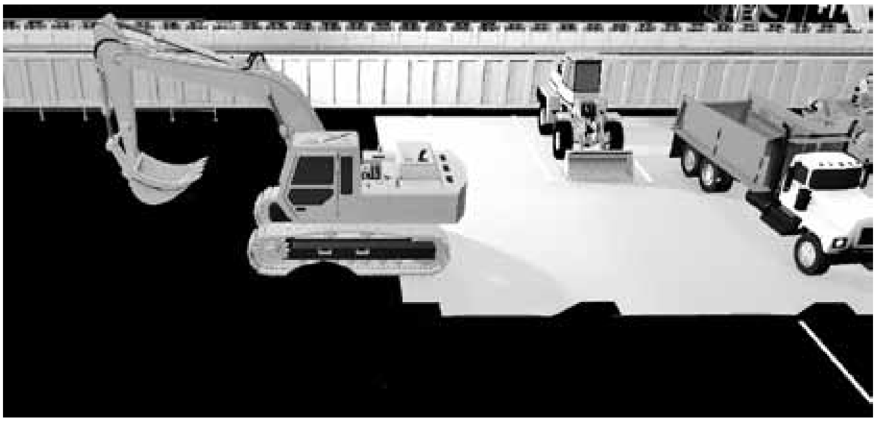


Figure 2 – Assigned materails and equipments

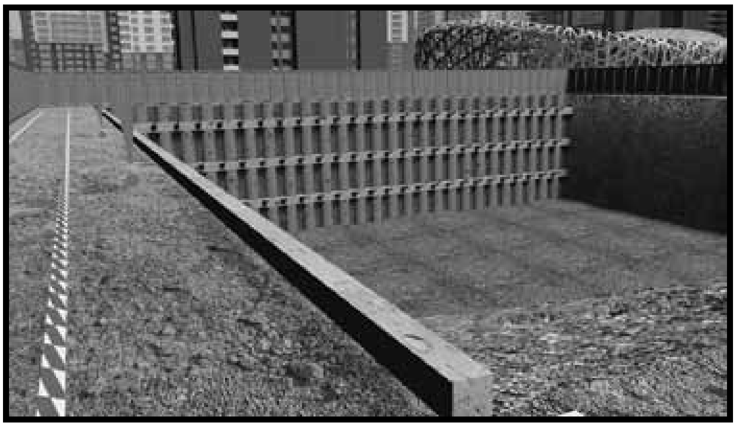
And finally the computer rendered the scenario according to the camera movements and the animation composed. While rendering the computer calculates the colour of every pixel according the light and material properties (Figure 3).

Figure – 3 Rendered screen

In the program some equipments modeled by the team of the Board but beside them some of ready equipments had been imported from some free libraries.
The animation shows the deficiencies of the excavation workplaces and the measurements that should be taken for these deficiencies according to the legislations.

2.2. VIRTUAL REALITY

Virtual Reality is a continuously evolving new computer technology, which allows users to interact with computers in a new way. Virtual Reality is also a simulator, but instead of looking at a flat screen and operating a joystick, the user who experiences with some special glasses, virtual reality is surrounded by a three-dimensional environment generated representation, and is able to move around in the virtual world and sees it from different angles, to reach into it, grab it and reshape it. After the creation of animations, in the scope of education of assistant labour inspector, the media built in the 3-D program exported to a simulation engine program. Then the environment built by the engine afterwards an environment created that can be used in an interactive way by user. For instance, in the program, when a user comes next to an excavation border without railing system, the program gives alert and wants user to find the deficiency (Figure – 4)



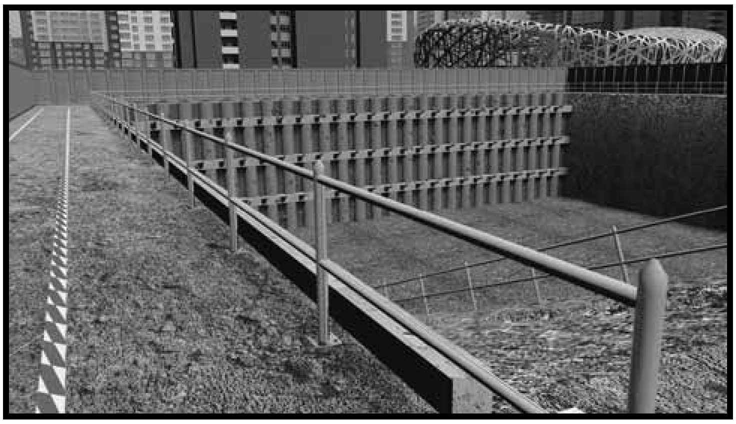


Figure – 4 Excavation border without precaution / with precaution

Another deficiency shown in the Figure - 5 is about where the entrance and exit to excavation areas should be located.

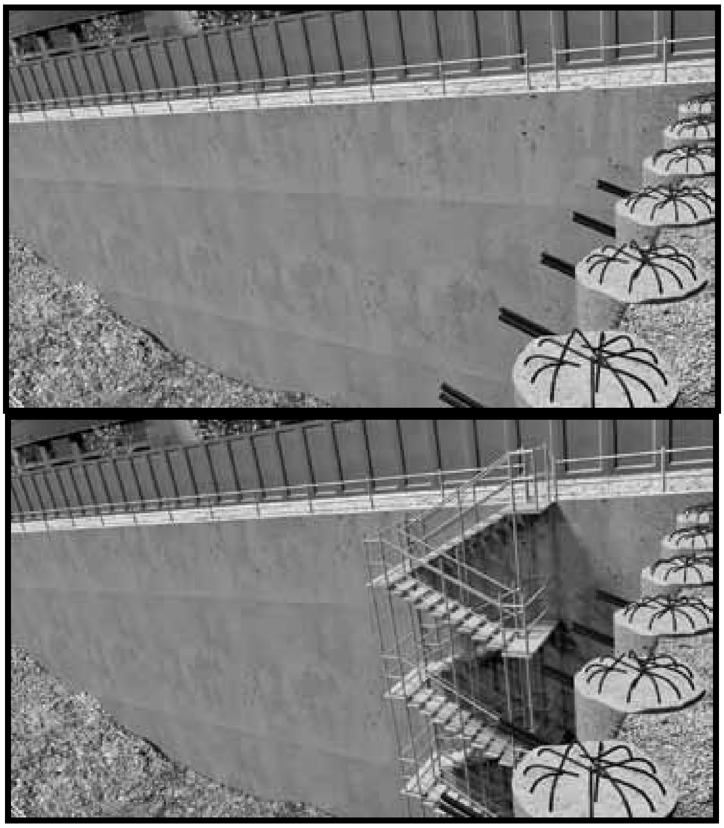


Figure – 5 the entrance and exit to excavation areas

The first part of AROSH is used to train assistant labour inspector. In 2016, the second part of AROSH, the simulation, is intended to be used in trainings of inspectors. For now three simulation trainings completed for construction site education. One of the subjects is about excavation, the other is related scaffoldings and the last is about general deficiencies of a building construction. The supply of special glasses is planned by the end of this year. So it will be used with the simulated environment next year.

Virtual reality is not just to see how the legislation is applied to workplaces, at the same time it is an excellent tool to predict how the accidents might be in workplaces. Investigating an accident by reconstructing it using advanced computer graphics techniques is an essential step towards improving the safety performance of the construction sites With this way poeple can understand:

- How the accident happened,
- Why it happened,

- How it could have been prevented,
- How injuries or fatalities could have been avoided.

With virtual reality it is possible to see 3D virtual environment of workplaces and to test the physical results of equipments.

2.3. AUGMENTED REALITY

Augmented reality is a live direct or indirect view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory input such as sound, video, graphics or GPSdata (Figure - 6). Augmented reality is a very important factor for the future as can be understood from the definition of it. In the long-term plan of Labour Inspection Board, the use of augmented reality is included in for occupational health and safety inspections. By special glasses which can be used in accordance with the virtual reality programs, an inspector will realize where is a deficiency at work places. For example, first of all the special glasses will perceive a worker and then it will control the helmet of him or the mask. And also when a personel protective equipment will be showed to the glasses it will check if it is suitable for the risk of workplaces.

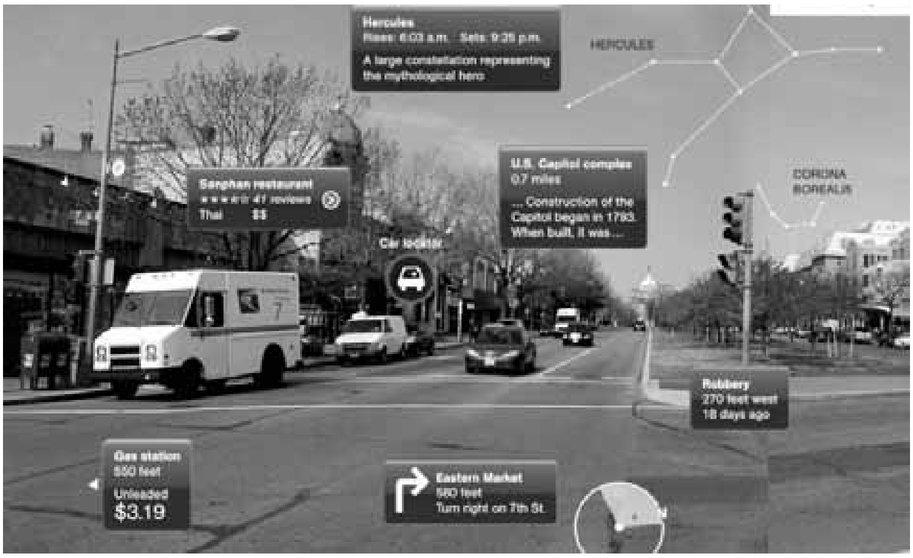


Figure – 5 Augmented reality for an environment

3.RESULTS AND DISCUSSION

All the animation, virtual and augmented reality are the parts of the future technologies. The animation education given to the assistant labour inspectors showed us that visual perception is very important to clucth the legislations. The subjects have been clutched by assistant labour inspection very clearly as can be understood from their exams. But of course it takes a lot of time to compose a 3D construction environment but if it once created it can be used by all the programs. Also Virtual Reality offers limitless possibilities in training, simulation and education. It has a great potential to increase productivity, better utilise time and most importantly improve safety awareness and therefore reduce incidents.

4.CONCLUSIONS

Workplace safety is paramount for all production sectors throughout the world.The aim of the preliminary and formative usability evaluation study was to investigate the design of the virtual reality system to trigger virtual reality design improvements and to prepare for more comprehensive usability evaluation studies in order to facilitate generalisation of research into virtual reality applications for real world scenarios to the greatest possible extent. So to increase awareness of occupational health and safety of all parts, and to improve the occupational health and safety conditions in workplaces virtual reality is a very good technological solution. Labour inspection Board of Turkey has been started to work on virtual reality and augmented reality fort his. As a result, a 3D program has been used to form an education program of assistant labour inspectors. Of course this program is an open program to develop. In the future, the workplace inspections will be possible when we are sitting in our office with augmented reality and so this is the first step of this dream.

5.REFERENCES

Kızıl, M.S., Virtual reality applications in the Australian minerals industry. *Application of Computers and Operations Research in the Minerals Industries,* South African Institute of Mining and Metallurgy, 2003 (pp. 569-574),

Nickel P., Lungfiel A., Naber B., Hauke M., Huelke M., *Virtual Reality in Occupational Safety and Health for Product Safety and Usability,* Proc. of the 7th International Conference on Safety of Industrial Automated Systems (SIAS), Montréal, 2012,

Zhao, D., Mobile Virtual Reality — An Approach for Safety Management, (p. 153,170),

Kizil, M.S., Joy, J., What can Virtual Reality do for Safety?, (p.1,8)

Change Laboratory: Formative Intervention and remodelling of the system of activity of a Centre of Reference for Worker Health in Brazil

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1. INTRODUCTION

Developing labour inspection activity is a challenging task. Interventions aimed at developing such activities should not be limited to the development of methods and tools (BRUHN and FRICK, 2011).

The Worker Health Services emerged in Brazil, in the 80's, as a result of social struggle for the paradigm change in the health-work relations in the country.

Embedded in the Institutional framework of Public Health and augmented in the Unified Health System (SUS, Portuguese acronym, from now on) after the enactment of the Brazilian Constitution of 1988, it acquired normative legitimacy and capillarization in several States of the federation (VASCONCELLOS and RIBEIRO, 2011).

In this perspective, the area of Worker Health in Brazil, influenced by the Italian sanitation reform, consolidated itself as a field of knowledge and practices, acting on the determinants of the health-illness process, originated from the production and service processes, shaped by the theoretical assumptions of Latin-American Social Medicine (VASCONCELLOS and RIBEIRO, 2011). It has as main objects of intervention, work accidents and work related illnesses.

After it inclusion in SUS, municipal services were set up, called Centres of Reference in Worker Health (CEREST- Portuguese acronym, from now on), representing the government policy strategy in the decade of 2000 to nucleate the actions in Worker Health, which would enable, depending on the success of the experiences with activities of surveillance and prevention, have a positive impact on the worker conditions in the formal and informal sectors of the economy. However, these services, with rare exceptions, still lack consistent articulation with other SUS organic structures, greater investment and consolidation with priority public policy in addressing the relevant epidemiological problems such as deaths, mutilations and incapacities, plus work related traumatic occurrences.

The directives of the Ministry of Health for monitoring initiatives related to Worker Health include: the principles of integrality, pluri-institutionality, social control, among others, apart from research-intervention which has as prerogative the characteristic of transforming the conditioners and determiners of occupational health hazards (BRASIL, 1998).

In order to address these questions some few services developed initiatives of prevention and promotion of worker health, with activities, dialectically articulated, but which contemplate two differentiated subject contents: the first being focussed on collective preventative practices in the workplace, processes and forms of work organization, health hazard generators, and the second, of an individualized therapeutic nature, interpreted as clinical assistance activities and rehabilitation. Both receive the broader denomination of Worker Health Surveillance and are developed by multi-disciplinary teams, whose composition varies according to the availability of human resources, but which can cover the technical professional categories of work security, engineers, doctors, psychologists, occupational therapists, physiotherapists, phonoaudiologists, social assistants, sociologists, nurses, and nurses in training, amongst others. With these types of intervention actions, it is possible to interrupt the cycle of illness and work related deaths, avoiding new cases, as well as minimizing the devastating consequences of these traumatic occurrences for the workers and their families.

1.1 Justification

Given the complexity of the surveillance actions, the professional of the multi-disciplinary team of a CEREST in the interior of São Paulo/Brazil, with twelve years of existence, complained about the conceptual and technical difficulties in the development of their activities, such as the planning of priority actions in the light of the numerical significance of demands induced by the notification system for severe and grave work accidents, and through the channelling of patients from the public and private medical care services and by means of the system of general public

complaint schemes. Other contradictions were also identified in relation to the low reach of the instruments in the light of heterogeneity of the object, since the traditional technical tools, such as inspections and supervisory monitoring on the basis of Regulatory Norms (RN) of the Ministry of Labour (MTE – Portuguese acronym) did not capture the hidden organizational questions, such as work rhythm, adequate workforce numbers, and abusive production targets, work density, work intensity, authoritative and harassing management style and contradictions between programmed work and real work.
By means of a University partnership integrating thematic project with a duration of five years, the proposal of a Change Laboratory (CL) was found to be appropriate with the needs to indentify and equate the crisis lived by the professional in service with the objective of identifying and discussing the contradictions in the system of activity with a view to their future remodelling. At the same time, their application would result in incorporation of the methodology by the team, in this way becoming a wider-ranging technical tool for the intervention in historically degraded security systems, contributing to the increase in preventative actions developed by the group.

1.2 General Objective

The main objective of this intervention research was to improve the preventative and promotion of worker health actions undertaken by CEREST.

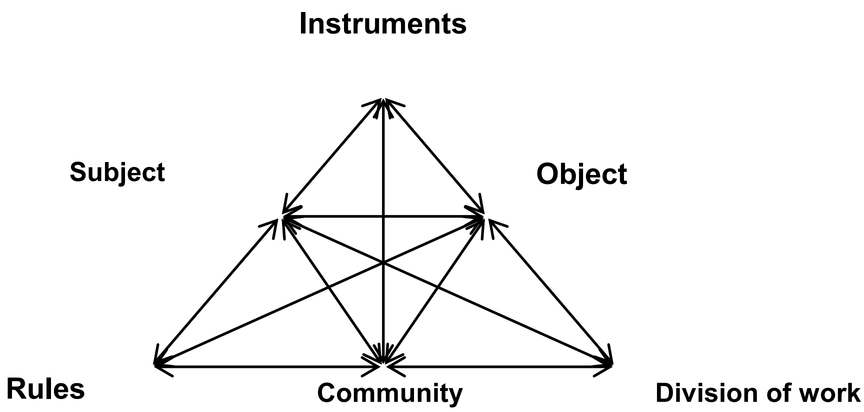
1.2.1 Specific Objectives

- To bring to the surface the contradictions existing in the system of activity of CEREST which impeded reaching more satisfactory results;
- To contribute to the remodelling of this system in such way so as to overcome these contradictions;
- To favour the learning process of the participants regarding Change Laboratory (CL) methodology.

2 METHODOLOGY

The methodology used was Change Laboratory, developed in Finland in the 90’s, and based on the referential, the Theory of Activity, originated by Vygotsky (1978), and developed by Leontiev (1978) and Engeström (1978). Using as guidelines a series of concepts and methods, it enables the possibility of contributing to the development and learning of subjects which come together to define and improve the activity system of which they are a part. Starting from planned sessions and with the participation of interventionist researchers, who would have the role of facilitators in the application of the methodology, the individuals themselves would develop new understanding concerning the purpose of their activity and its modifications over the length of the historical process to which they were being subjected (PEREIRA-QUEROL et al., 2011; VIRKKUNEN and NEWNHAM, 2015).
The intervention was based on the undertaking of meetings, in the workplace itself, to which analytical tools of the work process in focus were made available, prepared by the interventionists with assistance from the professionals of CEREST. Ethnographic research to collect historical data concerning the services and its functioning, the alterations in the quantity and quality of demand and the present practices, that is, the forms by which the activities are conducted in the present and in the past.
Regarding the information gathering of the main problems faced by the team, semi-structured interviews were applied on the professionals who took part in both the inspections as well as in therapeutic activities, including, the representatives of trade unions who are institutional partners of this service. Two management bodies were interviewed – the Coordination of CEREST and the Coordination of the Area of the Municipal Health Surveillance. Documental research was also undertaken in the records of the service itself.
The findings were used as *database mirror of the activity*, with the purpose of offering key information to the participants for the debate of the content of the activity over the length of time – past, present and future. The 13 sessions carried out followed the model proposed by Engeström (1996): (1) analysis and historic formation of the elements of the activity; (2) identification of the contradictions in the system of activities and between related systems; (3) modelling of a new system and new instruments with the purpose of resolving the contradictions identified; (4) testing of the application of the new model; (5) evaluation and consolidation of the new model.

For definition of the activity system, the following conceptual instrument was used, shown in Figure 1.



Source: Engeström et al., 1996 p.11

The elements presented can be defined as follows: A) *subject* – which can as much apply to an individual as well as to a group of people, whose visions will be valued regarding the perspective of analysis; B) *object* – understood as being the purpose of an activity system; C) *instruments* – all the action mediator tools of the subjects, of a physical or symbolic nature, such as devices, furnishings, support texts, legislation, concepts, action plans etc…; D) *community* represents the group of individuals, the organized groups who have interface with the activity system; E) *division of work* being the division of tasks among the subjects, the hierarchy between them, and the relations of conflict and resistance; F) *rules* are the regulations, norms, conventions and agreements, formal or informal, related to the context of activity (ENGESTRÖM, 1987; ENGESTRÖM et al., 1996).

The material was recorded, which facilitated its analysis and guidance in the undertaking of formation intervention sessions. The number of participants varied from 9 to 14 people, in that one group showed resistance related to mapping out the problematic situation and returning some sessions later. In sessions of creation of a new model the group reached a formation of 19 participants. The subjects participated voluntarily of the group, the ethical precepts of research being respected.

At this moment, this model redesigned by the participants is in test. The immediate coordination approved the model. After the test it will be presented with data of successes and failures to the senior management and other members of the community for validation and, if necessary, new adjustments will be made until the consolidation of the final model. The interventionist researchers of CL will accompany this process of testing undertaking sessions every so often.

3 RESULTS

The first sessions of CL were focussed on understanding how the activity system of CEREST was and what were the difficulties and present necessities. The participants discussed that although this was an already quite an advanced service when compared with others in CERESTs of the country; there still persisted some difficulties not overcome.

The first discussions showed consensus of the group as to the evolution in service activities and in the recognition of CEREST by the community (trade unions, companies, Ministry of Labour, Regional Superintendence of Labour, civil society).

"(...) *we evolved, but it's necessary to study more, but since the demand is big and the service has to give responses to the people that knock on our door, there is little or no time to study. And CEREST has become much more visible, and for this reason more sought after than three years ago, with much greater volume of activity and much more demand"* (Subject A).

"´*Previously there was more team work, everyone learnt more and the successful results were greater"* (Subject B).

The increase in demand created a need for a redesign of the service activity system, leading to a new division of work – what previously had been undertaken as a team, was now undertaken done individually, with productivity targets of ten inspections per month. The conversations demonstrated the discontent as a consequence of this induced demand and the perception that the lack of success was linked to the hypertrophy of the demand and the impossibility of going more deeply into the study of cases, understood as instrument of group work.
These conversations exemplify the discontent and the perception of lack of success in the actions.
In subsequent sessions the object of the work of CEREST was discussed. The participant made the point that the present object of the service was oriented just to work conditions with pathogenic potential for accidents or illnesses and that one-off inspections related to the approximate reasons were predominating in the functioning of the group, which was perceived as being incomplete, unsatisfactory and demotivating. The debate on the conceptual and technical difference between supervision and surveillance extended over a number of encounters until the understanding prevailed that the object needed to be broadened, and that new instruments and new rules needed to be added to the work. It was concluded that to operate in surveillance demands knowledge and planning not just about conditioning factors or causes closer to the events, but rather about the macro social determinants of work accidents and illnesses. These broader comprehensions of the object motivated the group to question and identify problems and contradictions that existed in the activity system.
The Table below represents a synthesis of the main changes suggested in the model of activity system after the CL interventions.

Table 1: CEREST Activity System before and after CL intervention

Elements of the Activity System	**Before the Intervention**	**After the Intervention**
Object	Inspection in companies on an individual basis regarding specific cases Sectoral Projects	**Worker Health Surveillance**
Division of Work	Differentiated teams for: Surveillance Rehabilitation Assistance Database typing	The same teams undertake the same tasks. The tasks were differentiated for: Emergency Actions Planned Actions Information Room
Instruments	Regulatory Norms Work divided by sectoral actions induced by demand Negotiation (meetings, round table, forums and public hearings) Conduct Adjustment Term Sanitary Authority MAPA Fire Brigade Sanitary Code Technical Notes from MTE	Regulatory Norms Work by planned actions Negotiation (meetings, round table, forums and public hearings) Conduct Adjustment Term Sanitary Authority MAPA Fire Brigade Sanitary Code Change Laboratory Information Room Ergonomic Analysis of Work
Subjects	Supervisor flavour of the month	Multidisciplinary Team
Rules	Compliance with Targets Inspect all the severe and fatal accidents Inspect all the denunciations through 156, trade unions and Ministry of Labour	Autonomous Consensus Planning To be present at meetings
Community	Universities , Workers, SUS, INSS, MPT, MTE, Trade Unions, Companies and Others	Universities, Workers, SUS, INSS, MPT, MTE, Trade Unions, Companies and Others

In continuity the contradictions in each element will be detailed and the redesign proposed will be explained regarding overcoming difficulties.

3.1 The Object

The main question brought up by the group was the broadening of the object of CEREST of consolidating what conceptually and legally[1] is understood by surveillance of worker health:

> "... *a continuous and systematic functioning, over time, in the sense of detecting, knowing, researching and analysing the conditioning factors and determinants of health hazard related to the processes and workplace ambiences, in its technological, social, organizational and epidemiological aspects, with the purpose of planning, executing and evaluating interventions in these aspects, in such a way as to eliminate and control them."* (BRASIL, 1998).

In the light of the legal and conceptual complexity of the object, the group indicated as contradictory the lack of efficacy of one-off inspections, individualized and traditional in the field of Surveillance.

The professionals, in general, expressed concern with the efficacy of their interventions, evaluating when they could have a pedagogical character, in the sense of guiding change. Their efficacy seems to be reached when they coincide with moments of replanning of the organization itself due to self-recognition of the existence of problems in the area of health and safety. However, in some situations, such as for example, in companies in which there is little protection from machinery, considered obstacles to activities and to productivity, the inspectors perceived that the infraction notice or the interdiction of the dangerous machine can be an inefficient measure of prevention of new occurrences, since the company does not assume recognition of the seriousness of the situation, not paying any attention to the infractions.

The theme of accompaniment of the company actions to resolve the problem, object of the infraction notice was also amply discussed. One of the complaints of the coordination and team itself was that the processes remain open for long periods of time due to difficulties in undertaking visits of accompaniment. Once again the question of high demand and production targets seem to conflict with the activity of surveillance.

Thus, remodelling the activity of CEREST signified to the group the broadening of the work object, reaching greater efficacy in the prevention acts, by means of planned multidisciplinary functioning, prioritised by epidemiological criteria and using technical instruments of greater reach.

3.2 The Division of Work

The division of work was an altered item which demanded change throughout the system. Initially CEREST had three work fronts based on professional rankings: inspection, assistance/rehabilitation and data processing. This division established an important contradiction, since at the moment of expanding the object to health surveillance, the knowledge required was also broadened, no longer being possible to be equated by specific disciplines. To address these demands it was decided to prepare a new division of work, not based on individual competencies, but rather on multi-professional and interdisciplinary teams. The tasks were thus divided in: 1) emergency actions to respond to immediate demands coming from denunciations or Work Accident Attendance Reports (RAATs[2]); 2) an information room

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[1] Decree MS n.3.120/1998.

[2] In 2002 the SIVAT (Information System and Surveillance of Work Accidents) was implemented and developed by means of a research project, financed by FAPESP in a development programme of Public Policies (FAPESP 06/51684-3). The SIVAT operated by means of a base of ambulatory obligatory notification through the filling in of the Work Accident Attendance Report – RAAT (Municipal Decree nº 9951/2002). This Report is filled at the location of attendance and emergency services to workers sustaining accidents (Hospitals and company Ambulatories). The RAAT contains information concerning the patient, the place of the accident, a summary description of the accident and the medical bulletin concerning the diagnostic. In continuity this information is sent to CEREST and feeds the database which supplies subsidy for the implementation of Public Policies with the objective of preventing the occurrence

responsible for the feeding in of data and qualitative analysis, according to the complexity of the case, and statistics according to the criteria considered most important to work out the action strategy (index of seriousness, incidence and frequency of the accident or illness); 3) planned actions prioritized by the team, after analysis of the information room, according to the complexity and size of the case. It is worth pointing out, however, that not only was the division of work altered (who does what) but advance was made in the direction of decentralization of the power to the team to decide collectively the priorities taking into consideration the knowledge of the group concerning the companies and role-players in the territory.

3.3 The instruments

The CEREST developed with the researchers of two Brazilian universities (UNESP and USP) a tool called MAPA (Model for Analysis and Accident Prevention) (ALMEIDA et al., 2014), whose purpose is to enable analysis of wider-ranging work accidents improving the quality of the surveillances actions, permitting taking initiatives related to organizational factors of the companies with accidentogenic potential. In spite of having participated in the preparation of MAPA, the professionals reported difficulties in the application of the method.

"*I apply MAPA, but I think it is difficult, and it takes time to do. As it takes time and the work demand is high, with new accidents arriving all the time, it not possible to apply it as one might like."* (Subject C).

This conversation reveals, however, that the difficulty with the tools is much more related with the rules and quantative targets and less with the complexity or inapplicability of the instrument.

To solution this contradiction, the remodelling process was to organize the work in project of sectoral actions, prioritizing according to the analyses of the information room, including, apart from the MAPA, other tools such as the ergonomic analysis of the activity and the change laboratory, used as instruments of greater reach in the identification of the conditioning and determining factors of illnesses or work accidents and actions of improvement of these situations.

3.4 The Subject

In the previous model the subject was the "inspector flavour of the month", decided by exclusive criteria of the management. This inspector was designated, primarily to verify the situation by telecommunication, and to analyse individually if it was the case or not to undertake inspection *in loco*, by means of an existing evaluation of serious and imminent risk and of behaviours of the organization in relation to aspects of health and safety.

One of the inspector conversations indicated this dissatisfaction, because despite considering, the individual experience of each inspector related to the productive and service sectors, in the management distribution of tasks, the reality consisted in single minded and highly subjective action:

"I have fear of doing some of jobs alone, especially in isolated companies in the suburbs. I would like to undertake these cases together with another colleague, but the collaboration is difficult, understandably, because by collaborating with a colleague *one runs the risk of being unable to achieve one's own targets"* (Subject D).

Two aspects of different natures can be drawn from the remark: the first one being the individualization of the action in the light of the complexity of the confrontation involved, by means of criteria, which for the greater number of instances, the inspector did not have objective evaluation resources available. The other question is to make inspections unaccompanied by a colleague or another public organ signifies putting oneself in a situation of risk, since the inspectors sustain threats, bribery attempts and intimidation. There are situations when the inspectors have been received by the owner of the company carrying a gun in his belt.

In the remodelling, the operational functioning of the inspection was increased to a multi-professional team. The division of the teams was undertaken by the workers themselves during the CL sessions.

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of work accidents. The serious cases are considered sentinel events, that is, generate a surveillance action whose objective is to analyse and understand the determinants of that occurrence.

3.5 The Rules

The rules of compliance with targets of 10 inspections per month and to inspect all the denunciations and RAAT (s) of serious and fatal accidents were altered. The weekly meeting with the whole of the CEREST team was established as a rule, with an interdisciplinary space for discussion of problems, dilemmas and difficulties faced during the week, as well as, prioritizing and planning the actions, according to technical data from the information room and autonomy of the team consensus regarding the strategic approach adopted.

3.6 The Community

The community remained the same, since the participants of CL consider its participation essential: a) the university with research projects which end up giving support to the surveillance actions; b) the workers who are sources of important essential and important data; c) the network of attention of SUS – Unified Health System at all levels (municipal, state and federal); d) in joint actions with professionals from Social Services (INSS-Portuguese acronym); e) of the labour prosecutors from the MPT (Ministry of Labour) in sectoral projects, processes that require Conduct Adjustment Agreement (TAC-Portuguese acronym), among others; f) the auditor work inspectors of the MTE (Ministry of Labour and Work); g) the trade unions who are sources of data and should also be present at the negotiating table to exert social control;

As for the organizations, since they represent the pathogenic organization *locus,* in the first instance, become targets of intervention, however, depending on their willingness to recognise their problems of internal deterioration of the area of health and safety and implement improvement initiatives of their processes, may also come to integrate in partnership with the service in question, especially in the application of the CL method.

4 DISCUSSION

CEREST studied in this research, has already been indicated by researchers as a service which stands out in Brazil for its innovatory and successful experiences in relation to worker health (JACKSON FILHO and BARREIRA, 2013). Even recognising that there have been advances and conquests, the team demanded the intervention by perceiving that the contradiction between analysis in depth and the productivity demanded by the management generated low efficacy of actions.

One very important mirror data used in the sessions was the incidence rate of the accidents and their seriousness. The graphs analysed in the sessions demonstrated that the seriousness of the accidents had diminished considerably, however the incidence had reduced little. The question of this first contradiction showed the team that although the interventions undertaken had had impacts, they had not led to a social construction of change, because there had not been effective participation of the organization in the process.

Numerous are the factors that make difficult the efficacy of the interventions in worker health, among them are the low adherence level of the workers, authoritarianism of the management, insufficient resources and prioritization of production in detriment of health and safety (WHYSALL et al., 2006). Approaches centralized on quantative evaluations and normatizations do not reach these factors.

The efficacy of work security norms have been much discussed (FARIA, 2008, LIMA, 2005; DWYER, 2006) and approaches which understand work as an element within a complex and imperfect system are ever more frequently indicated as a route to prevention (ALMEIDA, 2006a,b; MENDES, 2014; OWEN, et al., 2009).

The construction of change is problematic, although a good prognosis can be made. When one detects a situation of risk, the intervention should always be planned whenever possible based on theoretical and practical scientific knowledge about the sector in which the problem is occurring; subsequently one chooses a more adequate method of intervention for the case and makes the intervention always evaluating the results (GOLDENHAR et al., 2001; ROBSON et al., 2007). Approaches of interventions based on qualitative analyses can contribute more favourably with prevention (BARIL-GINGRAS et al., 2006). And the participative approaches in the risk management have been shown to be a key part in the efficacy of interventions in a number of sectors (KAZUTAKA, 2012).

Intervention using the method of Change Laboratory in this research offered the team a broader form of understanding the problem. They parted from an abstract idea of what was their object (surveillance) to a solid remodelling of the activity system. The manner that they perceived matters previously, generated the perception that the tools that they possessed were incompatible with the object which they intended to reach. During the length of the encounters, it was perceived that the problem was systemic, that is, it had its origin in a number of elements of the activity system. It was principally necessary to alter the subject, rules and division of work. The other noteworthy contribution of the method was the agencying of the participants. They had expectations regarding the change in the activity itself, but initially did not know from where to begin. The possibility of expressing themselves, analysing in depth and collectively the problems faced and to actively seek the solutions, is what guarantees the necessary conditions for these role-players to become protagonists of their own activity (BRITO, 2011).

This valorisation of the role-players in the analysis and search for solutions showed itself to be fundamental, since this team also demanded intervention as a form of learning method in order to use it in surveillance actions. The workers need to be heard, but also they themselves need to be the protagonists of the analyses of accidents and search of prevention solutions (OSORIO, 2008).

The method is configured in six distinct phases, as follows: 1) mapping of the situation (when one recognises that something should be done regarding the problematic situation); 2) analysis of the situation (how they worked before, what are the present difficulties); 3) creation of a new model (how one wants to work); 4) consolidation and model testing (what changes one wants for the next months); 5) application of the new model (putting into practise the proposals); 6) disseminating and consolidating (teaching others what was learnt).

At this moment, the intervention in CEREST is in phase 5 of application of the new model. The intervention has only given a start to the process of expansive learning. This is an extremely fragile process and needs constant support, since the model is never ready and completed, but rather in construction. The implementation will probably show that some elements are not compatible, needing a new round of redesign, a new analysis. It is hoped that even if the intervention is successful, probably the new activity system will enter into contradiction with other neighbouring activities, which will generate the necessity for a new intervention involving these activities.

5 FINAL CONSIDERATIONS

At the moment, the redesigned model is being applied in the form of a pilot project. Its experimentation in the four months planned for development of the new CEREST system activity needs to give response whether the idealised model managed to supersede in practise the contradictions between the subjects and their object, between these and the traditional instruments used and the existing rules in the service. In order to establish itself in the future, the model needs to be validated by the remaining hierarchies of the organization and by the community, and the institutions that have interface with Worker Health: the network of Social Security[3], the Ministry of Work and Labour, the Ministry of Labour and the Municipal Health Council which represents society in general.

In the same way, the resumption of the prominence of the multidisciplinary team began the process of more decentralized and democratic decision-making, recognised by the group as essential attributes to redesign and implement the desired changes.

The group and the interventionist researchers believe that revival of significance and expansion of the object had a transforming role. On the other hand, it helped in the diagnosis of a reduced operational functioning model, diverted from its main purposes to attend exclusively centralized rules in quantative demand, to be serviced superficially without qualitative criteria of public health, which resulted in low efficacy of the prevention actions. On the other hand, it represented a new germinal cell, visualized as being capable of equating the existing contradictions and of regaining the sense of work for the professionals of the service. Conscious of this real possibility they seek to consolidate (by passing the abstract to concrete) recreating, testing and reinventing new elements of the system. A new cycle begins. New tensions can arise in the future with the neighbouring systems and at higher levels. The RENAST (National Network of Attention to Worker Health) could be put to the test by those who make things happen at a local level, with possible future gains.

[3] INSS (National Institute of Social Security)

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7. REFERENCES

ALMEIDA, I.M. "Trajetória da análise de acidentes: o paradigma tradicional e os primórdios da ampliação da análise". Interface. Botucatu, v.10, n.19, pp. 185-202, 2006 a.

ALMEIDA, I.M. "Abordagem sistêmica de acidentes e sistemas de gestão de saúde e segurança do trabalho". **INTERFACEHS – Revista de Gestão Integrada em Saúde do Trabalho e Meio Ambiente** - v.1, n.2, Artigo 1, dez 2006 b.

ALMEIDA, I.M.; VILELA, R.A.G.; SILVA, N.A.; BELTRAN, S.L. Modelo de Análise e Prevenção de Acidentes (MAPA): ferramenta para vigilância em Saúde do Trabalhador. *Revista Ciência & Saúde Coletiva,* v.19, n.12, Rio de Janeiro, 2014.

BARIL-GINGRAS, G.; BELLEMARE, M.; BRUN, J.P. The contribution of qualitative analyses of occupational health and safety interventions: An example through a study of external advisory interventions. **Safety science**, v. 44, n. 10, p. 851-874, 2006.

BRASIL, Ministério da Saúde. Portaria 3908, de 31/10/1998. Dispõe sobre a Norma Operacional em Saúde do Trabalhador (NOST) no Sistema Único de Saúde, 1998.

BRITO, J. O trabalhador como protagonista da produção de saúde. **Tempus Actas de Saúde Coletiva**, v. 5, n. 1, 2011.

BRUHN, A.; FRICK, K. Why it was so difficult to develop new methods to inspect work organization and psychosocial risks in Sweden. *Safety science*, *49*(4), 575-58, 2011.

DWYER, T. **O surgimento da engenharia de segurança: empregadores, trabalhadores e a lâmpada de Davy**. Multiciência: população, bem-estar e tecnologia, UNICAMP/ Campinas. v.6, 2006.

ENGESTRÖM, Y. et al. The change laboratory as a tool for transforming work. **Lifelong Learning in Europe**, v. 1, n. 2, p. 10-17, 1996.

ENGESTRÖM, Y. *Learning by expanding.* An activity-theoretical approach to developmental research. Helsinki: Orienta-Konsultit Oy, 1987.

FARIA, M.P. **Fatores intervenientes na segurança do trabalho de abatimento mecanizado de rochas instáveis em uma mina subterrânea de ouro**. Dissertação de M.Sc. Universidade Federal de Minas Gerais UFMG, Belo Horizonte, pp. 66. 2008.

GOLDENHAR, L.M. et al. The intervention research process in occupational safety and health: an overview from the National Occupational Research Agenda Intervention Effectiveness Research team. **Journal of occupational and environmental medicine**, v. 43, n. 7, p. 616-622, 2001.

JACKSON FILHO, J. M. ; Barreira, T.H.C. . A construção da saúde do trabalhador em Piracicaba: análise da ação pública no período de 1998 a 2009.. In: SIMONELLI, A.P.; RODRIGUES, D.S.. (Org.). **Saúde do trabalho em debate: velhas questões, novas perspectivas**.. 1ed.Brasília: Paralelo 15, 2013, v. , p. 357-392.

KAZUTAKA, K. Roles of Participatory Action-oriented Programs in Promoting Safety and Health at Work. Safety and Health Work v.3 n.3 p.155-65, 2012.

LEONTIEV, A.N. *Activity. Consciousness. Personality.* Englewood Cliffs, Prentice Hall, 1978.

LIMA, F.P.A. **Norma e atividade humana: modelos dinâmicos da prescrição e historicidade das situações de trabalho.** DIEESE/CESIT (Orgs.). Trabalho e abordagem pluridisciplinar: estudos Brasil, França e Argentina. São Paulo (DIEESE) e Campinas (CESIT): p. 51-68, 2005.

MENDES, R.W.B. **Apropriação sistêmica de inovações tecnológicas para a prevenção: o caso do controle de poeira em mineradoras de granito**. 2014. Tese de Doutorado. Universidade Federal do Rio de Janeiro.

OSORIO, C. ACAT: o trabalhador como protagonista da análise de acidentes de trabalho. **Cadernos de Psicologia Social do Trabalho**, v. 11, n. 1, p. 111-120, 2008.

OWEN C.; BÉGUIN P.; WACKERS G. **Risky Work Enviroments**. Burlington. USA: Ashgate Publishing Company, 2009.

PEREIRA-QUEROL, M.A.; JACKSON FILHO, J.M.; CASSANDRE, M.P. Change Laboratory: uma proposta metodológica para pesquisa e desenvolvimento da aprendizagem organizacional. *Revista RAEP - Administração: Ensino e Pesquisa*, v. 12, n. 4, p. 609-640, 2011.

ROBSON, L.S. et al. The effectiveness of occupational health and safety management system interventions: a systematic review. **Safety Science**, v. 45, n. 3, p. 329-353, 2007.

VASCONCELLOS, L.C.F.; RIBEIRO, F.S. A construção e Institucionalização da saúde do trabalhador no Sistema Único de Saúde. In: VASCONCELLOS, L.C.F.; OLIVEIRA, M.H.B. (Org). EDUCAM, Rio de Janeiro, 2011. 598p.

VIRKKUNEN, J.; NEWNHAM, D.S. O Laboratório de Mudança: uma ferramenta de desenvolvimento colaborativo para o trabalho e a educação. Fabrefactumed. Belo Horizonte, 2015.

VYGOTSKY, L.S. *Mind and society:* The development of higher mental processes. Cambridge, MA: Harvard University Press, 1978.

WHYSALL, Z.; HASLAM, C.; HASLAM, R. Implementing health and safety interventions in the workplace: An exploratory study. **International Journal of Industrial Ergonomics**, v. 36, n. 9, p. 809-818, 2006.

Rhetorical accounts of risk: Interprofessional risk assessment in operational planning meetings

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Abstract
In the context of high-risk industries, risk assessment takes place not only through standardized methods for risk analysis, but is frequently negotiated and discussed as an integral part of operational decision making. This is not least the case in the context of operational planning. Frequent changes in operations require ongoing assessment of risk as tasks are rescheduled and resources reallocated. The current study explores how professionals account for the presence or absence of risk in a setting in which risk analysis is not the primary objective. With data from the offshore petroleum industry, the rhetorical aspects of risk assessments in operational planning are examined. A series of interprofessional planning meetings were video recorded, transcribed and analyzed using a rhetorical discourse analytic framework. The data is analyzed at a micro-interactional level in order to study how accounts of risk are presented and negotiated in this particular setting. The meaning and consequences of operational plan changes, and their implications for safety, are issues that need to be established and negotiated discursively through interprofessional meeting talk. The analysis shows that accounts of risk are characterized by shifting rhetorical strategies that can be seen to echo established risk discourses often referred to as 'technico-scientific' and 'contextualized' conceptions of risk. Rhetorical devices are used interchangeably and strategically by the participants as they account for risk from their respective institutional positions and their specific areas of expertise and responsibility. The accounts are found to be increasingly persuasive and rhetorical in style as disagreements over risk and prioritizations surface. Established risk discourses can in this way be seen as rhetorical resources for the participants in their negotiations over the meaning of risk and in support of their specific communicative projects. The accounts of risk are, in other words, not seen as simply objective presentations of probability and consequence, but rather as powerful tools for achieving specific professional outcomes. The study contributes to the understanding of risk assessment at its most concrete and practical level, as it takes place through professional interaction in an operational setting and through the presentation of persuasive accounts. Acknowledging the discursive and rhetorical elements of risk assessment might encourage awareness among professionals and managers of the interactional dynamics that are at play when professionals negotiate the meaning of risk across departments and fields of expertise.

Keywords: Risk assessment, rhetoric, discourse analysis, interprofessional interaction, operational planning

1. INTRODUCTION

In the context of high-risk industries, structured methods for risk analysis are key tools in risk management. These methods are closely linked to ideals of rational decision making, systematically approaching apparently tangible and objective factors, indexing risk through probability-based methods of expected values or risk matrices. But risk analysis is not only performed in these structured meeting formats. Risk is also continuously dealt with in other organizational settings, in which the continuous management of operational change takes place. This paper considers risk assessment in the domain of operational planning in offshore oil and gas production and studies the risk talk that occurs in an interprofessional meeting in which plan changes are addressed, with subsequent re-scheduling of activities and reallocation of resources. Decisions made at this level are crucial for the day to day operations and ultimately for the safety and the bottom-line of production. However, these arenas for operational decision making have rarely been studied as sites for interprofessional interaction in which assessments of risk take place.

The last few decades have seen what has been called a 'discursive turn' in organization studies, in which the role of language and discourse, text and talk, is seen as central in the shaping and changing of organizations (Alvesson & Kärreman, 2000; Grant, Hardy, Oswick, & Putnam, 2004; Mumby & Clair, 1997). Organizations are increasingly seen as complex formations where discursive practices are both "in" organizations and productive of them

(Cooren, Taylor, & van Every, 2006; Putnam & Nicotera, 2009). Weick (1995) has contributed significantly in turning our attention to the social nature of sensemaking. A similar discursive turn can also be observed in the safety practices of the petroleum industry itself, evidenced by extensive procedures for ensuring that operators talk about risk and safety – preceding, during, and following work operations (e.g. “Before the job talk”, “Open safety conversation”, “Check your colleague”, and “Safe job analysis”). Risk talk is seen to affect risk behavior and to serve a function in preventing misunderstandings to occur. The communicative events in which professionals discuss and negotiate risk have received limited attention in safety science. The research field of risk communication is still growing, but has largely oriented to mass communication of societal risk, to perception studies or the rhetorical shaping of mass media messages (Fischoff, 1995; Roeser, Hillerbrand, Sandin, & Peterson, 2012). Few studies have examined the role of discourse in defining and negotiating risk at a micro-interactional level (Rasmussen & Kroon Lundell, 2012).

This article brings attention to the formulation and negotiation of risk at the level of interprofessional interaction where professionals meet, talk and negotiate the meanings and consequences of risk in a particular setting. The data is taken from a weekly planning meeting that attends to the optimization of the maintenance plan for offshore oil and gas wells. The research questions can be formulated as follows: How do the meeting participants account for the presence or absence of risk in the planning meeting and what interactional negotiations can be found to take place? The data is analyzed within the framework of rhetorical discourse analysis, which involves attention to micro-interactional features and the recurrent patterns of argumentation (rhetorical strategies) that are employed in accounts of risk. Accounts are, in this context, descriptions of risk given by the participants, and these descriptions are seen as interactionally designed with reference to how they will be recognized and understood by others, and as constructing preferred meanings for problematic events (Antaki, 1994). The term risk will be used broadly to refer to the perceived possibility of any unwanted event or effect, not only those related to the safety of personnel or the integrity of technical equipment. In this setting, risk is also related to the threat of losing production and the threat of producing an unfeasible plan. If problems arise due to poor planning, decisions will have to be made on the spot and with limited information, imposing increased risk for both safety and production.

1.1 The study of risk

The technico-scientific approaches to risk are and have been dominant in attempt to understand and control risk (Lupton, 1999). Based on the principles of probability theory and scientific methods, risk is defined as the product of the probability of an unwanted event and the severity of its effects (Haimes, 2009; Lowrance, 1976). The hazard that gives rise to the possibility of an event is considered to exist independently of our perception of it and to be controllable through appropriate measures. However, the probabilistic and objectivistic approaches to risk have been challenged by more contextualized perspectives on risk and what has been called a constructivist turn in safety science (Le Coze, 2013). This brings in new paradigms of thinking from human and social sciences.

The field of cognitive psychology has, for example, described the heuristics and biases that people employ when making decisions, and how they generally do not follow the principles of probability theory when appraising probability and consequence (Kahneman, Slovic, & Tversky, 1982). The role of emotion and styles of information processing, for example, are directing reason and affect. Importantly, the non-probabilistic thinking, often seen as ‘human flaws’, are now increasingly seen as a resource in risk assessment (Jackson, Allum, & Gaskell, 2006). From an anthropological perspective, Douglas (1992) has provided a cultural approach to risk, in which risk is seen as shared cultural understandings and practices. Social relations and organization brings meaning and value to risk, and culture therefore place a role in determining what risks people perceive as significant. In these contextualized approaches to risk, probability is one among many attributes of risk, not the singular condition for classification, and risk does not exist independently of human interpretation and meaning-making.

The current study takes a discourse analytic approach to risk, emphasizing the role of language and interaction in the interpretation and assessment of risk. This approach investigates language as social action, which implies studying language use, text and talk, as it is manifested in actual, real-life situations (Candlin & Sarangi, 2011). Frequently, the assessment of risk is a fundamentally communicative activity: planning for safe behavior, breaking down work processes into steps, formulating possible future scenarios, assessing probability and consequences of different circumstances. These are all activities in which language and interaction are key tools for reaching shared decisions in a high-risk setting. The information processing that organizational members do is rarely done in the solitary mind and it is rarely based on knowledge and information that is completely certain or uncontested. Rather it is created in dialogue and with the influence and expertise of others (Linell, 1998; Sarangi & Coulthard, 2000). Expert assessments of risk, in turn, are not only based on facts and input but also on institutional constraints and social hierarchies (Cicourel, 1990). Sarangi & Roberts (1999) distinguish between professional and institutional constraints, the latter regulating who has access to information, who has the position to legitimately assess information, and who holds the authority to decide based on this information. Sarangi & Clarke (2002) show how professionals, in the face of uncertainty, demarcate their own expertise with the help of specific discursive resources. Even the production and assessment of evidence has been shown to be a result of interactional work. What counts as evidence for one profession might be circumstantial for another. Evidence in an interprofessional setting must be established as relevant and applicable for other professions (Cicourel, 1986; Måseide, 2006) and the evidential status of information can change in the course of an interactional episode (Sarangi, 1998). This is highly relevant in risk assessment scenarios in which information and evidence play a crucial role in decision making.

1.2 Empirical site

The plan optimization meeting, which is the empirical site for this study, is a key meeting for prioritizing service activities on oil and gas wells and for optimizing the well service plan across a field of oil and gas installations. Well service tasks involve maintenance or treatment that will restore, prolong, or enhance the productivity of the wells. These are in other words crucial activities for the total production of the plant and consequently for the revenue of the company. Well services are in this particular case performed by 5-6 roving crews that travel from installation to installation performing tasks according to the plan produced onshore.

The objective of the planning meeting is to ensure an optimal and feasible plan for well service tasks that continuously responds to the changes that occur offshore and that is coordinated with the plans in related domains on the installation (drilling, operations, modifications, maintenance). Around ten people meet once and twice a week for this plan optimization meeting, and representatives of up to six different departments participate. The meeting lasts about one hour and is conducted in English. Two to three of the participants are native speakers of English, while the rest have English as a second language. All participants are on shore, in the same room, gathered around a small table. Two large screens are used for displaying the current well service plans.

Risk analysis is not formally a part of the agenda for this meeting, but a change in the operational plan might also involve a change in risk picture, and this will have to be dealt with by the professionals involved in planning and rescheduling. Expertise across departments is needed to assess the meaning and consequences of operational changes and their implications for safety. Inability to produce a feasible plan, or the occurrence of unplanned events or plan conflicts, might create unanticipated effects and threats to both safety and production.

2. MATERIALS AND METHOD

The data for the paper is part of a larger study on decision making in operational planning. The author conducted ethnographic field work with an international oil and gas operator during 2010, attending and recording key meetings in operational planning. The plan optimization meeting was one such meeting, observed throughout the period and video recorded on five occasions, with later supplements of another four audio recordings. Following usual ethics clearance surrounding informed consent, the recorded data have been anonymized and transcribed, allowing the researcher to “slow down” the interaction and explore in detail the patterns of activity and the rhetorical choices made by the participants.

2.1 Rhetorical discourse analysis

Discourse analysis is the study of language in use, how we accomplish actions, goals and purposes with language (Gee & Handford, 2012). In light of the research question, the meeting data is approached with a qualitative rhetorical discourse analysis (Arribas-Ayllon, Sarangi, & Clarke, 2011), focusing on the process of risk assessment through analyzing the accounts of risk given by the participants, i.e. how they use language and discourse in negotiating understandings of risk as part of a decision making trajectory. The analytic focus is on micro-level discourse, which includes not only spoken and written language but also nonverbal and multimodal representations, while the analysis remains attentive to the broader social context. Importantly, rhetoric is here not seen as counter-factual or superficial ways of using language in order to persuade or deceive. Rather, rhetorical devices are seen as participants' strategic and competent ways of using language to achieve communicative goals (whether these are collaborative and shared or not).

Rhetorical discourse analysis approaches discourse as accounts and focuses on the discourse strategies employed in the meeting as participants describe or present accounts in which risk as a focal theme. How is risk or safety "accounted for", formulated, conceptualized, presented, supported, or challenged? What elements of risk are made relevant through the meeting talk, and what risks are perceived to be salient or contested? Accounts are descriptions in which speakers attend to content by establishing facts, identifying causes, backing up claims, providing explanations, or justifying actions. But they also attend to relational aspects by implicating motives and intentions, assigning responsibility, managing credibility, etc. This indicates that accounts are interactionally designed with reference to how they will be recognized and understood by others and as constructing preferred meanings for problematic events (Antaki 1994). Accounts provide, in other words, a rich intake into rationalities and relations that pervade in settings such as the planning meeting of this study.

The approach attends to the discursive choices that participants make in response to previous utterances, in anticipation of projected next turns, and for the purposes of contributing to the communicative project of the meeting (Linell, 1998). Underlying this approach is a perspective of language that does not consider it as mirroring an objective world outside of perception or interpretation. Language is seen as a social practice and as playing a constitutive role in our perception and production of social reality. Accounts reflect, in other words, culturally embedded and normative explanations, they are not seen as expressions of inner feelings, perceptions or intentions as such.

3. RESULTS AND DISCUSSION

The first two examples below illustrate some of the rhetorical strategies employed in risk assessment in the planning meetings and how the accounts of risk can be seen to lean on different conceptualizations of risk. In the first example (Excerpt 1), a Well service engineer accounts for the risk, or rather absence of risk, related to the timing of a specific well service task. The current plan has it scheduled before the drilling rig arrives, but the chair expresses some uncertainty as to the feasibility of this plan. The account given by the Well service engineer is marked with arrows. Transcription conventions can be found in section 6 Appendix.

<u>Excerpt 1 (20/8)</u>

36 Production we'll try to do it be<u>fore</u> the rig is-
37 Chair yeah we try to do but if not- I mean-
→ 38 Well service I think we'll probably have a pretty good shot at it= the rig's not supposed to be there- (.) so after task 7 right?
39 Chair yeah?
→ 40 Well service so we'll have time either in between task 7 phase one and phase two or before the rig is XscheduledX to [xxx-]
((turns omitted, digression))
45 Chair it would be good to have an idea whether it <u>is</u>- I mean <u>if</u> for some reason we sh- e:h we need to reprioritize both usage and xx of-
→ 46 Well service I've - I would say there's a ninety nine percent chance we're going to do it before the rig gets there.
47 Chair okay

Through turns 38-46 the Well service engineer is increasingly persuasive in his attempt to reassure the Chair that the current plan is feasible and does not entail great risk of plan conflicts. In turn 38, he presents a mitigated account through several modifying devices, or hedges (Fraser, 2010), such as ’I think’, ‘probably’, ‘pretty good’, and ‘supposed to’. This creates an attenuated claim that represents only partial commitment to its content. The account continues in turn 40 adding more technical and practical detail of when the task will take place, which lends more credibility to the account. After a short digression, the Chair still expresses some concern and calls for further reassurance about this plan (turn 45), and this triggers a boosted account form the Well service engineer in turn 46, in which he chooses to describe his assessment of risk in terms of numerical value of probability (‘a ninety nine percent chance’). He frames his claim as an expert judgment (‘I would say’) and his account is now of a more persuasive character, with the rhetorical help of a form of scientific risk talk. He presents the likelihood of a plan change as minimal, and the risk of a plan conflict, with subsequent risk to safety and production, is presented as nearly inexistent. This establishes his sense of certainty as well as his expertise in support of the current plan as it stands. The account is accepted by the chair and the meeting moves on. The rhetorical strategy of presenting risk in terms of numerical value, combined with an expert framing of the claim, is persuasive, and countering such a claim is difficult as it would involve questioning the speaker’s expertise.

In the next example (Excerpt 2), we will see a range of other rhetorical devices that, in the face of disagreement, allows the speaker to present a highly persuasive account of risk. The Well integrity manager, in charge of the technical state (safety) of the wells, updates the participants about a discussion outside the meeting about prioritizing a specific task (‘coiled tubing’) on platform T. This information is met with skepticism and expressions of discontent, mainly because the discussion should have been brought to this particular meeting and not been taken without involving the participants here present. The negative response triggers a persuasive account of risk from the Well integrity manager:

<u>Excerpt 2 (27/4)</u>

510 Well integrity [we’ve initiated] a discussion with operations with (name manager) about the prioritization of this coiled tubing job
511 Production1 yeah but he hasn’t talked to us
512 Well integrity WELL
513 Production2 this is the forum-
514 Production1 =this is the forum for those things
515 Well service yeah and therefore I meant [because we xx]
516 Chair [you talked about] P&A jobs- no one said coil
→ 516 Well integrity basically this coiled tubing job on that platform T well could potentially save about two months of the (vessel) time. (. .)
517 NN mm
518 Production1 what well is it?
→ 519 Well integrity it’s E5 (. .) technically the well is in such a poor condition that it would be very hazardous for us to rig up BOP ((blow-out preventer)) x xx. It really is a job that needs to be done with coiled tubing. I know it’s a strain (.) E5- it’s a strain on the organization already to resource that coiled tubing job but if we don’t get it rigged up during the shutdown (.) we’re not going to have time to do it.
((turns omitted, series of clarifications))
→ 531 I mean fundamentally we- the well is in that poor a condition our only other option is to rig up coiled tubing through the (vessel). And I think if we look at the cost consequences of having to do coiled tubing work through the (vessel) on time that ain’t an attractive option.

The discontent from the other participants leads the Well integrity manager to first present an argument for the upside of this decision (turn 516), namely that it will save vessel time. She receives minimal response to this from the other participants, and in turn 519 she moves on to present a more persuasive account for why this decision is sound and necessary. She employs several modifying devices here that function to boost the strength of her account. Intensifiers such as ‘such a poor condition’, ‘very hazardous’, ‘really’, and ‘needs to’ all creates a sense of urgency and necessity to her claim, and they divert the attention away from the procedural error, namely that she has not involved the other participants in the discussion. Following this strong chain of argument, she employs an elegant persuasive structure in which she first gives a concession (Kotthoff, 1993), an acknowledgment of a counter-argument ('I know it's a strain'), and then follows with a contrast marker ('but') and a reprise of her initial claim in a more extreme form. She repeats her position in the form a conditional statement of causality ('if not – then'), indicating that if they do not do it this way, it will not get done at all. This structure is an example of a 'show concession' (Antaki & Wetherell, 1999), in which the speaker makes a show out of appreciating opposing views but by doing so, strengthens her own position at the expense of the counter-argument, thereby dismissing any rival claims.

After some clarifications (omitted turns), the well integrity manager chooses to further intensify her account in turn 531 with a series of extreme-case formulations (expressions using extreme terms, here 'fundamentally', 'our only option'). This strategy of maximizing one's case is often used when a speaker finds herself in an adversarial situation and expect other interactants to undermine her claims (Pomerantz, 1986, p. 222). She closes her account with a move from Standard English to vernacular English dialect ('aint'), a shift of tone and style which allows her to lighten up her account and assume a less formal-managerial position. Disclaiming the contrastive status ('ain't attractive') in this manner, allows her to end her account on a more attenuated and less adversarial note. This closing statement receives no comment, instead, the other participants move directly to discussing the necessary reprioritization of resources for accommodating the coiled tubing job, in other words a quiet acceptance of the decision to prioritize this job. The Well integrity manager has presented a highly persuasive account, with a range of rhetorical devices that legitimize her judgment and that blocks counter arguments. Her account is based on knowledge of specifics with the current situation and can rhetorically be described as a case of 'particularization' (Billig, 1996). She strengthens her claim by constructing a narrative of urgent circumstances, and this can be heard to echo a contextualized conception of risk.

The third and final example is chosen to illustrate how participants can be found to strategically shift between technical-scientific and contextual rhetorical strategies when facing disagreement. The episode also shows the tensions that exist between the different domains of expertise that are present. In excerpt 3 below, problems with boat availability to platform B forces them to reschedule some of the tasks in the plan. Task B18 is currently in the plan, a so-called P&A job, which prepares for closing down the well permanently ('plug and abandon'). The Subsurface manager is contesting this priority and calls for another job, B1, to be selected instead. This is a so-called perforation job, which prepares for stimulating the well to restore or increase production. The increasing intensity of the discussion is visible in the transcript by the short speaking turns, few pauses, and frequent overlaps and interruptions (marked by brackets).

<u>Excerpt 3</u>

294 Chair [then you] should take B18 first and [then eh- do B10]
295 Subsurface [E:::H bah] bah bah- ((indicating 'stop right there')) there is debate on- still debate on B18 or B1. I brought it last week and then I brought it to (Well integrity manager) and she was going to bring it to the (production optimization) people cause we are eh in favor of B1 at first and restim (.)
((Turns omitted, on events preceding the meeting))
301 Subsurface [I have-] I have talked to (name) to clarify this but we are asking for B1.
302 Well Service1 has- has- but what about- what about the boat for stimulation on B1?
303 Subsurface it's xx perforation so- ((implies there is no need for a boat))
304 Well service2 it's perforation so yeah- have we- have we seen a (plan) for B1 yet?
305 Subsurface yes. yeah yesterday
((turns omitted))
→ 310 Subsurface B18 as you know is going to be XrebuiltX [next year]
311 Chair [so next eh] we need [to:-]
→ 312 Subsurface [it's] not a red well
313 Chair huh?
314 Subsurface this is not [a red one]
315 Well integrity [wo wo wo]

316 NN yes
317 Well integrity it doesn't- it doesn't need to be a red well to be- to get prio[ritization]
318 Subsurface [okay, all right]
319 Well integrity it has to do with risk
320 Subsurface okay
321 Well integrity so we have wells that are not red and that are [xxx-]
→ 322 Subsurface [quoting-] quoting (Well integrity manager) it is still in much better condition now than it was eh [xxx-]
323 Well integrity [but we] will- we'll take it outside and- and weight it up
324 Well service could we have an uh- we- come with eh- we need a decision today. because now I will go down and say hold again to (subcontractor) and everyone that is involved in B18 because we have to rig that up today e:h so we need to put a hold on everything

The Chair suggests taking well B18 first when the Subsurface production manager stops her emphatically to point out a conflict of interest ('bah bah bah', turn 295). The debate whether B18 should be prioritized is evidenced by his account of his personal actions, and when stating his claim he shifts pronominal form from 'I' to 'we', establishing the conflict of interest ('we are in favor of B1'). This underlines the formality of his request while keeping the request mild and mitigated ('in favor of'). After further accounts of interactions prior to the meeting, he restates this position more explicitly and unmodified in turn 301 ('we are asking for B1'). The disagreement concerning the plan is now evident and this triggers two questions from the Well service representatives, both concerning the feasibility of doing B1 instead of B18 (boat availability and plan readiness, turns 302 and 304). As practical objections to his request are cleared, the Subsurface manager continues the argument for his stance in turn 310, and he proceeds to bring in a piece of contextual information about the future of B18 (to be rebuilt next year). He frames this information as known to the other participants ('as you know'), aligning with them and appealing to shared knowledge. Just as the well integrity manager in the previous example, the Subsurface manager here employs a strategy of particularization to strengthen his claim, drawing on specifics surrounding the issue.

Interestingly, immediately following this statement, he turns to the contrasting rhetorical device of 'categorization' (Billig, 1996) to further strengthen his claim, placing the issue in a category with similar characteristics rather than seeing it in its particularity. He now turns to the color coding of wells ('it's not a red well', turn 312), and places B18 in the category of non-red wells, which implies it has not reached a critical safety level and therefore need not be prioritized for maintenance. Categorization represents a resource for making authoritative, de-contextualized claims. Such statements provide a basis for making decisions that may be portrayed as objective (Horlick-Jones, 1998). The Subsurface manager can, in other words, be seen to lean on a technical-scientific conception of risk as he turns to established categories that are independent of context. With this statement, however, he has moved into the territory of Well integrity and he is stopped fervently by the Well integrity engineer in turn 315 ('wo wo wo'). Well integrity rejects the use of the color coding as an argument and claims that the well does not have to be red to be prioritized. He indicates that the color category is not the only criterion for prioritization, but he does not specify what this might be (turn 319).

What becomes evident here is that also seemingly objective categories such as color coding of wells do not evade interpretation. Risk related to safety is clearly a matter of degree; it is not an either-or issue. Once a category has been assigned, an interpretation still needs to be made as to whether it indeed qualifies for priority. The Subsurface manager gives what could be seen as a token agreement with the Well integrity engineer (turns 318 and 319), and he moves on to focus precisely on the interpretation of the color coding. Having failed the categorization strategy, he now shifts back to particularization, but designing his claim as reported speech, referring to the Well integrity manager and her alleged assessment of the condition of the well (turn 322). Reported speech is a device that functions as an interactional evidential, using the voice of another for supporting your argument. This lends an air of objectivity to the claim and defers responsibility to an outside authority (Clift, 2006), in this case the Well integrity manager.

The Well integrity engineer refrains from commenting this reported claim, instead he suggests that the issue is taken out of the meeting and re-assessed (‘weight it up’, turn 323). He does not have the authority to decide and possibly not sufficient information to discuss the issue further. He uses the metaphor of weighing, which alludes to a rational method of decision making that will conclude which well should be prioritized. A well-known, scientific approach is here used as a rhetorical device for postponing the issue and for distancing himself from the argument. The last turn in the excerpt finds the Well service representative again expressing concern for the feasibility of the plan and calls for a quick decision so he can make the necessary arrangements with the subcontractor (turn 324).

What this excerpt has shown is how both the Subsurface manager and the Well integrity engineer draw on both scientific and contextualized conceptions of risk, as they choose rhetorical devices that serve their purposes at the given moment of interaction and in response to the preceding talk. Both scientific and contextual elements are used as evidence for their respective cases, as exemplified in the Subsurface manager’s shifts between particularization and categorization strategies. This allows us to see that different conceptions of risk are not necessarily related to different epistemological or ontological perspectives, but to interactional negotiations, communicative goals, and role-responsibilities that come to expression at the level of everyday interprofessional interaction.

Also, the professionals’ responsibilities and entitlements mediate their accounts of risk (cf. also Linell, Adelswärd, Sachs, Bredmar, & Lindstedt, 2002). In the last example we have seen that Subsurface is concerned with risks to production (B18 does not contribute to increasing production but ties up resources that could be used for production-enhancing activities, such as B1); Well integrity is concerned with the technical state of the well and B18 has been assessed as a prioritized well despite not being categorized as red; Well service, on their end, are repeatedly concerned with feasibility and the practical arrangements for the crew (including subcontractors). The tensions present are, in other words, not simply based in differing risk perceptions, but seem to surface from diverging agendas, interests, and their specific role-responsibilities in the organization. This calls into question the achievement of balanced interprofessional risk assessment if disagreements over the meaning of risk grow out of a battle over resources or performance targets, for example.

4. CONCLUSIONS

Much of the decisions related to risk and risk assessment in high-risk operations are made during and as a result of talk. Interaction is at the heart of risk assessment, as groups of professionals use language and interaction as tools for achieving legitimacy for operational decisions and a sense of collective control of the perceived risks associated with operations. The current study has explored how risk is accounted for at the level of interprofessional interaction and in a meeting setting in which risk analysis is not the primary objective, namely operational planning meetings. Risk assessment frequently occur as an integral part of the decision making processes in these meetings, however, not in the form associated with formal methods of risk analysis. The paper has aimed to contribute with a micro-interactional analysis of risk talk in this context, illustrating the rhetorical aspects of accounts of risk.

Interprofessional risk assessment, as it occurs in both formal and informal meeting settings, is a dynamic process involving persuasive elements and rhetorical strategies that go beyond traditional conceptions of risk or established methods for risk analysis. The analysis showed examples of shifting rhetorical strategies, invoking different paradigms or conceptions of risk in a strategic manner and for persuasive purposes. Rhetorical devices such as categorization and particularization were found to be strategic resources for participants in their efforts to achieve communicative goals and fulfill organizational role-responsibilities. What is frequently seen as competing paradigms of risk – the technico-scientific and the contextualized conceptions of risk – might in actual interaction function as rhetorical resources for participants. The accounts of risk in the present data were also found to be highly mediated by the organizational role-responsibilities of the participants, revealing tensions between the different domains of expertise and responsibility that were present in the meeting.

The findings support an argument for nuancing the predominant cognitive approach to risk, and calls for considering a practice-oriented approach that emphasize the role of language and interaction in risk assessment. Discourse analysis has the potential for complementing and advancing existing risk and safety research by studying in detail how notions of risk are manifested in actual talk and interaction. The analysis shows that risk assessment in interprofessional settings is an activity that requires interactional competence as well as technical expertise. As the analysis has shown, the speakers are not just presenting information to other participants. Organizational members are pragmatic and pursue communicative projects specific to the situation and constructs accounts that relate to the preceding talk and the possible ways in which other participants might respond to their claims. In Myers' (2007) words: "Risk talk is not just about risk, it is about me and you and them, and any statement might have more to do with the immediate context of interaction than with the underlying attitude or with calculations of probabilities and dangers." (p. 287). Understanding the interactional and rhetorical dimensions of interprofessional risk assessment can help us understand the dynamics that are at play in decisions pertaining to risk.

This implies that as students of risk and safety, we should interest ourselves in the communicative activities in which risk assessments takes place, whether these are formal or informal, structured or unstructured. Efforts to improve safety and organizational robustness can also benefit from addressing the topic of interprofessional interaction and the functionality of the meeting sites in which risk assessments take place. This is relevant for facilitators of formal risk analysis, in which the interactional dynamics to a greater extent can be controlled or guided, as well as for meeting chairs of operational meetings who might show awareness of the impact that rhetorical accounts of risk might have on decision making trajectories.

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6. APPENDIX: LIST OF TRANSCRIPTION SYMBOLS

Word- : truncated word or phrase
<u>Word</u> : increased emphasis
(.) : micro pause
(3s) : pause in seconds
xx : inaudible word
XwordX : uncertain transcription
[word] : overlapping talk
=word : latching utterance
WORD : louder voice
((word)) : comment to transcription
(word) : anonymized information

7. REFERENCES

Alvesson, M., & Kärreman, D. (2000). Taking the linguistic turn in organizational research: Challenges, responses, consequences. *The Journal of Applied Behavioral Science*, *36*(2), 136–158.

Antaki, C. (1994). *Explaining and arguing: The social organization of accounts*. London: SAGE.

Antaki, C., & Wetherell, M. (1999). Show Concessions. *Discourse Studies*, *1*(1), 7–27.

Arribas-Ayllon, M., Sarangi, S., & Clarke, A. (2011). Rhetorical discourse analysis. In *Genetic testing. Accounts of autonomy, responsibility and blame* (pp. 55–77). London: Routledge.

Billig, M. (1996). *Arguing and thinking: A rhetorical approach to social psychology* (2nd ed.). Cambridge: Cambridge University Press.

Candlin, C., & Sarangi, S. (2011). *Handbook of communication in organisations and professions*. Berlin: Walter de Gruyter.

Cicourel, A. V. (1986). The reproduction of objective knowledge: Common sense reasoning in medical decision making. In G. Böhme & N. Stehr (Eds.), *The knowledge society: The growing impact of scientific knowledge on social relations* (pp. 87–125). Dordrecht, NL: D.Reidel.

Cicourel, A. V. (1990). The integration of distributed knowledge in collaborative medical diagnosis. In J. Galegher, R. E. Kraut, & C. Egido (Eds.), *Intellectual teamwork. Social and technological foundations of cooperative work* (pp. 221–242). London: Lawrence Erlbaum.

Clift, R. (2006). Indexing stance: Reported speech as an interactional evidential. *Journal of Sociolinguistics*, *10*(5), 569–595.

Cooren, F., Taylor, J. R., & van Every, E. J. (Eds.). (2006). *Communication as organizing. Empirical and theoretical explorations in the dynamics of text and conversation*. London: Lawrence Erlbaum.

Douglas, M. (1992). *Risk and blame*. New York: Routledge.

Fischoff, B. (1995). Risk perception and communication unplugged: Twenty years of process. *Risk Analysis*, *15*(2), 137–145.

Fraser, B. (2010). Pragmatic competence: The case of hedging. In G. Kaltenböck, W. Mihatsch, & S. H. Schneider (Eds.), *New approaches to hedging* (pp. 15–34). Bingley, UK: Emerald Group.

Gee, J. P., & Handford, M. (Eds.). (2012). *The Routledge handbook of discourse analysis*. New York: Routledge.

Grant, D., Hardy, C., Oswick, C., & Putnam, L. (Eds.). (2004). *The Sage handbook of organizational discourse*. London: Sage.

Haimes, Y. Y. (2009). *Risk modeling, assessment, and management* (3rd ed.). New York: Wiley.

Horlick-Jones, T. (1998). Meaning and contextualisation in risk assessment. *Reliability Engineering & System Safety*, *59*(1), 79–89.

Jackson, J., Allum, N., & Gaskell, G. (2006). Bridging levels of analysis in risk perception research: The case of the fear of crime. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *7*(1).

Kahneman, D., Slovic, P., & Tversky, A. (Eds.). (1982). *Judgment under uncertainty: Heuristics and biasis*. Cambridge: Cambridge University Press.

Kotthoff, H. (1993). Disagreement and concession in disputes: On the context sensitivity of preference structures. *Language in Society*, *22*(02), 193–216.

Le Coze, J.-C. (2013). New models for new times. An anti-dualist move. *Safety Science*, *59*, 200–218.

Linell, P. (1998). Discourse across boundaries: On recontextualizations and the blending of voices in Professional discourse. *Text - Interdisciplinary Journal for the Study of Discourse*, *18*(2), 143–158.

Linell, P., Adelswärd, V., Sachs, L., Bredmar, M., & Lindstedt, U. (2002). Expert Talk in Medical Contexts: Explicit and Implicit Orientation to Risks. *Research on Language & Social Interaction*, *35*(2), 195–218.

Lowrance, W. W. (1976). *Of acceptable risk: science and the determination of safety*. Los Altos, CA: W. Kaufmann.

Lupton, D. (Ed.). (1999). *Risk and sociocultural theory: New directions and perspectives*. Cambridge, UK: Cambridge University Press.

Måseide, P. (2006). The deep play of medicine: Discursive and collaborative processing of evidence in medical problem solving. *Communication & Medicine*, *3*(1), 43–54.

Mumby, D. K., & Clair, R. P. (1997). Organizational discourse. In T. A. van Dijk (Ed.), *Discourse as social interaction* (Vol. 2, pp. 181–205). London: SAGE.

Myers, G. (2007). Commonplaces in risk talk: Face threats and forms of interaction. *Journal of Risk Research*, *10*(3), 285–305.

Pomerantz, A. (1986). Extreme case formulations: A way of legitimizing claims. *Human Studies*, *9*(2-3), 219–229.

Putnam, L. L., & Nicotera, A. M. (Eds.). (2009). *Building theories of organization. The constitutive role of communication*. London: Routledge.

Rasmussen, J., & Kroon Lundell, Å. (2012). Understanding “communication gaps” among personnel in high-risk workplaces from a dialogical perspective. *Safety Science*, *50*(1), 39–47.

Roeser, S., Hillerbrand, R., Sandin, P., & Peterson, M. (Eds.). (2012). *Handbook of risk theory - Epistemology, decision theory, ethics, and social implications of risk*. London: Springer.

Sarangi, S. (1998). Interprofessional case construction in social work: The evidential status of information and its reportability. *Text*, *18*(2), 241–270. http://doi.org/10.1515/text.1.1998.18.2.241

Sarangi, S., & Clarke, A. (2002). Zones of expertise and the management of uncertainty in genetics risk communication. *Research on Language & Social Interaction*, *35*(2), 139–171.

Sarangi, S., & Coulthard, M. (Eds.). (2000). *Discourse and social life*. London: Longman.

Sarangi, S., & Roberts, C. (Eds.). (1999). *Talk, work and institutional order: Discourse in medical, mediation and management settings*. New York: Mouton de Gruyter.

Weick, K. E. (1995). *Sensemaking in organizations*. London: SAGE.

Managing preventive occupational health and safety activities in Danish enterprises during a period of economic recession

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Abstract
The onset of the economic recession in 2008 has put severe pressure on enterprises that in turn have downsized and reorganized. Research has shown that economic recessions have an effect on psychological and behavioural health that is attributed to working environment problems. The objective of the study is to unravel whether the onset of a general economic recession has had an impact on companies and public institutions' preventive occupational health and safety activities. Hypotheses of the role of pro-cyclical and countercyclical effects are presented. The study is based on a quantitative questionnaire based survey of enterprises preventive occupational health and safety activities. The baseline for the survey was established in 2006 before the onset of the recession with a follow up in 2011. We discuss findings that support both the pro-cyclical and the countercyclical hypotheses. The results suggest a mixed picture. It is concluded that there is a need for more focus on the management of preventive workplace health and safety activities in enterprises during a period of economic recession.

Keywords: occupational health and safety; preventive actions, survey, pro-cyclical, countercyclical, economic recession.

1. INTRODUCTION

Most economies in the world have suffered from the worst financial crisis since World War II. The onset of the crisis has been much debated in the literature, but the International Monetary Fund in their World Economic Outlook (IMF 2009) state that the outbreak of the U.S. subprime crisis in August 2007 led to mild economic recessions in mid-2008. However, the Fund state that the fall of the U.S. investment bank Lehman Brothers, the deep financial problems of and the intervention into the leading U.S. insurance company American International Group and a range of other major financial institutions in US and Europe lead to the histrionic onset of a full-blown financial crisis in the fourth quarter of 2008. As such the developed countries witnessed deep recessions with an unmatched 7½ percent drop in the economies. Apart from the financial problems in the western part of Europe the trade also suffered severely and in some of the countries housing correction was a factor. In Denmark the Committee on financial crisis in 2013 in their analysis of the causes conclude that the financial crisis began in summer 2008 with a collapse of one the major banks. Denmark in the next years suffered from a general financial crisis in the banking sector that was heavy influenced by the international financial crisis. Moreover the crisis intensified with severe real estate market problems due to a housing price bubble caused by a preceding generally good economy, low interest rates and innovative lending forms (Rangvid 2013).

The recession has put substantial pressure on companies that in turn have downsized and reorganized of business functions. The effect of downscaling has been documented by the International Labour Office (ILO 2009). Here ILO ascertained that descaling has led to more part-time and temporary work, outsourcing and subcontracting including business functions as the management of occupational health and safety activities. In the same vein, ILO have later stressed that there are some evidence that the recession has a negative impact on a series of occupational mental health and risk factors, but that there is a need for a more profound understanding on the impact of recession on the management of the occupational health and safety activities (ILO 2013).

Accordingly, with respect to the impact on the economic recession on the working environment the result of a Europe- wide survey carried out by the European Agency for Safety and Health shows that nearly two-thirds of the respondents claim that the recession could adversely have a great (21%) or some (40%) effect on occupational health and safety. The Danish respondents however showed a less negative attitude with approximately 45% answering that occupational health and safety would greatly (7%) or to some extent (38%) be affected by the

economic recession. Other studies have shown that in general employees are exposed to higher mental and physical workload and fatigue due to a lack of financial resources.
In this vein Westgaard and Winkel (2011) has carried out a systematic review of production system rationalization in terms of general restructuring (n=67 studies) and downsizing (n=34 studies) measures and their association to health and risk factors in the area of musculoskeletal and mental health. The review showed that 76% of the studies point at negative downsizing health effects. Only 6% of the studies included showed a positive effect of downsizing, while 11% showed mixed results. Moreover, the review revealed that in terms of general organizational restructuring measures with downsizing excluded, 16 % showed a positive effect and 16% showed mixed results while an overwhelming 67% of the studies pointed at negative health outcomes.
In a 2008 survey approximately half of the human resources and people development professionals included in the survey reported from their companies that individual staff workload had increased as result of the economic recession. In addition, a similar proportion of the respondents said that employee stress levels have increased (Wisdom et al 2008). On the other hand there are also more positive statistics indicating that in the US and the UK there has been a decline of fatal work induced accidents in the period just prior to 2008 compared to period just after (ILO 2013). In response to these findings ILO claim that the decline could be due to the reductions in economic activities in for example the construction sector. In a survey carried out by the International Social Security Association in 2009 among the contributing organisations in its members states also show mixed result as a consequence of economic recession on occupational health (ISSA 2009; 2010; 2011). One of the key findings in the survey was that health costs are raising as an added effect to the financial crisis, but the survey also showed that the different countries different social security systems seemed to have played an important role to “buffer” elements of the crisis and thereby strengthen social cohesion, socio-economic stability and restoring public confidence. On the other hands ISSA also points out that the recession can lead to less spending on occupational preventive measures by employers. At the same time employees may be more reluctant to claim safe and healthy working conditions. As such the ISSA survey showed that in some countries (Argentina, Brazil, Cameroon, Poland and Spain) reduced investments in occupational preventive occupational health and safety management systems, while in other countries according to the result of the survey such systems have not suffered during the crisis. However, the ISSA survey is up-to-the-minute of the situation in early 2009 before the full scale intensification of the current economic recession.
Not much research has focused on psychosocial working environment factors and national or international economy. This has for example been documented by a systematic analysis of the content of two influential journals within the area of occupational health psychology where it was found that only a very limited number of the research papers published in the journal paid attention to the impact of economic factors on occupational factors at the work place (Kang et al 2008).
None the less, in a UK work force survey initiated during times of economic recession it was found that a significant part of the workers share the opinion that the economic conditions have an influence on working environment factors like for example relationship to colleges or working longer and harder (Mind/Populus Workplace Health and Stress Survey 2010). Moreover, in the Stormont study it was found that several psychosocial factors are negatively correlated with the onset of an economic recession (Houdmont et al. 2012). One of the conclusions brought forth in the study is that there is a need for more focus on the management of preventive safety activities in enterprises during a period of economic recession. From a theoretical point of view models explain that a number of working environment psychosocial factors is negatively related to economic stress in two ways. First, workers may be affected directly, for example, dependent on their ability to cope with economic stress. Second, workers may be affected indirectly by for example enterprise organisational changes with respect to managing occupational preventive safety activities. Another issue brought forth by Houdmont el al. (Ibid) is that much research within occupational health and safety research has focused on work context. Houdmont and colleges argument is that this focus may due to certain hegemonic research paradigms that favour theoretical models of occupational stress that builds upon contextual features of work.
The job demand–control model has for example been very influential (Karasek 1979, Karasek and Theorell 1990; for a critical approach se for example Kristensen 1995). The model has later been refined to incorporate social support (Johnson and Hall, 1988). Doef and Maes

has carried out a systematic review of twenty years of studies applying the model and its refined version and found that the employees exposed to high job demand, low control and low social support has the highest risk of experiencing the most negative psychological well-being.

However, as pointed out by Kristensen (1995) the model may carry with it theoretical and methodological problems. Moreover, as mentioned above there is a growing body of research that recognize that occupational mental health and safety depends both on local work context in combination with external global factors like international economy (Kang et al, 2008). Wallis and Dollard (2008) has, for example, stressed that the job demand-control model needs further refinement to incorporate job external factors like national globalization or free market forces including economic factors on a national or international level. In a similar vein it could be argued that the same issue applies when it comes to the companies and public institutions' management of occupational health and safety activities.

Research has also shown that economic recession has an effect on psychological and behavioural health that is attributed to working environment problems (Catalano 1979; Boone and Ours 2006; Goldman-Mellor 2010). On the one hand; the research suggests that one of the mechanisms involved a "countercyclical" effect which means that financial crisis can lead to an increase of occupational health and safety problems induced by, for example, stress caused by expectation of job loss. On the other hand; it is suggested that recession can have "pro-cyclical" effect which means that the decline in economy results in a decrease of occupational health and safety problems.

Boone and Ours (2006) points out that pro-cyclicality is seen in that workplace accident rates decrease during recessions, which again means that occupational health and safety increases during financial crises. This effect has also been shown by Ruhm (2000) who found strong evidence that occupational health increase in case of economic decline. In addition, pro-cyclical research points at employees' capability to manage occupational health safety increases when job demands in terms of time and quantity decrease (Catalano et al, 2011).

All in all, an interesting research question to be pursued in this paper is, whether the onset of a general economic recession has had an impact on enterprises' preventive occupational activities? In particular, we will discuss trends in a period spanning from non-recession in 2006 to a full scale recession in 2011 that might reveal change in practises in the administration of parts of the health and safety risk assessment in Danish companies and public organisations. Likewise we wish to explore preventive actions related to the management of occupational risks within the area of psychosocial work environment and occupational accidents according to the hypotheses of pro-cyclicality and counter-cyclicality.

2. MATERIALS AND METHODS

In 2005 the Danish government launched an action programme that focus on occupational health and safety activities. The goal of the plan was during a five year period to put focus on four problem areas: psychosocial work environment, occupational accidents, noise at the workplace and muscle-skeletal distress. I addition, it was decided to follow the development of Danish enterprises' occupational safety activities through a five year period based on a quantitative survey (Sønderstrup-Andersen et al 2010). A baseline for the study named "Surveillance of health and safety activities in enterprises" was established in 2006, which is prior to the onset of the financial crisis in 2008 as discussed above in the introduction. Follow-up data was collected in 2011 during the recession period. The participants were randomly selected from the Danish national register of companies and public institutions. The samples are stratified according industrial sector and size of company or public institution. We have included all sectors listed in the Danish Industrial Classifications of All Economic Activities, which is the National version of EU's nomenclature (NACE). During 2006 and 2011 NACE has changed its classifications. The Danish Industrial Classifications has been refined according to the change of NACE. I 2006 data was stratified into 49 classifications and in 2011 into 36 classifications. We have stratified data into three size groups: In 2006 1-4 employees, 5-19 employees and 20 and above employees, while in 2011 1-9 employees, 10-19 employees and 20 and above employees. The change of enterprise size groups follows the changes in the legislation with regard to the organization of occupational health and safety activities within enterprises. 2006 data is weighted according to the change in classifications and organizational size to make it comparable with the 2011 data.

The questionnaire was distributed to an employee safety representative and an employer or an employer representative in each of the participating organizations. In the results presented

in this paper we have used data from only one representative from each of the participating organization. We have used data from employer representatives as a primary source if available, because employers by law have the formal responsibility for managing the actual occupational preventive activities. For the remaining cases we used data from the employee representatives. In 2006 the proportion of employee representative data comprises 20% while in 2011 the proportion amounts to 30%.
Data was collected through mail based questionnaires, telephone interviews and internet based questionnaires. The survey is anonymously administered, the organizations were free to answer and did not receive any participation fees. The survey contain 80 items designed to measure the general management preventive working environment activities and to measure preventive activities within the following occupational health and safety areas: Work accidents, psychosocial working environment, physical working environment, noise, and substances and materials. In this paper we focus on selected items within the management of preventive activities in general and on the psychosocial and work accidents items.

3. RESULTS

The 2006 survey sample consists of 9720 companies and public institutions. The dropout rate was 1245 (defunct or non- accessible) so the questionnaire was distributed to 8475 private companies and public institutions. The participation rate was 76% (N=6423) when counting companies and institutions with at least one returned questionnaire. The 2011 survey sample consists of 7550 questionnaire companies and public institutions. The dropout rate was 826, which means that the questionnaire was sent to 6724 private companies and public institutions. The participation rate was 49%.

Table 1 – Workplaces that as part of the general working environment activities have produced an plan for initiating preventive occupational health and safety actions within specific working environment areas shown as percentage of organizations that as part of the health and safety risk assessment has identified and recorded working environment problem areas. Based on Cochran-Armitage trend test. 2006 data are weighted according industrial sector and size of workplace.

Occupational health and safety areas	**2006**		**2011**		**Development 2006-2011**
	Nweigthed	Percentage	N	Percentage	P values
Work accidents	4284,7	43,8	1913	39,4	<0,001
Psychosocial working environment	3362,3	41,7	1833	52,2	<0,001

Table 1shows the proportion of work places that has documented the state of affairs in their working environment and as result of that mapping has produced plan to take preventive action according to problems identified within the different occupational health and safety areas. Data from 2006 are compared to 2011. The table shows that more companies and public institutions in 2011 compared to 2006 have made a record of occupational health and safety problems, estimated the seriousness and the extent of the problems and as part of the analysis have produced action plans to intervene in relation to the problems in the specific occupational health and safety areas.
Moreover, Table 1 shows that significantly more workplaces in 2011 have produced action plans compared to 2006 within the psychosocial working environment, while significantly fewer workplaces in 2011 have produced action plans compared to 2006 in relation to the area of accidents at work.

Table 2 shows two examples with respect to the workplaces initiatives within the psychosocial working environment in terms of implementation of appraisal interviews and job satisfaction surveys (surveys of psychosocial well-being) and compares the development from 2006 to 2011. The table shows an increase of the proportion of companies and public institutions that have implemented the forms of initiatives within the area of psychosocial occupational health and safety along no matter the size of companies and public institutions.

Table 2 - Implementation of appraisal interviews and job satisfaction surveys according to the size of companies and public institutions. Based on Cochran-Armitage trend test. 2006 data is weighted according industrial sector and size of workplace.

Psychosocial occupational health safety activities	**Number of employees**	**2006**		**2011**		**Development 2006-2011**
		Nweigthed	Percentage	N	Percentage	P values

Implementation of appraisal interviews	1-9	1577,4	49,4	790	54,5	<0,001
	10-19	1917,4	60,4	978	73,6	<0,001
	20 +	2581,3	78,2	1356	85,8	<0,001
	In total	6076,2	65,1	3133	74,9	<0,001
Job satisfaction surveys	1-9	1530,4	25,5	788	34,3	0,001
	10-19	1824,6	32,4	953	46,1	<0,001
	20 +	2481,4	51,2	1313	61,1	<0,001
	In total	5636,3	38,9	3063	49,4	<0,001

Table 3 shows the development from 2006-2011 with respect to the workplaces' implementation of regularly occupational health and safety rounds. As seen there is a minor but significant decrease in the implementation of the safety rounds.

Table 3 - A comparison of the proportions of workplaces that undertake safety rounds on a regular basis in 2006 and 2011 respectively. Based on Cochran-Armitage trend test. 2006 data is weighted according industrial sector and size of workplace

Have regular safety rounds been implemented at your workplace?	**2006**		**2011**		**Development 2006-2011**
	Nweigthed	Percentage	N	Percentage	P values
	6172,1	74,8%	3149,00	69,7%	<0,001

Table 4 - The companies and public institutions preventive occupational health and safety activities with respect to avoid falls from heights. 2006 and 2011 data are compared. Based on Cochran-Armitage trend test. 2006 data is weighted according industrial sector and size of workplace.

What have you done to avoid accidents as a result of falling from heights?	**2006**	**2011**	**Development 2006-2011**
	Percentage	Percentage	P values
We have kept the workplace clear	37,2%	44,7%	<0,001
Safety equipment are maintained regularly	51,3%	47,1%	0,027
Ensured proper communication of instructions	48,5%	41,4%	0,000
Safety equipment must be used	55,5%	51,4%	0,028
Kept ladders and scaffolds in secure condition	65,8%	59,4%	0,000
Ensured proper use of ladders and scaffolds	60,4%	55,1%	0,004
Avoided time pressure	9,9%	11,2%	0,281
Nweigthed N	1713,3	1225	

Table 4 compares the workplaces' preventive activities in 2006 and 2011 with respect to prevent to accidents caused by falling from heights like falling from ladders and scaffolds. The table shows that there is a significant decrease in the following activities in 2011 compared to 2006: "Safety equipment are maintained regularly," "Ensured proper communication of instructions," "Safety equipment must be used," "Kept ladders and scaffolds in secure condition,"
"Ensured proper use of ladders and scaffolds," and "Avoided time pressure." In a single case there is a significant increase in activity namely with respect to keeping the workplace clear.

4. DISCUSSION

Several issues might limit the study. Firstly, a prospective analysis would have been possible at least with respect to the largest enterprises if the study had not been anonymous. Because we have relative few large companies and public institutions the sample will inevitably contain the same enterprises in 2006 and 2011. However, the large sample and the large number of responses in the two surveys allow for relatively firm conclusions. Secondly, the sample size and the high response rate to some extent rule out the possibility that only enterprises with a high occupational health and safety performance participated. Conversely, the response rate (49%) at the follow-up assessment in 2011 is lower than when the baseline was established in 2006 (76%). Especially, it is difficult to get small private companies to answer questionnaires. Thirdly, the difference in response rate is most likely due to the general economic recession during the data collection period – some enterprises might not be so willing to reply on questionnaires if they are struggling to survive. Moreover, it might be due to differences in data collection techniques. That is, the conclusions might be less robust with respect to small private companies.

Data from the surveys has been compiled at enterprise level. We aimed to gain data from both an employer representative and an employee safety representative. Nevertheless, for the 2006 data in approximately 80% of the cases we used data from employer representatives, while for the 2011 data the proportion was approximately 70%. In both data samples the employer representatives tended to have a marginally (but statistically significant) higher score on the indices than the employees. The difference for the small companies is 1-2 %: For medium sized companies the difference is 1-5%. There is no significant difference for the largest companies.

For example, in the 2011 data there is a 93% agreement between employer representative and the employee safety representative with respect to whether or not a health and safety risk assessment has been prepared. In 3% of the cases the employer representative gives a positive answer, while the employee safety representative in the same organization gives a negative answer. In 1% of the cases the opposite response pattern is found. With respect to the remaining 3% of the cases then at least one of the different representatives give the answer "do not know. We estimate that the difference in response patterns have an insignificant effect on the results.

We have compared data sampled in 2006 with data gathered in 2011. I the intervening period of time the classification of the international industrial sectors (NACE) have changed. Accordingly the Danish variant of the classifications has been transformed. Moreover, legislative changes in the period meant that we had to stratify differently with respect to size of enterprise in 2011 compared to 2006. Since the samples also are stratified according to the sector classifications we had to put weights on the 2006 data and rearrange data according to enterprise size groupings to make it possible directly to compare the two data samples. We do not think that this impact the analyses presented in this paper. Nonetheless, it means that the 2006 results presented in this paper differ from earlier publications (e.g. Sønderstrup- Andersen et al 2010).

The study shows that more enterprises 2011 compared to 2006 have made a record of psychosocial occupational health and safety problems and that they as part of the analysis have produced plans to take action in relation to problems. Conversely, this could indicate that enterprises being better to actually producing action plans to deal with the problems discovered. Nonetheless, we found that more enterprises had implemented appraisal interviews and job satisfaction surveys. Such actions are quite costly and resource demanding, but shows that the enterprises nevertheless the economic recession seem to keep a focus on learning to operate more effectively with respect to occupational health and safety and not focus solely on cost cutting strategies. All in all, these findings within the psychosocial health and safety area supports the countercyclical hypothesis, that economic recessions results in an increase of occupational health and safety problems.

Furthermore, our study shows that fewer enterprises in 2011 have produced a register of occupational health and safety problems in relation to the area of accidents at work compared to 2006, but as part of the analysis they have produced plans to take action to deal with the problems. On the one hand; this could indicate that fewer problems related to accidents at work are detected. On the other hand; this could point toward enterprises showing a better performance with respect to actually producing action plans for handling the problems identified. However, we also found that fewer enterprises had implemented safety rounds as part the prevention of accidents at work and that fewer enterprises had initiated actions to prevent accidents caused by falling from heights like falling from ladders and scaffolds.

In the aggregate, these findings within the work accidents area supports the pro-cyclical hypothesis, that economic recessions results in a decrease of occupational health and safety problems. All analyses presented regarding the developments with respect to occupational health and safety activities are based on the assumption that an increase in activity level is viewed as an enhancement. To what extent a decrease in activity level is caused by enterprises having reached a satisfactory level according to legal regulations and that they thereby judges that no further action is needed has not be taken in to account in this study.

4. CONCLUSIONS

The results of our study indicate that the enterprises in 2011 have had more focus on managing psychosocial risk factors that they did in 2006. We have only showed a few examples from our data, but other parts of our data seem support this pattern. For example, with respect to preventive activities in terms of increasing employees possibilities for personal development and for increasing the possibility to excert an influence over own work. We will pursue these issues in a later paper. In addition, we found that in 2011 more companies and public organisations have worked out psychosocial work environment actions plans as part of their health and safety risk assessment activities. With respect to the management of preventive activities within the area of occupational accidents the picture is a bit different. In 2011 fewer companies and public organisations have prepared occupational accident actions plans as part of their health and safety risk assessments. In addition, it is found that fewer companies than in 2006 have initiated safety rounds on a regular basis. Finally, there has been a decrease in several categories of preventive activities with respect to prevent falls. In the aggregate our research suggests a mixed picture and we have discussed findings that support both the pro-cyclical and the countercyclical hypotheses. Further research wait ahead to dig further into these mechanisms and the impact of economic recession on occupational health and safety activities.

5. REFERENCES

Houdmont, J., Kerr, R. and Addley, K., (2012), Psychosocial factors and economic recession: the Stormont Study, *Occupational Medicine*, 62(2), pp 98-104

ILO*, Health and Safety at Work: A basic human right*, (2009), ILO, Retrieved from http://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/publication/wcms_108686.pdf (acsessed 24 june 2015).

ILO, *Protecting Workplace Safety and Health in Difficult Economic Times. The Effect of the Financial Crisis and Economic Recession on Occupational Safety and Health.* (2013), Programme on Safety and Health at Work and the Environment (SafeWork). Seiji Machida Director. International Labour Office, Geneva.

ISSA, *Survey on social security in times of crisis: Final report on findings and conclusions*, (2011), (accessed 15th June 2015)

ISSA, *Survey on social security in times of crisis: Summary of findings and conclusions*, (2009), (accessed 15th June 2015)

ISSA, *The impact of the financial crisis on safety and health at work*, (2010), https://www.issa.int/-/the-impact-of-the-financial-crisis-on-safety-and-health-at-work? (accessed 14th June 2015)

Johnson J., V., Hall E., M., (1988), Job strain, work place support and cardiovascular disease: a cross-sectional study of a random sample of Swedish working population, *Am J Public Health,*78, pp 1336–42.

Kang, S. Y., Staniford, A., Dollard, M.F., Kompier, M. (2008). Knowledge Development and Content in Occupational Health Psychology: A Systematic Analysis of the Journal of Occupational Health Psychology, and Work & Stress, 1996-2006, pp 27-63. In J. Houdmont & S. Leka & (Eds), *Occupational Health Psychology: European Perspectives on Research, Education and Practice,* Vol. 3, Maia, Portugal: ISMAI Publishers.

Karasek , R., A., (1979), Job demands, job decision latitude and mental strain: implications for job redesign. *Administrative Science Quarterly*, 24, pp 285-308.

Karasek R, Theorell T., (1990), *Healthy work: stress, productivity and the reconstruction of working life*, New York (NY): Basic Books.

Kristensen, T., S., (1995), The demand-control-support model: methodological challenges for future research. *Stress Med.*, 11, pp 17–26.

Mind / Populus Workplace Health and Stress Survey, (2010), retrieved from http://www.populus.co.uk/wp-content/uploads/download_pdf-210310-Mind-Workplace-Health-and-Stress-Survey-March-2010.pdf (accessed 10 January 2015).

Rangvid, J., (2013) *THE FINANCIAL CRISIS IN DENMARK– causes, consequences and lessons*, The Committee's conclusions on the causes of the financial crisis in Denmark, Retrieved from http://www.evm.dk/english/news/2013/18-09-13-the-financial-crisis-in-denmark, (acsessed 12 june 2015)

Ruhm, C., R., (2000), Are recessions good for your health? *The Quarterly Journal of Economics*, May 2000, pp 617-650.

Sidra J. Goldman-Mellor, S. J., Saxton, K., B., and Catalano, R. , C., (2010), Economic Contraction and Mental Health, A Review of the Evidence, 1990–2009, *International Journal of Mental Health,* vol. 39, no. 2, Summer 2010, pp 6–31.

Sønderstrup-Andersen, H., H., K.; Fløcke, T., Mikkelsen, K., L., Roepstorff, C., (2010), Measuring enterprise proactiveness in managing occupational safety, *Safety Science Monitor*, Vol. 14, No. 1.

Wallis A, Dollard MF. Local and global factors in work stress—the Australian dairy farming examplar. SJWEH Suppl. 2008;(6):66–74.

Westgaard, R.,H., Winkel, J., (2011) Occupational musculoskeletal and mental health: Significance of rationalization and opportunities to create sustainable productive systems – a systematic review", in *Applied Ergonomics* Vol 42, No 2, pp 261-296

Wisdom, K. Wright, O. and Tsagli, M., (2008), KPMG and Chartered Institute of Personnel and Development, *Labour Market Outlook*, winter 2008, http://www.cipd.co.uk/binaries/labour_market_outlook_winter_2008-09-full-version.pdf, (accessed 12 June 2015)

Houdmont, J., Kerr, R. and Addley, K., (2012), Psychosocial factors and economic recession: the Stormont Study, *Occupational Medicine*, 62(2), pp 98-104

ILO*, Health and Safety at Work:A basic human right*, 2009), ILO, Retrieved from http://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/publication/wcms_108686.pdf (acsessed 24 June 2015).

ILO, *Protecting Workplace Safety and Health in Difficult Economic Times. The Effect of the Financial Crisis and Economic Recession on Occupational Safety and Health.* (2013), Programme on Safety and Health at Work and the Environment (SafeWork). Seiji Machida Director. International Labour Office, Geneva.

IMF, International Monetary Fund, (2009), World economic outlook, *World Economic and Financial Survey*, by the staff of the International Monetary Fund, Washington, DC, Retrieved from http://www.imf.org/external/pubs/ft/weo/2009/01/pdf/c1.pdf, (accessed 13 June 2015).

ISSA, *Survey on social security in times of crisis: Final report on findings and conclusions*, (2011), (accessed 15th June 2015)

ISSA, *Survey on social security in times of crisis: Summary of findings and conclusions*, (2009), (accessed 15th June 2015)

ISSA, *The impact of the financial crisis on safety and health at work*, (2010), https://www.issa.int/-/the-impact-of-the-financial-crisis-on-safety-and-health-at-work? (accessed 14th June 2015)

Johnson J., V., Hall E., M., (1988), Job strain, work place support and cardiovascular disease: a cross-sectional study of a random sample of Swedish working population, *Am J Public Health,*78, pp 1336–42.

Kang, S. Y., Staniford, A., Dollard, M.F., Kompier, M. (2008). Knowledge Development and Content in Occupational Health Psychology: A Systematic Analysis of the Journal of Occupational Health Psychology, and Work & Stress, 1996-2006, pp 27-63. In J. Houdmont & S. Leka & (Eds), *Occupational Health Psychology: European Perspectives on Research, Education and Practice,* Vol. 3, Maia, Portugal: ISMAI Publishers.

Karasek , R., A., (1979), Job demands, job decision latitude and mental strain: implications for job redesign. *Administrative Science Quarterly*, 24, pp 285-308.

Karasek R, Theorell T., (1990), *Healthy work: stress, productivity and the reconstruction of working life*, New York (NY): Basic Books.

Kristensen, T., S., (1995), The demand-control-support model: methodological challenges for future research. *Stress Med*., 11, pp 17–26.

Mind / Populus Workplace Health and Stress Survey, (2010), retrieved from http://www.populus.co.uk/wp-content/uploads/download_pdf-210310-Mind-Workplace-Health-and-Stress-Survey-March-2010.pdf (accessed 10 January 2015).

Rangvid, J., (2013) *THE FINANCIAL CRISIS IN DENMARK– causes, consequences and lessons*, The Committee's conclusions on the causes of the financial crisis in Denmark, Retrieved from http://www.evm.dk/english/news/2013/18-09-13-the-financial-crisis-in-denmark, (acsessed 12 June 2015)

Ruhm, C., R., (2000), Are recessions good for your health? *The Quarterly Journal of Economics*, May 2000, pp 617-650.

Sidra J. Goldman-Mellor, S. J., Saxton, K., B., and Catalano, R. , C., (2010), Economic Contraction and Mental Health, A Review of the Evidence, 1990–2009, *International Journal of Mental Health,* vol. 39, no. 2, Summer 2010, pp 6–31.

Sønderstrup-Andersen, H., H., K.; Fløcke, T., Mikkelsen, K., L., Roepstorff, C., (2010), Measuring enterprise proactiveness in managing occupational safety, *Safety Science Monitor*, Vol. 14, No. 1.

Wallis A, Dollard MF. (2008), Local and global factors in work stress—the Australian dairy farming examplar. *SJWEH Suppl.,*6, pp 66–74.

Westgaard, R.,H., Winkel, J., (2011) Occupational musculoskeletal and mental health: Significance of rationalization and opportunities to create sustainable productive systems – a systematic review", in *Applied Ergonomics* Vol 42, No 2, pp 261-296

Wisdom, K. Wright, O. and Tsagli, M., (2008), KPMG and Chartered Institute of Personnel and Development, *Labour Market Outlook*, winter 2008, http://www.cipd.co.uk/binaries/labour_market_outlook_winter_2008-09-full-version.pdf, (accessed 12 June 2015)

Supporting Managers’ Commitment to Safety Management and Leadership: Good Practices from the Managers’ Viewpoint

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Abstract

Managers’ strong commitment to safety can result in both positive safety outcomes as well as increase desirable non-safety outcomes in employees’ attitudes and behaviours. Therefore, managers’ commitment and active participation towards safety is a key element for successful safety management, culture and climate. This qualitative study identifies factors that hinder or promote managers’ commitment to safety and reviews organisational measures that could support such commitment. 49 managers in five industrial organisations (energy and processing industries and industrial services) were interviewed. The interview data was categorised and examples of the factors are presented. The interviews showed that contextual factors such as role overload, production demands, formal safety procedures, mandated safety goals, workforce attitudes and managers’ attitudes hinder managers’ commitment to safety. The factors that promote managers’ commitment to safety are increasing safety awareness among managers, influencing managers’ safety attitudes, recognising managers’ safety commitment, emphasising managers’ safety responsibilities, developing adequate organisational safety procedures, superiors providing encouragement and support, benchmarking others’ safety activities, understanding the economic effects of safety and safety improvement itself. Finally, the researchers and safety professionals of the participating companies held a workshop where they reviewed the interviews and suggested organisational measures to support managers’ commitment to safety. The suggested measures included organisational support for safety activities, such as inspirational and participative management training; appropriate safety objectives; peer, superior and top management support; campaigns and competitions; employee safety training and simplified safety procedures and reporting. The results of the study may be utilised in a variety of organisations to promote managers’ commitment to safety.

Keywords: Safety commitment, engagement, managers’ active participation, organisational support.

1. INTRODUCTION

1.1. Importance of Managers’ Commitment to Safety

Managers’ commitment to safety can be defined as the extent to which they place a high priority on safety and how effectively they communicate and act regarding safety issues (Neal and Griffin, 2004 as cited in Fruhen et al., 2014). Engagement is often synonymous with commitment (Conchie et al., 2013) and is defined as the extent to which a person shows energy, enthusiasm, a sense of inspiration, and full concentration (Schaufeli and Bakker, 2004, as cited in Conchie et al., 2013). Here, commitment refers to managers’ commitment to safety management and leadership.

Achieving sustainable safety performance requires paying attention to both safety management systems and cultural change in organisations, and it is vital that the right issues are emphasised (Fitzgerald, 2006; Killimett, 2006). The importance of top management’s support of successful safety performance is almost universally claimed (e.g., Fernández-Muñiz et al., 2007; Hale and Hovden, 1998; Michael et al., 2005; Shannon et al., 1997). Management’s level of safety commitment is one of the most significant predictors of accidents and near accidents (Cohen, 1975; Hale et al., 1997; Rundmo, 1992; Smith et al., 1978). Geldart et al. (2010) emphasise the attitudes and values of top management and their manifestations in the workplace. Management’s commitment and active participation towards safety is one major aspect of occupational health and safety (OHS) and safety management systems (e.g., Fernández-Muñiz et al., 2009; OHSAS 18001:2007; Robson et al., 2007; Redinger and Levine, 1998) and effective safety interventions (Chen et al., 2009; Hale et al., 2010; Mearns et al., 2003; O’Toole, 2002; Vinodkumar and Bhasi, 2011; Vredenburgh, 2002).

Through their actions and examples, managers can positively affect the safety culture and climate to encourage safe behaviours and activities for employees (Fernández-Muñiz et al., 2007; Flin, 2003; Guldenmund, 2000, 2007; Reason, 1997; McDonald et al., 2000),). Safety leadership now receives great emphasis concerning the development and promotion of safety culture and climate (e.g., Killimett 2006; Künzle et al. 2010; O'Dea & Flin 2001; Wu et al. 2008; Zohar 2002). Research has increasingly supported the view that leadership style affects employees' safety behaviour and levels of safety performance (Griffin and Hu, 2013; Griffin and Neal, 2000; Hoffmeister et al., 2014; Kapp, 2012), and managers should visibly express their commitment to safety (Michael et al., 2005; Wu et al., 2008). Managers can provide visible demonstrations of their commitment to continual improvement of safety performance by visiting and inspecting work environments, participating in incident investigation, being actively involved at OHS meetings, communicating OHS, and acknowledging good safety performance (OHSAS 18002:2008).

Employees' perceptions of senior managers' safety attitudes and behaviours form the basis of their safety behaviour, and therefore, their safety performance (Cox et al., 1998; Clarke, 1999; Cooper and Phillips, 1994; Zohar, 1980). According to Clarke (1996), employees' perceptions of managers' commitment to safety is also predictive of incident reporting. Moreover, managers' visible commitment is essential for employees to accept changes to the working routines (Clarke, 1996; Huse and Cummings, 1985). According to Clarke (1999), safety attitudes and collective concern for safety should be recognised at all management levels and between different groups. Employees typically do not have direct contact with senior management; therefore they base their perceptions on middle managers and supervisors.

Organisations with a strong management's commitment to safety may improve safety performance while also increasing desirable non-safety outcomes regarding employee attitudes and behaviours such as job satisfaction, organisational commitment and job-related performance (Michael et al., 2005). According to Veltri et al. (2013), the top-performing organisations on operational outcomes were also the top performers on safety outcomes, all having supportive culture for safety; for example, commitment to safety was an integral part of operations and safety was a core value. Several studies (Hale et al., 2010; Killimett, 2006; Veltri et al., 2013; Yorio and Wachter, 2013) suggest, that an organisation's industry or operating environment are not predictive of safety performance, but commitment to safety is important. These findings highlight the value of managers exhibiting a strong commitment to safety. Nevertheless, these studies cannot model the likely effect of a particular type of factor or intervention in a particular type of organisation (Michael et al., 2005; Robson et al., 2007).

Petersen (2000) suggests criteria for safety excellence at different organisational levels reflecting management's commitment to safety:

- Safety system enforcing supervisory performance
- Middle managers' involvement in their threefold role of:
  - Ensuring supervisory performance
  - Ensuring the quality of that supervisory performance
  - Doing something that shows commitment
- Top executives visibly demonstrating that safety is a value

Despite managers' essential role, some show low levels of commitment to safety and prioritise production criteria over safety. Thus, the level of implementation of safety management procedures may be quite low, resource allocation for preventive actions could be limited, and managers may only seek avoidance of legal responsibilities when adhering to formal compliance with regulations. (Fernández-Muñiz et al. 2009) Managers who successfully demonstrate honest and consistent prioritisation of worker safety may promote the development of workers' trust in the importance of safety and this may motivate workers to behave safely (Törner, 2011). A combination of transformational and active transactional leadership styles (Bass 1985, 1990) is suggested to be most effective towards managing workplace safety (Clarke, 2013; Tappura and Nenonen, 2014). There is a need to support managers' safety participation and commitment in order to achieve real improvements in safety (Simola 2005). Moreover, safety leadership behaviour expressing commitment to safety should be emphasised in organisations.

Previous research related to managers' safety commitment has focused on different managerial actions that demonstrate commitment from employees' viewpoint (e.g. Michael et al., 2005). Conchie et al. (2013) studied supervisors' commitment towards safety leadership from managers' perspective. Huang et al. (2012) studied the interconnection between employees' and supervisors' perceptions of management safety commitment. Nevertheless, research approaching managers' commitment from managers' own viewpoint is scarce (Fruhen et al. 2014). Moreover, while relatively little research in the safety field has focused on factors that influence managers' commitment to safety, non-safety domain factors that promote commitment have gained increasing attention (Conchie et al. 2013). Thus, information is needed about the factors that promote and hinder managers' commitment to safety and implementation of organisational measures that support managers in safety activities.

This paper discusses the factors that influence managers' commitment to safety (e.g. organizational safety policies and procedures), as well as organisational measures that could support their commitment. The objective of this paper is to identify factors that hinder or promote managers' commitment to safety and review organisational measures to support managers' commitment to safety.

1.2. Factors that Hinder or Promote Managers' Commitment to Safety

Research in the non-safety domain has shown that, in addition to individual factors, contextual factors existing in the work environment significantly affect leadership engagement (Arvey et al., 2006), although they are less frequently studied (Bommer et al., 2004; Porter and McLaughlin, 2006). Physical, social and organisational demands (e.g., hazardous work environment) and resources (e.g., peer support) may affect engagement positively or negatively depending on context and whether each is perceived as a hindrance or a challenge (Conchie et al., 2013; Crawford et al., 2010; Demorouti et al., 2001). Factors affecting managers' commitment to safety in the safety literature are presented in Table 1 and discussed in the following section.

Table 1 – Factors that may hinder or promote managers' commitment to safety in the literature.

Study	Industry	Hindering factors	Promoting factors
Conchie et al. 2013	Construction	Role overload Production demands Formal procedures Workforce characteristics Management's lack of training and experience	Social support Perceived autonomy Organisational support Training addressing safety knowledge and confidence to lead
Michael et al. 2005	Wood products manufacturing		Developing management's knowledge about the manufacturing process Emphasising managers' role of showing personal concern for employee safety Developing consistent safety attitudes and actions among production managers
Simola 2005	Metal manufacturing		Management training Safety improvement programmes
Tappura & Hämäläinen 2011			Management training and workshops with joint discussions and company-specific examples
Fruhen et al. 2014	Air navigation services		Senior management training and guidance in problem-solving abilities and perceptions of others
Tappura et al. 2013		Underestimation of occupational accident costs	Knowledge of overall occupational accident costs

Managers' commitment to safety arises from increased safety awareness, which may be induced by an accident or other crisis, or by a training or safety improvement programme (Simola 2005). According to Tappura and Hämäläinen (2011), commitment can be promoted by workshops and training, which consists of joint discussions that build a shared understanding of safety issues. Fruhen et al. (2014) propose that training and guidance designed for senior managers should focus on their problem-solving abilities and perception of others in order to support them demonstrating a commitment to safety.

After studying supervisors' commitment to safety leadership, Conchie et al. (2013) identify several contextual factors. Multiple, often conflicting, role responsibilities and production pressures reduced supervisors' time dedicated to safety activities and hindered their commitment to safety. Formal procedures related to administration and discipline, as well as conflict between formal discipline procedures and their preferred style of leadership, were also regarded as hindrances. Workforce characteristics which include subcontractor safety attitudes, inadequately skilled employees and language barriers, emerged as a hindering factor. For some supervisors, a lack of management training or experience was regarded as a hindrance. Consequently, supervisors exhibited coping mechanisms such as adopting a directive approach of telling rather than consulting and adapting their leadership approach to the situation or employee, thus helping them with the role's demands. Social support and autonomy were perceived to be main resources promoting engagement. Providing organisational support, conveying a message that safety is the top priority and expected from supervisors, equipping supervisors with adequate safety knowledge and providing supervisors with necessary tools supported supervisors' safety commitment. The importance of peer support and both professional and personal relationships with co-workers was emphasised. Moreover, support and 'back-up' from managers was perceived to be crucial. However, most supervisors agreed that managers could provide more support, such as verbal recognition. Moreover, Tappura et al. (2014) find that organizational support, particularly support from immediate superiors and peers is crucial towards challenging safety management situations when such support is especially needed, but this support is often insufficient.

According to Michael et al. (2005), developing managers' knowledge and understanding of the manufacturing process helps them to identify unsafe working conditions, equipment or behaviours and take corrective actions reflecting their commitment to safety. Emphasising managers' and supervisors' responsibility of showing personal concern for employee safety and health, implementing job-training programmes, participating in safety committees and considering safety in job design may help their commitment to safety. Moreover, developing consistent attitudes and actions (e.g., not allowing safety to be compromised) among production managers and supervisors helps them in demonstrating such a commitment.

According to a study by Tappura et al. (2013), estimating overall occupational accident costs could increase managers' safety awareness and help them to focus on optimal safety investments and the introduction of preventive actions (that is, help managers to internalise the importance of safety measures from the economic perspective). However, these costs are often underestimated, which may decrease managers' commitment to safety.

Previous studies (Conchie et al., 2013; Frick, 2013; Hardison et al., 2014; Tappura et al., 2014) identify the importance of safety resources, competence development and organisational support for managers to succeed in their safety work. However, upper management often ignores the importance of its own role, instead delegating safety issues to front-line managers without providing adequate resources or support (Frick 2013).

The objective of this study is to chart the factors that hinder or promote managers' commitment to safety from the managerial perspective and to complement the literature with empirical findings. In addition, organizational measures that could support managers' commitment to safety are suggested.

2. MATERIALS AND METHODS

The study was carried out as part of a research project which focuses on safety leadership, competence and commitment according to managers' perspectives from five industrial organisations (energy and processing industries and industrial services) (Table 2). The motivation for the study of the participating organisations arises from the need to support and advance managers in their safety role. Thus, the focus is on the managerial viewpoint, as well as organisational factors and measures. The study is based on managers' thematic interviews (n=49) about the five participating companies. It exploits a qualitative research strategy due to its exploratory nature and focus on managers' own perceptions of the topic, for which a qualitative approach is suitable (Creswell, 2013; Palys, 2003). It also charts factors affecting managers' commitment to safety from managers' perspectives and complements the literature with empirical findings.

Table 2 – Background information about participating organisations (in 2014).

Company	Industry	Turnover	Number of employees	Number of interviewees
A	Energy	819 million €	1 500	15
B	Industrial services	640 million €	7 800	14
C	Chemical processing		550	7
D	Industrial services	100+ million €	700	7
E	Industrial services		22	6

Purposive sampling was applied to recruit interviewees from different organisational levels and different business units within the participating organisations. The organisations' safety professionals named and invited the interviewees to participate in the study. The interviewees were selected based on the needs of organisational development projects. Researchers conducted the interviews. Each researcher scheduled and conducted the interviews individually. Thematic interviews were used to explore the contextual factors that managers perceive in relation to their commitment to safety. The interviewees were middle- and line-managers including production managers, maintenance managers, project managers and supervisors. Managers were asked about both the hindering and supporting factors affecting their commitment to safety. The interviews were conducted either individually or in focus groups of 2-3 participants. Three interviews were conducted by phone due to scheduling difficulties. The anonymity and confidentiality of the responses was emphasised during the interviews to facilitate interviewees' free and open responses, which improves the validity of qualitative research (Stenbacka, 2001). Interviews were conducted between May 2014 and January 2015 and lasted between 30 and 60 minutes.

The interview data was recorded and transcribed. The researchers analysed the data by comparing and categorising it according to the findings from the literature. The interview data was reviewed during a workshop in March 2015 and complemented by organisational measures that could support managers' commitment to safety. The participants of the workshop were the safety professionals of the participating companies.

3. RESULTS AND DISCUSSION

Based on the results in Table 3, the most important factors hindering managers' commitment to safety are contextual in nature. The results are well in line with the previous study of Conchie et al. (2013) and they confirm that the major factors hindering managers' commitment to safety are related to managers' role overload, production demands and formal safety procedures. In addition to Conchie et al. (2013), the interviews showed that managers perceived (negative) employee and management attitudes to safety, as well as external safety objectives to be hindrances.

Table 3 – Categorisation of factors hindering managers' commitment to safety.

Category	Examples
Role overload	A lot of managerial activities Lack of resources (e.g., time) for safety activities Time consuming safety administration and paper work
Production demands	Daily production activities and revenue are prioritised Office work impedes being present and supervising at work sites
Formal safety procedures	Slow procurement process for safety equipment Complicated registration procedures and systems Too many meetings
Safety goals	External safety goals Unable to influence goal-setting Tightening of safety goals despite previous goals not being achieved
Employee attitudes	Negative attitudes during safety meetings Negative attitudes about safety among senior employees Making unnecessary safety notifications
Management attitudes	Disinterest in safety Not perceiving safety as a necessity Overlooking safety negligence Shooting down safety proposals Conflicting safety alignments between different managerial levels Fairness and equal treatment of managers Neglecting formal safety procedures (e.g. issuing a warning) Resistance to changes and new safety procedures

According to managers' perceptions (Table 4), the factors that promote managers' commitment to safety are increasing safety awareness among managers, influencing managers' safety attitudes, recognition of managers' safety commitment, emphasising managers' safety responsibilities, developing adequate organisational safety procedures, encouragement and support from superiors, benchmarking others' safety activities, understanding the economic impacts of safety and safety improvement itself.

Table 4 – Categorisation of the factors promoting managers' commitment to safety.

Category	Examples
Safety awareness	Increasing managers' safety awareness Understanding manager's safety role Personal growth in relation to safety Adequate tools for accessing safety information Emphasising the effects of a positive/negative safety culture Safety communication via various channels
Managers' safety attitudes	Influencing managers' safety attitudes by inspiring training Improving safety knowledge Peer discussion and support
Recognition of safety commitment	Clear safety goals (e.g., zero accidents) Rewarding good safety results Possibility to influence goal-setting Resources (time) for achieving the goals provided Competitions, campaigns and bonus Verbal recognition
Management safety responsibilities	Emphasising managers' regulatory and moral responsibility to take care of employees
Organisational safety procedures	Top management resourcing, appreciation and emphasis on safety Uniform, mandatory and scheduled safety procedures Instructions for safety procedures Support and help in safety activities

Support from superior	Own superior encouraging and expressing interest in safety Pressure and discussions, when the safety goals are not achieved
Safety benchmarking	Visiting other units and learning from them Competitions between units Wide participation for safety rounds Participating in forums outside of the company
Economic effects of safety	Understanding the economic effects of good/poor safety and accident costs
Safety improvement	Seeing the progress and the benefits of good safety Ability to influence safety improvement

The major factors promoting managers' commitment to safety were related to managers' safety awareness, attitudes, recognition, responsibilities and organisational safety procedures. Moreover, managers' perceived support from superiors, safety benchmarking, economic effects and safety improvements itself acted as promoting factors for their commitment to safety. According to Conchie et al. (2013), major factors helping supervisors' commitment to safety leadership were social support and perceived autonomy. Tappura et al. (2014) and Frick (2013) find that to succeed in safety management, organisational safety procedures, as well as upper management support, resourcing and guidance, should be in place to support managers. Inadequate support from managers' own superiors was a key challenge for some managers, as the principal support was expected to come from one's superior (Tappura et al., 2014).

The results of the interviews were reviewed in a related workshop carried out with the participating companies. Based on the results, effective measures to support managers' commitment to safety were suggested. Measures that support managers in their safety activities include organisational support in safety activities, such as inspirational and participative management training; appropriate safety objectives; support from peers and superiors; campaigns and competitions; employee safety training and simplified safety procedures and reporting. Including safety responsibilities and activities in the recruitment process (e.g., interviews) and job description supports managers' commitment to safety from the very beginning of their career. Management training, workshops and safety meetings enabling discussions on regulatory safety requirements, topical safety issues and related problem-solving give managers both concrete and emotional support. In order to support managers' personal growth (e.g., attitudes) and to express superiors's interest in safety, safety issues can be included in yearly development discussions and informal discussions. Defining clear, uniform and achievable safety goals and developing a safety bonus system as a part of the general reward system may support managers' commitment to safety. Support from safety, occupational health, human resource and law professionals may assist managers when their own competence or resources are inadequate. Top management's expressed commitment (e.g., safety walks, safety communication), allocation of resourcing for safety activities at all managerial levels and investment in an adequate safety management system are crucial towards supporting lower-level managers' commitment to safety. Creating unified safety instructions and ensuring their enforcement at all organisational levels gives managers back-up when conflicts arise. Other organisational supports for managers include learning from customers' safety procedures, internal and external safety audits, information on absence and accident costs, increasing use of mobile devices for safety reporting and meetings, and active communication of safety improvements and success stories.

Managers' commitment to safety can be promoted through workshops and training consisting of joint discussions with peers, which build a shared understanding of safety issues and enable peer support (Conchie et al., 2013; Tappura and Hämäläinen, 2011). Senior management's training programmes should focus on their problem-solving abilities and perception of others in order to support them towards demonstrating a commitment to safety (Fruhen et al., 2014), which is crucial for maintaining the commitment of lower-level managers. Diverse organisational measures are beneficial for improving managers' consistent commitment to safety. This is important towards improving safety performance and other positive outcomes such as fostering favourable employee attitudes and behaviours (Michael et al., 2005). These organisational measures include top management activities expressing their commitment to safety, defining managers' safety responsibilities, providing inspirational and participative management training and providing superior and peer support, as well as support from safety, health, human resource and law professionals.

The scientific contribution of this study relies on the identification and categorisation of the factors affecting managers' commitment to safety. The results support and extend previous research on these factors and provide new information about organisational measures that support managers' commitment to safety. Moreover, the information and examples of factors and organisational supports for managers provide a practical contribution. Organisations may utilise this new information on the hindering and promoting factors of managers' commitment to safety when they design organisational-specific safety management interventions (e.g., training). In addition, various organisations may utilise the measures suggested by the participating companies to support managers' commitment to safety and to promote safety. In the future, the researchers will study the effects of particular factors or organisational supports towards managers' commitment.

4. CONCLUSIONS

This paper explores the contextual factors hindering and promoting managers' commitment to safety. Based on the results, organisational measures are suggested that can be used to increase managers' commitment to safety in various organisations. Increasing managers' resources for safety activities or simplifying safety activities helps them when conducting their daily responsibilities. Participation towards defining safety goals improves managers' commitment to these goals. Developing managers' safety awareness from the very beginning of their career also supports their commitment. Managers' commitment to safety should be recognised at least verbally or by rewarding good safety results. Increasing organisational support by providing uniform safety procedures and inspirational training, developing consistent safety attitudes and behaviours among all managers and offering social support and top management's support are important for promoting managers' commitment to safety. A formal peer support system such as managers' forums could be beneficial especially for less experienced managers. Managers' commitment to safety is important at all organisational levels. Upper-management's support, resourcing and guidance are essential for lower-level managers, especially when they encounter conflicting role responsibilities. Moreover, developing consistent safety attitudes among managers requires top management's support.

This study contributes to safety research as it extends the literature on managers' commitment to safety into an area that has seen few past works. Presenting examples of the factors that may hinder or promote managers' commitment to safety provides guidance for organisations, managers and researchers towards defining the organisational development activities that promote managers' commitment to safety.

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6. REFERENCES

Arvey, R. D., Rotundo, M., Johnson, W., Zhang, Z. & McGue, M. (2006). The determinants of leadership role occupancy: genetic and personality factors. *The Leadership Quarterly,* 17, 1–20.

Bass, B. M. (1985). *Leadership and Performance Beyond Expectation*. New York: The Free Press.

Bass, B. M. (1990). From Transactional to Transformational Leadership: Learning to Share the Vision. *Organizational Dynamics,* 18(3), 19-31.

Bommer, W. H., Rubin, R. S. & Baldwin, T. T. (2004). Setting the stage for effective leadership: antecedents of transformational leadership behavior. *The Leadership Quarterly,* 15, 195–210.

Chen, C.-Y., Wu, G.-S., Chuang, K.-J. & Ma, C.-M. (2009). A comparative analysis of the factors affecting the implementation of occupational health and safety management systems in the printed circuit board industry in Taiwan. *Journal of Loss Prevention in the Process Industries,* 22(2), 210–215.

Clarke, S. (1996). The effect of habit as a behavioural response in risk reduction programmes. *Safety Science,* 22(l-3), 163-175.

Clarke, S. (1999). Perceptions of organizational safety: implications for the development of safety culture. Journal of *Organizational Behavior,* 20, 185-198.

Clarke, S. (2013). Safety leadership: A meta-analytic review of transformational and transactional leadership styles as antecedents of safety behaviours. *Journal of Occupational and Organizational Psychology,* 86, 22–49.

Cohen, A. (1975). Factors in successful occupational safety programs. *Journal of Safety Research,* 9, 168–172.

Conchie, S. M., Moon, S. & Duncan, M. (2013). Supervisors' engagement in safety leadership: Factors that help and hinder. *Safety Science,* 51, 109–117.

Cooper, M. D. & Phillips, R. A. (1994). Validation of a safety climate measure. Paper presented at the BPS Occupational Psychology Conference, Birmingham, UK.

Cox, S., Tomás, J. M, Cheyne, A. & Oliver, A. (1998). Safety culture: the prediction of commitment to safety in the manufacturing industry. *British journal of management*, 9(September), S3–S11.
Crawford, E. R., LePine, J. A. & Rich, B. L. (2010). Linking job demands and resources to employee engagement and burnout: a theoretical extension and meta-analytical test. *Journal of Applied Psychology,* 95, 834–848.
Creswell, J. W. (2013). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (4th ed.). Washington DC: SAGE Publications Inc.
Demorouti, E., Bakker, A. B., Nachreiner, F. & Schaufeli, W. B. (2001). The job demands-resources model of burnout. *Journal of Applied Psychology,* 86, 499–512.
Fernández-Muñiz, B., Montes-Peón, J. & Vázquez-Ordás, C. (2007). Safety culture: analysis of the causal relationships between its key dimensions. *Journal of Safety Research,* 38(6), 627–641.
Fernández-Muñiz, B., Montes-Peón, J. & Vázquez-Ordás, C. (2009). Relation between occupational safety management and firm performance. *Safety Science,* 47, 980–991.
Fitzgerald, M. K. K. (2006). Safety performance improvement through culture change. *Process safety and environmental protection 83.B4*, 324-330.
Flin, R. (2003). 'Danger – men at work': Management influence on safety. *Human Factors and Ergonomics in Manufacturing,* 13, 261–268.
Frick, K. (2013). Work environment dialogue in a Swedish municipality—Strengths and limits of the Nordic work environment model. *Nordic Journal of Working Life Studies,* 3(1): 69–93.
Fruhen, L. S., Mearns, K. J., *Flin, R. & Kirwan, B. (2014). Skills, knowledge and senior managers' demonstrations of safety commitment. Safety Science,* 69, 29-36.
Geldart, S., Smith, C. A., Shannon, H. S. & Lohfeld, L. (2010). Organizational practices and workplace health and safety: A cross-sectional study in manufacturing companies. *Safety Science,* 48, 562–569.
Griffin, M. A. & Hu, X. (2013). How leaders differentially motivate safety compliance and safety participation: The role of monitoring, inspiring, and learning. *Safety Science,* 60, 196-202.
Griffin, M. A. & Neal, A. (2000). Perceptions of safety at work: a framework for linking safety climate to safety performance, knowledge, and motivation. *Journal of Occupational Health Psychology,* 5, 347–358.
Guldenmund, F. (2007). The use of questionnaires in safety culture research – an evaluation. *Safety Science,* 45(6), 723 -743.
Guldenmund, F.W. (2000). The nature of safety culture: a review of theory and research. *Safety Science*, 34, 215–257.
Hale, A. R. & Hovden, J. (1998). Management and culture: the third age of safety. In Feyer, A.-M., Williamson, A. (Eds.), *Occupational Injury: Risk, Prevention and Intervention.* London: Taylor & Francis, London (pp. 129–166).
Hale, A. R., Guldenmund, R. F., van Loenhout, P. L. C.H. & Oh, J. I. H. (2010). Evaluating safety management and culture interventions to improve safety: Effective intervention strategies. *Safety Science,* 48(8), 1026-1035.
Hale, A. R., Heming, B. H. J., Carthey, J. & Kirwan, B. (1997). Modelling of safety management systems*. Safety Science,* 26, 121–140.
Hardison, D., Behm, M., Hallowell, M. R. & Fonooni, H. (2014). Identifying construction supervisor competencies for effective site safety. *Safety Science,* 65, 45–53.
Hoffmeister, K., Gibbons, A. M., Johnson, S. K., Cigularov, K. P., Chen, P. Y. & Rosecrance, J. C. (2014). The differential effects of transformational leadership facets on employee safety. *Safety Science,* 62, 68–78.
Huang, Y.-H., Verma, S. K., Chang, W.-R., Courtney, T. K., Lombardi, D. A., Brennan, M. J. & Perry, M. J. (2012). Supervisor vs. employee safety perceptions and association with future injury in US limited-service restaurant workers. *Accident Analysis and Prevention,* 47, 45-51.
Huse, E. F. & Cummings, T. G. (1985). *Organisational Development and Change.* St. Paul Minneapolis: West Publishing.
Kapp, E. A. (2012). The influence of supervisor leadership practices and perceived group safety climate on employee safety performance. *Safety Science,* 50(4), 1119–1124.
Killimett, P. (2006). Organizational factors that influence safety. *Process Safety Progress,* 25(2), 94–97.
Künzle, B., Kolbe, M. & Grote, G. (2010). Ensuring patient safety through effective leadership behavior: A literature review. *Safety Science,* 48, 1-17.
McDonald, N., Corrigan, S., Daly, C. & Cromie, S. (2000). Safety management systems and safety culture in aircraft maintenance organisations. *Safety Science,* 34(1), 151–176.
Mearns, K., Whitaker, S. M. & Flin, R. (2003). Safety climate, safety management practice and safety performance in offshore environments. *Safety Science,* 41(8), 641-680.
Michael, J. H., Evans, D. D., Jansen, K. J. & Haight, J. M. (2005). Management commitment to safety as organizational support: Relationships with non-safety outcomes in wood manufacturing employees. *Journal of Safety Research,* 36, 171 – 179.
Neal, A. & Griffin, M. (2004). Safety climate and safety at work. In Barling, J., Frone, M.R. (Eds.), *The Psychology of Workplace Safety.* American Psychological Association, xi, Washington, DC, US (pp. 15-34).
O'Dea, A. & Flin, R. (2001). Site managers and safety leadership in the offshore oil and gas industry. *Safety Science,* 37(1), 39-57.
O'Toole, M. (2002). The relationship between employees' perceptions of safety and organizational culture. *Journal of Safety Research,* 33, 231-243.
OHSAS 18001:2007 *Occupational health and safety management systems – Requirements*. OHSAS Project Group BSI, London.
OHSAS 18002:2008. *Occupational health and safety management systems – Guidelines for the Implementation of OHSAS 18001*. OHSAS Project Group BSI, London.
Palys, T. S. (2003). *Research Decisions: Quantitative and Qualitative Perspectives*. Scarborough, Ontario, Canada: Thomson Nelson,
Petersen, D. (2000). The barriers to safety excellence. *Occupational Hazards,* 62(12), 37-42.
Porter, L. W. & McLaughlin, G. B. (2006). Leadership and the organizational context: like the weather? *The Leadership Quarterly,* 17, 559–576.
Reason, J. (1997). *Managing the risks of organizational accidents*. Aldershot: Ashgate Publishing Ltd.
Redinger, C. F. & Levine, S. P. (1998). Development and evaluation of the Michigan occupational health and safety management system assessment instrument: A universal OHSMS performance measurement tool. *American Industrial Hygiene Association Journal,* 59, 572-581.

Robson, L. S., Clarke, J. A., Cullen, K., Bielecky, A., Severin, C., Bigelow, P. L., Irvin, E., Culyer, A. & Mahood, Q. (2007). The effectiveness of occupational health and safety management system interventions: A systematic review. *Safety Science,* 45, 329–353.

Rundmo, T. (1992). Risk perception and safety on offshore petroleum platforms—part II: perceived risk, job stress and accidents. *Safety Science,* 15, 53–68.

Schaufeli, W. B. & Bakker, A. B. (2004). Job demands, job resources and their relationship with burnout and engagement: a multi-sample study. *Journal of Organizational Behavior,* 25, 293–315.

Shannon, H. S., Mayr, J. & Haines, T. (1997). Overview of the relationship between organizational and workplace factors and injury rates. *Safety Science,* 26(3), 201-217.

Simola, A. (2005). *Turvallisuuden johtaminen esimiestyönä. Tapaustutkimus pitkäkestoisen kehittämishankkeen läpiviennistä teräksen jatkojalostustehtaassa.* (In Finnish with English abstract). Dissertation. University of Oulu.

Smith, M. J., Cohen, H. H., Cohen, A. & Cleveland, R. J. (1978). Characteristics of successful safety programs. *Journal of Safety Research,* 10, 5–15.

Stenbacka, C. (2001). Qualitative research requires quality concepts of its own. *Management Decision*, 39(7), 551-556.

Tappura, S. & Hämäläinen, P. (2011). Promoting occupational health, safety and well-being by training line managers. In *Proceedings of the 43th Nordic Ergonomics Society Conference, NES 2011* (pp. 295-300).

Tappura, S. & Nenonen, N. (2014). Safety leadership competence and organizational safety performance. In Arezes, P. & Carvalho, P. (Eds.), *Advances in Safety Management and Human Factors. Advances in Human Factors and Ergonomics*, Vol. 10, Section 3 (pp. 129-138).

Tappura, S., Nenonen, N., Heikkilä, J. Reiman, T., Rasa, P.-L. & Ratilainen, H. (2013). Estimating overall costs of occupational accidents in the Finnish industry. In *Proceedings of the 45th Annual International Conference of the Nordic Ergonomics and Human Factors Society, NES 2013*.

Tappura, S., Syvänen, S. & Saarela, K. L. (2014). Challenges and Needs for Support in Managing Occupational Health and Safety from Managers' Viewpoints. *Nordic Journal of Working Life Studies,* 4(3), 31-51.

Törner, M. (2011). The ''social-physiology'' of safety. An integrative approach to understanding organisational psychological mechanisms behind safety performance. *Safety Science,* 49(8), 1262–1269.

Veltri, A., Pagell, M., Johnston, D., Tompa, E., Robson, L., Amick III, B. C., Hogg-Johnson, S. & Macdonald, S. (2013). Undestanding safety in the context of business operations: An exploratory study using case studies. *Safety Science,* 55, 119-134.

Vinodkumar, M. N. & Bhasi, M. (2011). A study on the impact of management system certification on safety management. *Safety Science,* 49(3), 498–507.

Vredenburgh, A.G. (2002). Organizational safety: Which management practices are most effective in reducing employee injury rates? *Journal of Safety Research,* 33, 259-276.

Wu, T.-C., Chen, C.-H. & Li, C.-C. (2008). A correlation among safety leadership, safety climate and safety performance. *Journal of Loss Prevention in the Process Industries,* 21, 307–318.

Yorio, P. L. & Wachter, J. K. (2013). The impact of human performance focused safety and health management practices on injury and illness rates: Do size and industry matter? *Safety Science,* 62, 157–167.

Zohar, D. (1980). Safety climate in industrial organizations: Theoretical and applied implications. *Journal of Applied Psychology,* 65(1), 96-102.

Zohar, D. (2002). The effects of leadership dimensions, safety climate, and assigned priorities on minor injuries in work groups. *Journal of Organizational Behavior,* 23, 75–92.

Safety management issues in the transition from project development to project construction in the construction industry

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Abstract

Many of the accidents in the construction industry could have been prevented by improved systematic safety management and safety awareness in the project development phase and in the transition between the development and construction phase. The purpose of this paper is to study safety challenges in the interaction between the project development phase where plans and drawings are made and the project construction phase where the construction work is done. The paper is based on 24 interviews with representatives from clients, consulting engineers, main contractors and sub-contractors at two different construction projects. Both projects are large projects where transportation infrastructure was constructed. The interviews demonstrate the importance of safety management in the transition between project development and project construction. Furthermore the interviews indicate three types of challenges for safety management in the interface between project development and project construction: 1) the transition from project development to project construction; 2) inadequate safety focus in early project phases; and 3) resulting challenges for safe work in project construction. A common issue for the interface challenges identified in the case projects is transition of both tacit and explicit knowledge between the two project phases. Feedback mechanisms to ensure that knowledge about practical work is applied to modify and improve the formal structures facilitating safe work are missing. Additionally, the formal structures (plans, procedures) are not suited the real situation at the site. Establishing a collaboration phase between planning and operation to create a common understanding between involved actors; give feedback on the formal structures; and modify the formal structures if necessary, will improve the mechanisms for knowledge transition between the phases.

Keywords: construction industry; project management; interface; knowledge management; feedback.

1. INTRODUCTION

Safety management in early phases of a construction project (business development and project development) can have a huge impact on reducing the risk of occupational accidents when the construction work is performed (Szymberski, 1997; Abdelhamid and Everett, 2000; Gibb, 2004; Behm, 2005; Frijters and Swuste, 2008; Jørgensen, 2013). The construction industry is one of the industries with the highest accident risk. Annually, the industry experience several fatal accidents in addition to numerous severe accidents and minor accidents. The affected workers are injured in the operative construction phase. Studies from Denmark, the Netherlands and the US show that 40-60 % of these accidents could have been prevented by better decisions and actions in early project phases (Behm, 2005).

Generally, a construction project includes four main phases (Kjellén, 2000). First, the business development phase that includes investigations of business opportunities and pre-feasibility studies. Second, the project development phase where plans and drawings are made. Third, project construction where the operative construction work is performed, which also is the phase were workers are exposed to risk. The fourth phase is operations and maintenance, i.e. usage of the constructed building or infrastructure. Safety-related decisions, plans and commitment in the two first phases are correlated to the safety performance at the sharp-end (Behm, 2005). This paper pays attention to the interface between early project phases and the operative phase in construction projects.

The purpose of this paper is to study safety challenges in the interface between the project development phase and the project construction phase. To approach this purpose the following research questions are answered: 1) What safety problems may occur in the interface between project development and project construction? 2) Why do these safety problems occur? 3) How should the safety problems be dealt with? The three questions are answered by an analysis of 24 interviews with representatives from both clients and construction companies at two different case projects. Both cases were large projects where transportation infrastructures were being constructed.

2. LITERATURE REVIEW

Both nationally and internationally, the construction industry is one of the most risky businesses to work in compared to other industries (Norwegian Labour Inspection Authority, 2010; Frijters et al., 2010; Weeks, 2011; Jørgensen, 2013). In Norway, the construction industry is one of the sectors with most occupational accidents per working hour. A report from the Norwegian Labour Inspection Authority (2010) states that about 25 % of the fatalities due to occupational accidents in Norway happens in this industry.

The reasons for the hazardous conditions in the construction industry are complicated. Hale et al. (2012) made a root cause analysis of fatal accidents for the industry in the UK. Their study shows that the most frequent root causes to fatal accidents in this industry are: inadequate risk management; inadequate competency and training; lack of compliance; inadequate employee participation; poor man-machine interaction and poor acquisition and maintenance of machinery; inadequate monitoring of the management system; poor contracting strategies; and lack of top management involvement. The situation is likely to be similar in Norway. An in-depth study of fatal accidents by the Norwegian Labour Inspection Authority (2010) is pointing at two particular issues in the industry: use of foreign employees and the complexity of organizing work that requires collaboration between different actors.

Construction projects are complex socio-technical systems that can take many different organisational forms. The industry is project-based and operates in an ever-changing environment (Lingard and Rowlinson, 2005). One dimension of the complexity is related to the many actors involved in a construction project, that all impact on safety, e.g. authorities, clients, designers, specialist consultants, subcontractors, suppliers. Another dimension of the complexity is related to the labile characteristics of the portfolio of projects in the industry. Each project is unique related to type of project (a building, a railway, a road or a bridge), ways of doing work, partners and techniques for construction. This requires adaptive safety management systems. Construction workers tend to be given a high degree of self-control over their own work. When this situation is combined with the pressure to be productive and to reduce construction project times, they tend to select non-standard solutions and cut corners (Lingard and Rowlinson, 2005).

The safety situation for construction workers in the project construction phase, as well as for operation and maintenance of the end product, depends on prior planning and on considerations for safety and health in the project development and design phases (i.e. architects, constructers, engineers and others that plan and design a construction project). Construction designers have a legal obligation to take working conditions and safety during construction, maintenance and demolition work into account in their designs. This obligation is contained in “Directive 92/57/EEC”, a Directive that has been incorporated in Norway as well. However, Frijters and Swuste (2008) and Jørgensen (2013) claim that the actors in the development and design phases have not seen their responsibility to provide safety during the execution of construction projects, and have passed the responsibility in the hands on the contractors. A root cause analysis of three fatal accidents by Abdelhamid and Everett (2000) show three main root causes that also demonstrate safety challenges in the interface between planning and operation: failing to identify an unsafe condition that existed before an activity was started or that developed after an activity was started; deciding to proceed with a work activity after the worker identifies an existing unsafe condition; and deciding to act unsafe regardless of initial conditions of the work environment.

Behm (2005) demonstrates that decisions made upstream from the construction phase have a strong influence on safety in the construction phase. His study shows that the design of a project relates to 42 % of the fatalities. The safety of an operation is determined long before people, procedures, and equipment come together at the worksite (Stephenson, 1991). Designers’ (architects and engineers) lack of safety knowledge (Gibb, 2004) and their unawareness of regulations (Cosman, 2004) are obstacles for safety improvements in this industry. The early project phases’ ability to influence safety at the operational phase is illustrated in Figure 1. Szymberski’s (1997) time/safety influence curve (upper part of Figure 1) illustrates how early phases of a project are able to influence safety. The lower part of Figure 1 shows a conceptual framework for the phases of project work based on Kjellén (2000). Decisions and actions made by clients and designers in early phases will influence the safe performance of the construction phase.

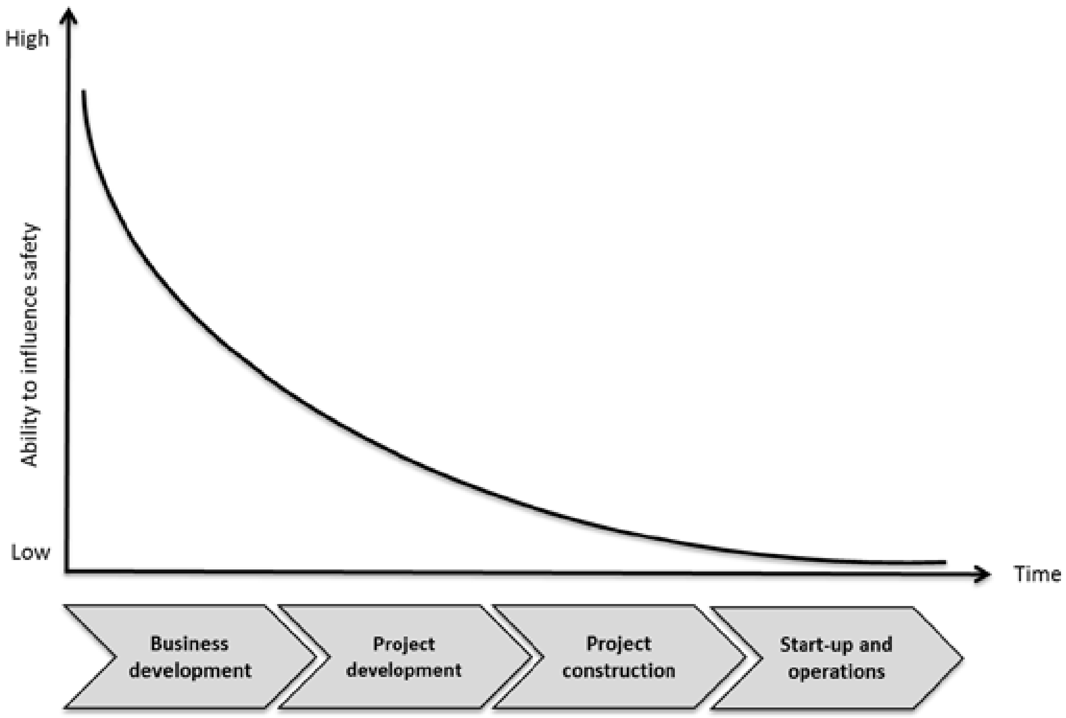

Figure 1 – A phase model for project work (based on Kjellén, 2000) and the ability to influence safety in the phases (based on Szymberski, 1997).

The presented literature review demonstrates that many of the safety problems for sharp-end work are initiated and created in early project phases (Szymberski, 1997; Behm, 2004; Frijters and Swuste, 2008; Jørgensen, 2013). Walter and James (2009) presented an extensive literature review on supply chain relationships and their role in influencing health and safety management. These sources of evidence provided considerable support for the view that the dynamics of supply chains frequently lead to adverse health and safety effects. Following this line of argument, the safety challenges at the operative phase are not only due to the decisions made in early project phases. Abdelhamid and Everett (2000) show that safety challenges in the interface between planning and operation also occur when workers decide to proceed with a work activity after unsafe conditions, which may be due to design choices, are identified. An interview study by Albrechtsen and Hovden (2014) shows that lack of communication and inadequate flow of information between phases and actors, in particular related to the interface between planning and operation, create both safety and efficiency challenges for sharp-end work. Their study points out the need to establish feedback loops between actors and phases, in particular from lower levels (sharp-end) to higher levels (management levels) to avoid misunderstandings and disturbances.

As a result, interface management, i.e. communication, coordination and allocation of responsibility across a common boundary between two or more organizations, organizational units or project phases, matters. The dynamic nature of construction projects and the high number of involved actors (Lingard and Rowlinson, 2005) strengthen the importance of systematic management of interfaces in the construction industry. Pavitt and Gibb (2003) proposed three main interface types in the construction industry. First, physical interfaces which are the actual, physical connection between two or more building elements or components. Second, contractual interfaces between different activities and sub-activities that are agreed on at an early stage and managed throughout the project. Third, organizational interactions between various actors involved in projects from it initial start-up to final handover.

3. METHOD

Interviews were conducted in two case projects to study challenges in the interaction between project phases. In total 24 interviews were conducted, 13 in the Case 1 and 11 in Case 2. These interviews were analysed to answer the research questions.

3.1. Case studies

The study is based on data collection from two case projects concerning construction of transportation infrastructure in southern part of Norway. The data collection was performed at two major construction sites in September and November 2014. Both projects were large in scale and the construction periods were lasting three to four years. The clients as well as the main contractors were large and professional companies. Both case projects were divided into several sub-projects, with a main contractor on each. One sub-project in each case project was visited.

As the case projects are both large in scale and encompass professional builders and contractors, they might therefore not be representative for the Norwegian construction industry, as many construction projects involve small clients, small contractors and often many small sub-contractors. Further, the clients and contractors had worked together before and knew each other well in these two case projects.

3.2. Sample

The interviewees were representatives from the client, consulting engineer, main contractor and sub-contractors. In Table 1 the distribution of the informants and their roles are presented. Most of the informants had higher positions, but also opinions from workers in the sharp-end were obtained. At both cases there were safety representatives among the informants.

Table 1 - Sample distribution according to enterprise (actor) and role.

Case 1			**Case 2**		
#	Actor	Role	#	Actor	Role
1	Client	Main construction manger	1	Client	Main construction manager
2	Client	HSE advisor	2	Client	Project manager
3	Client	HSE advisor	3	Client	HSE coordinator
4	Consulting engineer	Projecting engineer	4	Client	HSE coordinator
5	Main contractor	Project manager	5	Consulting engineer	Projecting leader
6	Main contractor	Project leader	6	Main contractor	Project manager
7	Main contractor	Production supervisor	7	Main contractor	Production supervisor
8	Main contractor	Production supervisor	8	Main contractor	Supervisor
9	Main contractor	Supervisor	9	Main contractor	HSE advisor
10	Main contractor	Safety representative	10	Main contractor	Safety representative
11	Main contractor	Purchasing manager	11	Sub-contractor	Traffic coordinator
12	Main contractor	HSE advisor			
13	Sub-contractor	Site manager			

3.3. Interviews

The aim of the interviews was to get insight into challenges related to safety management in construction projects in the interaction between clients, designers, planners, contractors, subcontractors and suppliers. An interview guide was used in semi-structures interviews. The guide consisted of the following five main topics: safety management in construction projects; cooperation and coordination; information flow; safety analysis; and work practices (execution phase). All the topics had three to eight main questions. The guide was not successively followed, but served as a support with the intention to cover all topics in the guide.

The interviewees answered to the questions by applying their experience from previous projects in addition to their knowledge on the current project they were working on. All the interviews were conducted at the construction sites with two to three interviewers. Each interview lasted around 1½ hour and was written down during the interview.

3.4. Analytical approach

The 24 documented interviews were analysed following basic guidelines for qualitative data analysis described by e.g. Miles and Huberman (1994). The main topics from the interview guide were used for the analysis and each interview was examined to collect all relevant information on each topic. New topics recurring in the interviews, such as the transition phase, were included as main subjects for analysis. Thereafter the collected data from both cases was analysed for each topic. The analysis consisted of understanding safety activities and safety performance of each phase and processing the opinions of the informants about the phase. Further the results were discussed in two meetings with representatives from the construction industry, including one meeting with sharp-end workers/safety representatives, to hear their opinions and validate the findings.

4. RESULTS OF INTERVIEW STUDY

The interviews indicate that the interface and transition between project development and project construction is a critical contribution to the safety performance of a project. Both representatives from clients and contractors agree about the criticality of this interface to facilitate safe sharp-end work. A shared understanding among the interviewees is that a common continuous safety approach and attention is required from the start of a project to operation and maintenance of the final product, i.e. a joint and coherent safety focus throughout the project life cycle. However, based on experience from various projects, the interviewees have seen different challenges regarding this common and continuous safety approach in the move from early project phases and the construction work. The challenges identified in the interviews can be categorized into three types of interface challenges, ref. to Figure 2. First, the interviewees have experienced poor communication and collaboration between early project phases and the construction phase, i.e. challenges in the transition from project development to project construction. Second, which also is an important reason for the first challenge, there are challenges related to lack of safety focus in business development and project development. Many of the interviewees claim that there is only a minimal attention to safety in the early project phases. Third, the two first challenges generate challenges for safe performance in the construction phase. Inadequate plans and drawings and inadequate risk assessments and safety management in the early project phase can create time pressure; deviations; ad hoc solutions; practical trouble regarding physical solutions; and unexpected situations for sharp-end work which all can produce hazardous situations.

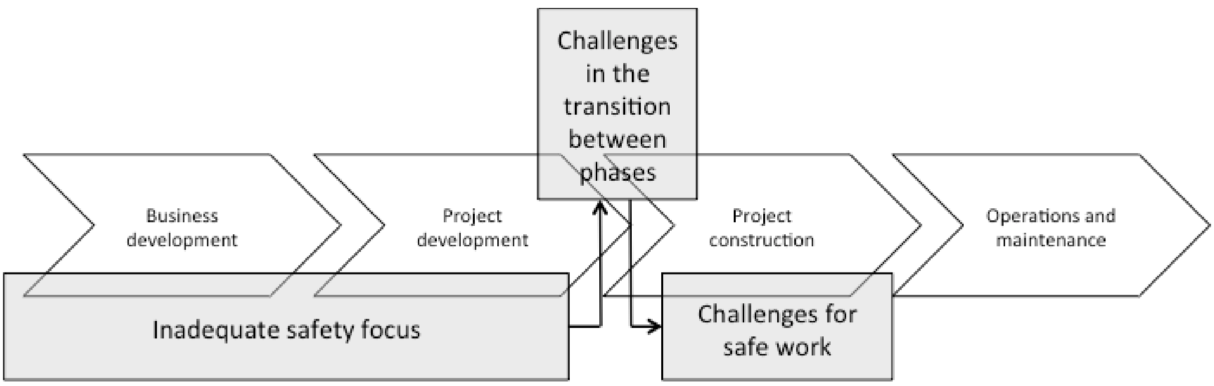

Figure 2 – Three types of interface challenges between early project phases and project construction. Inadequate safety focus contributes to challenges in the transition between project development and project construction, which furthermore lead to sharp-end safety problems.

4.1. Challenges in the transition from project development to project construction

Based on experience from previous and current construction projects, both representatives from clients and contractors talk about collaboration and communication problems between project development and project construction. This is related to lack of continuity of personnel involved in planning and operation; obstacles for flow of critical information; no chance for contractors and sub-contractors to give feedback on plans and drawing before starting work. Representatives from contractors are seldom involved in the project development phase, and only few of the involved persons in the project development phase are involved in project construction. Furthermore, new persons and companies enter the construction phase after start-up, which implies that some of those who perform work at the construction site are not necessarily represented at construction start-up.

> *"There should be added some more time after contract signing, so the contractor could be a part of some of the engineering. This would ensure better execution of the project, better quality and better predictability for both the client and the contractor"* [project manager, main contractor].

For large projects, the two clients involved in the current case study have implemented a "collaboration phase" between project development and project construction. The objective of the collaboration phase is to develop common guidelines and shared ambitions and standards for the project between the stakeholders. Many of the interviewees feel that this phase is useful for safety performance as well as other parts of the project execution. Such a collaboration phase will include representatives from the contractor at the final parts of the project development. Some interviewees claim that such a collaboration phase will lead to better performance in terms of efficiency as well as safety; improved quality and better predictability for both clients and contractors. Improved collaboration is generated by: short and efficient meetings with a clear agenda; reviews of plans when required; good flow of information from shift to shift; all necessary documents provided on time; awareness of dependencies between disciplines and activities; detailed and robust plans; coordination meeting when there are parallel activities; knowledge sharing; quick response for all requests; mutual respect for each other; and frequent, honest and open dialogue.

The collaboration between client, consulting engineers/designers and contractors a period before construction start-up is perceived as useful since there is a dialogue about important information for efficiency, quality and safety of the project construction. Depending how far the project planning has come, changes can be agreed upon and made. Additionally, mutual trust between actors is created. Several of the interviewees point out that getting to know the people you will work with and agreeing on common communication rules will make the cooperation in the project easier.

> *"We get to know people and get information about the project. That is good. If something happens later and you already know people, it is easier to solve problems and avoid misunderstandings"* [HSE-coordinator, client].

Most interviewees find this phase useful as it serves as a common starting point for the construction works, but there are some critical issues mentioned by some of the interviewees. The critical voices regarding the "collaboration phase" claim that it should last longer; that sub-contractors are not included; and that more specific discipline meetings should be arranged. It was pointed out that persons from the project development phase should be a part of the collaboration phase and carry on to the first stage of construction phase to assure continuity. In many cases new personnel come into the construction phase without knowledge about the basis for decisions that are made in earlier phases. Therefore it was said that as much personnel as possible should be kept throughout the phases.

4.2. Inadequate safety focus in early project phases

Many of the interviewees ascribe the reasons for some of the safety problems at the sharp-end to inadequate safety focus in the early project phases. Lack of knowledge about practical work at the sharp-end is mentioned by several of the interviewees as a main reason for the weaknesses in plans and drawings. The situation would improve if specific expert knowledge in addition to practical knowledge in early project phases was integrated in the project development process. In addition, lack of time in early project phases is described as a reason for poor quality of plans and drawings. Some interviewees explain this by a desire from clients to start the construction work as quickly as possible. It is also claimed that actors in project development tend to focus on the end product of the construction without paying significant attention to safety of execution of work.

> *"98% of the planning work is on a good technical result. They don't consider safe work in the project phase to a large extent"* [project manager, main contractor].

Several of the interviewees tell about poor plans for safety and health made in the early project phases, mainly because the plans are too general and are not sufficiently adapted to the specific project. As part of the project development, clients are obliged to make plans for safety and health that govern the safety work in the construction phase. In that sense this plan is a highly relevant framework condition for the safety work in the construction phase. The plan should be based on a coarse risk analysis. The risk analyses are criticised by some of the interviewees as vague and without concrete risk reducing measures. Inadequate risk information and safety plans from clients make a poor basis for contractors' safety plans. Further, the risk analyses made in the different phases of a project are often not related to each other, i.e. the risk analysis for the health and safety plan might not build upon the risk analysis enclosed with the tender.

According to many of the interviewees, safety performance and safety management systems count for a very small part of tender evaluations. It is mentioned that the tenders' safety system only counts for 1-2 % of the total evaluation. Other factors such as price and feasibility are much more important than safety. It is also mentioned that the same problem occurs when appointing contractors (e.g. designers, architects, consulting engineers) for the project development phase. This type of contracting shares the same problem regarding weight of safety. Some of the interviewees indicate that increased emphasis on safety when selecting contractors would be a significant contribution to better safety in the industry. However, this is a measure that the whole industry must collaborate on to have any meaningful effect.

4.3. Challenges for safe work in the construction phase

The problems in the interface between project development and construction lead to new challenges for the operative work in construction phase. The interviews indicate that the interface problems create a reactive mind-set and approach in the construction phase, which results in ad-hoc solutions and even time rush. The interviewees have experienced that contractors and subcontractors get behind the time-schedule because of poor plans from project construction. Poor planning is typically when plans and reality are not matched. One of the interviewees provided this example of poor safety planning:

> *"Area for rigging is not thought about before construction start-up. There are constructions and equipment that require large amounts of space; mobile cranes, tower crane, reinforcement and shuttering. Such a narrow space leads to hazardous situations. Visibility is reduced and material and equipment are stored on each other. It should have been considered during project development, but was not"* [supervisor, main contractor].

The time dimension is mentioned as another crucial aspect that creates problems at the sharp-end. According to the interviewees from the operative level, there is no extra space of time allocated in the plans, which could have worked as a buffer in situations where one gets behind the time schedule. Another explanation for this is that the start-up of project construction work is too early, before plans and drawings are adequate. Another related challenge mentioned in the interviews is the delays in project development taking time away from the operative work, as the end-dates of most projects are a fixed date.

> *"The consulting engineers are planning with the lowest possible times for sharp-end activities"* [HSE advisor, client].

5. DISCUSSION

5.1. Interface challenges

The interface challenges identified in the interview study can be recognized as a combination of the three main types of interfaces in the construction industry: physical, contractual and organizational interfaces (Pavitt and Gibb, 2003). The physical interface challenges in the interview study are a result of poor planning and drawings that are not suited to the reality of sharp-end work, e.g. narrow spaces for lifting operations. Contractual interface challenges are expressed in the tender evaluation phase where contractors' and sub-contractors' safety performance and safety management systems only represent a small part of decision criteria. Organizational interfaces, i.e. communication, coordination and responsibility across boundaries between different organizations, phases, or organizational entities, are mentioned as an experienced challenge by most of the interviewees. Examples of this challenge are: inadequate HSE plans from clients; no continuity in involved personnel along the project life cycle, inadequate dialogue between client, consulting engineers/designer, contractor and sub-contractors before start-up of construction. Other studies demonstrate the same challenges. An empirical study performed by Albrechtsen and Hovden (2014) also show that communication between phases and organizations in projects often are weak. Their study also demonstrates that the client's safety control in the construction phase often is rather vague. A root cause analysis of severe accidents by Abdelhamid and Everett (2000) also shows the same patterns.

A common issue for the interface challenges identified in the case projects is flow of information between phases and actors. The flow of information is related to transition of explicit knowledge but also about sharing tacit knowledge. Sharp-end action is partly based on espoused theory (rules, norms, expressed values) and theory-in-use (how work actually is done) (Argyris and Schön, 1992). The first is mainly related to tacit knowledge of sharp-end workers, while the latter is related to explicit knowledge (e.g. procedures, guidelines, databases). Knowledge creation in organizations is created in a combination of transformations of two types of knowledge: explicit and tacit (Nonaka and Takeuchi, 1995).

For the case projects, the feedback process is a combination of transfers of tacit and explicit knowledge. First, applying explicit knowledge in terms of plans, procedures and verbal stories for sharp-end work, i.e. internalization (Nonaka and Takeuchi, 1995), creates operational tacit knowledge through learning by doing supported by explicit knowledge. Second, utilizing tacit knowledge about sharp-end work in planning processes, i.e. externalization (Nonaka and Takeuchi, 1995), makes tacit knowledge explicit through articulation of tacit knowledge using language. This knowledge creation is according to many of the interviewees missing in many construction projects. The interview study shows obstacles for the feedback mechanisms from the execution level to the planning level. For the industry in general there is often lack of arenas for dialogue between these two layers. One is related to obstacles for giving feedback on practical limitations in plans, either before work has been started, during work or after work has started. Another obstacle is related to the tacit knowledge of sharp-end workers. Planners and designers are criticised for lack of practical and local knowledge, which the sharp-end personnel hold.

For the case projects, the externalization and internalization problems are related to formal and informal feedback mechanisms, respectively, in combination with inadequate formal structures (e.g. plans, drawings) from planning to execution. Feedback is here understood as the process by which information on the actual or expected results of an activity is fed back to decision makers as new input to modify and improve the actual or subsequent activities (based on Kjellén, 2008). For simplicity the related feedforward process is included in this characterization of feedback i.e. providing information to decision makers before an activity as support to modifying the frames and plans for an activity. The interviews indicate that operative experience and practical knowledge often is lacking in the planning phase. In addition the interviews indicate that the formal structures (e.g. HSE plans, project plans, drawings) often are not suited the actual work practice and work conditions. The externalization and internalization problems are interwoven, as improved feedback ideally will be applied to modify and improve the formal structures.

5.2. Problem solving at three levels

Management of safety can be understood as problem solving at three levels (Hale et al., 1997; Hale, 2003), where the central problem is the potential occurrence of damage and uncontrolled hazard at the execution level; the plan and procedures level; and the structure (and policy) level, ref. to Figure 3. For a construction project, the execution level is where contractors and sub-contractors perform sharp-end work. This is also the level where the primary control of hazards, through the actions taken by those in contact with the hazards, is taking place. HSE plans, safety procedures and guidelines make these control actions explicit, which are a result of the plan and procedure level. Drawings and construction plans are other relevant documents for a construction project. The client's project management and consulting engineers/designers represent this level. A third level is the structure and policy level. At this level, clients, have company standards representing the philosophy of risk control in the organizations. Figure 3 illustrates the three levels and transition of knowledge in the interface between levels. The figure is inspired by Hale's (2003) model for three levels of safety management and modified based on Rasmussen's (1997) framework for risk management in a dynamic society.

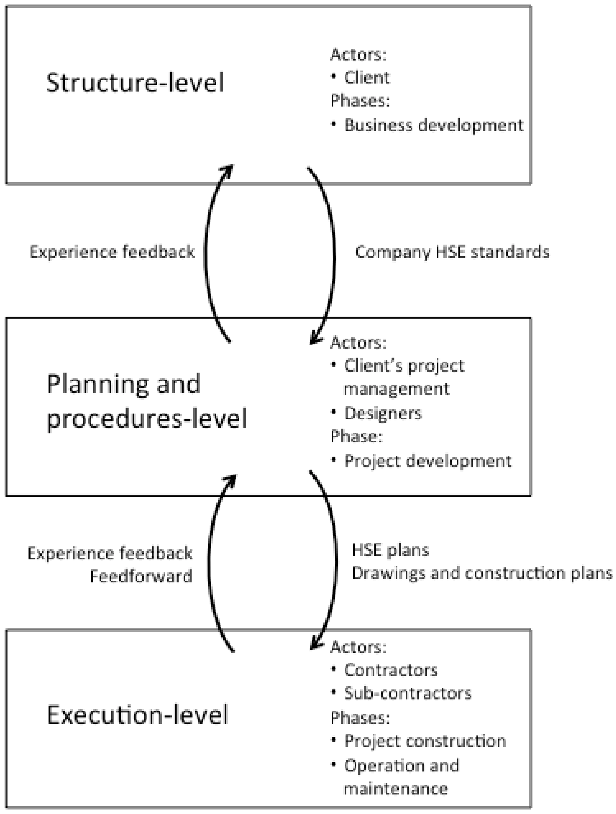

Figure 3 – Knowledge transition in interfaces between three levels of safety management in construction projects (inspired by Hale, 2003 and Rasmussen, 1997).

Despite the challenges for feedback between execution and planning, there are mechanisms that work well between the structure and planning level in the case projects. The collaboration phase introduced by the clients of the case projects is a good attempt to create arenas for feedback by changing the company HSE standards. This collaboration phase is based on experience feedback from previous projects and is thus a combination of different sources of explicit knowledge.

In addition to externalization and internalization, Nonaka and Takeuchi (1995) describe a third and fourth knowledge transfer: socialization (transfer of tacit knowledge to shared mental models and practices among several members of the organization) and combination (generating new explicit knowledge through systemizing and combining different sources of explicit knowledge). Together, the four types of transitions make a spiral of knowledge creation with the following continuous order: socialization-externalization-combination-internalization (starting at the beginning). The identified challenges in the case projects are thus linked; it implies that improved externalization will improve the formal structures. An extensive review of rules and rule compliance by Hale and Borys (2013a) reasons about the merits and limitations of safety rules and rule compliance. Similar to the case study, they point at the problem that rules are not fitted the reality of actual work. Reality cannot be modified according to the rules, but the rules can be developed and modified to reality. The study of Hale and Borys (2013b) emphasises the importance of feedback on experience with practical work and use of rules as key input to development of appropriate rules.

Another aspect of the knowledge sharing and creation in the interface between actors and phases can be compartmentalization of information; simplification and misrepresentation of information; accumulation of incidents are either not noticed or misunderstood; ignored warning signals; and normalization of deviations. The complex nature of the interface issue between planners and doers in construction projects can lead to such problems. These characteristics are central in the theory of man-made disasters (Turner and Pidgeon, 1997). They found that limitations or lack of information sharing is the cause of most major accidents. In the build-up to accidents, someone has known something that could have prevented the accident, but this information is not shared to those who could have made a significant change based on this decision-making support.

5.3. Conflicting objectives

Conflicting objectives between safety and efficiency is mentioned as a root cause to the interface challenges by several of the interviewees. Rasmussen (1997) explained this conflict by two forces that may contribute to an unacceptable risk picture if not dealt with. First, there is an economical pressure aiming at cost reduction and income increase, which is a pressure towards efficiency. Second, there is a pressure towards least effort, i.e. avoiding unacceptable work load. Many of the interviewees pointed out that poor planning can lead to time pressure and quick solutions, which are not always as safe as they could be. The end date of the project is usually fixed and not moved even when project planning is not on time. This may lead to less efficient projects, several simultaneous operations and higher accident risk. Some interviewees were of the opinion that project plans have too small time margins, and that some additional time should be added, as unexpected changes are not accounted for by planners and designers.

Both the client and contractor want to spend as little money and time as possible and get a highest possible profit, while safety should be dealt with. Safety is seen as important and necessary to invest in, however often there is a conflict about who should pay for the safety measures. In some cases the client finds the safety measure as part of the job and the contractor's responsibility, in other cases as their own responsibility. As both parties want the profit to be as high as possible, additional costs for safety measures can become a threat for safety if neither is keen on paying the extra costs, which might result in fewer safety measures being implemented. The cost effect of saving on safety can be seen in the short run on a project; however an accident can be more costly for a project or the whole company. In the long run investing in safety might rather be seen as saving costs, as shown by this citation form a production manager:

> *"Actually there is a correlation between safety and production and a good economy, but in the short term economic gains can be achieved by saving on safety"* [production manager, contractor].

6. CONCLUSIONS AND RECOMMENDATIONS

The interviews at the two construction projects indicate that safety management in the interface and transition between project development and project construction is a critical contribution to the safety performance of a project. A shared understanding among the interviewees is that a common continuous safety approach and attention is required from the start of a project to operation and maintenance of the final product. The interface challenges can be categorized into three types: 1) the transition from project development to project construction; 2) inadequate safety focus in early project phases; and 3) resulting challenges for safe work in project construction.

In general there are two interrelated main improvements for the interface challenges. First, improving the formal and informal feedback on practical experience with plans and sharp-end work (from the execution phase to the planning phase). Second, improving the formal structures (from the planning phase to execution, e.g. plans and procedures). Improvement of feedback mechanisms can both be related to explicit knowledge (formal feedback mechanisms such as safety management elements as reporting and monitoring system) and tacit knowledge. Transfer of tacit knowledge to explicit knowledge is in particular related to mechanisms for utilization of operative personnel’s knowledge on practical experiences from the on-going as well as previous projects.

The clients of the case studies have implemented a collaboration phase between project development and project construction. According to several of the interviewees this collaboration between representatives from the client, consulting engineers/designers and the main contractor is an important mean to create a common understanding; give feedback on the formal structures and modify the formal structures if necessary. A collaboration phase as a transition from project development to project construction is thus a mean to improve the feedback of tacit knowledge among operators to planners and designers.

7. ACKNOWLEDGMENT

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8. REFERENCES

Abdelhamid, T. & Everett, J. (2000). Identifying Root Causes of Construction Accidents. *Journal of Construction Engineering and Management*, 126 (1), 52–60.

Albrechtsen, E. & Hovden, J. (2014). Management of emerging accident risks in the building and construction industry. Paper presented at *Working on Safety 2014*, Glasgow, Scotland, 30 September - 3 October 2014.

Argyris, C., & Schön, D. A. (1992). *On organizational learning.* Cambridge, MA: Blackwell, pp. 115-130.

Behm, M. (2005). Linking construction fatalities to the design for construction safety concept. *Safety Science*, 42 (8), pp. 589-611.

Cosman, M. (2004). Roles, culture, outcomes, what does the UK experience mean? In: Hecker, S. et al. (Eds.). *Designing for Safety and Health in Construction: Proceedings from a Research and Practice Symposium*, Portland, USA, pp. 59-68.

Directive 92/57/EEC - *Temporary or mobile construction sites*, June 1992.

Frijters, A. C. P. Mud, M. & Hakhoff, R. (2010). Construction StoryClient; an instrument for analysing accidents and exchanging measures in the construction industry. Paper presented at *Working on Safety 2010,* Røros, Norway, 7-10 September 2010.

Frijters, A. C. P. & Swuste, P. (2008). Safety assessment in design and preparation phase. *Safety Science*, 46 (2), pp. 272-81.

Gibb, A. (2004). Designing for safety and health in construction – a European/UK view. In: Hecker, S. et al. (Eds.). *Designing for Safety and Health in Construction: Proceedings from a Research and Practice Symposium*, Portland, USA, pp. 44-57.

Hale, A. R., Heming, B. H. J, Carthey, J. & Kirwan, B. (1997). Modelling of safety management systems. *Safety Science*, 26 (1-2), pp. 121-140.

Hale, A. R. (2003). Management of Industrial Safety. Technical memo, TU Delft

Hale, A. & Borys, D. (2013a). Working to rule, or working safely? Part 1: A state of the art review. *Safety science*, 55, pp. 207-221.

Hale, A. R., Walker, D., Walters, N. & Bolt, H. (2012). Developing the understanding of underlying causes of construction fatal accidents. *Safety Science*, 50 (10), 2020-2027.

Hale, A., & Borys, D. (2013b). Working to rule or working safely? Part 2: The management of safety rules and procedures. *Safety science*, 55, pp. 222-231.

Jørgensen, K. (2013). System design integrated in the building delivery system. *Safety Science Monitor*, 17 (1).

Kjellén, U. (2000). *Prevention of accidents through experience feedback*. London: Taylor & Francis.

Kjellén, U. (2008). Experience feedback. In: Melnick, E. L. & Everitt, B. S. (Eds.). *Encyclopedia of Quantitative Risk Analysis and Assessment*, Wiley, ISBN: 978-0-470-03549-8.

Lingard, H. & Rowlinson, S. (2005). *Occupational Health and Safety in Construction Project Management*. London: Spon Press.

Miles, M. B. & Huberman, A. M. (1994). *Qualitative Data Analysis*. Thousand Oaks, CA: SAGE publications.

Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation.* Oxford university press.

Norwegian Labour Inspection Authority (Arbeidstilsynet) (2010). *Arbeidsskadedødsfall. Utviklingstrekk og Arbeidstilsynets aktivitet.* In Norwegian. Report January 2010.

Pavitt, C. T. & Gibb, G. F. A. (2003). Interface Management within Construction: In Particular, Building Facade. *Journal of Construction Engineering and Management*, 129, pp. 8-15.

Rasmussen, J. (1997). Risk management in a dynamic society: a modelling problem. *Safety Science*, 27(2-3), pp. 183-213.

Stephenson, J. (1991). *System Safety 2000: A Practical Guide for Planning, Managing, and Conducting System Safety Programs*. Van Norstrand Reinhold, New York.

Szymberski, R. (1997). Construction Project Safety Planning. *Tappi Journal,* 80 (11), pp. 69-74.

Turner, B. A. & Pidgeon, N. F. (1997). *Man-made disasters*. Butterworth-Heinemann.

Walters, D. & James, P. (2009). *Understanding the role of supply chains in influencing health and safety at work*. IOSH Institution of Occupational Safety and Health, Leicester.

Weeks, J. L. (2011). Health and Safety Hazards in the Construction Industry. In: Ringen, K., Seegal, J. L. & Weeks, J. L. (Eds.). *Health, Prevention and Management, Encyclopedia of Occupational Health and Safety*, International Labor Organization, Geneva.

Does Bridge Resource Management (BRM) work? Assessment of a training course

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Abstract
Bridge and engine room resource management (BRM/ERM) courses are mandatory to gain necessary certification according to STCW 2010 (The Convention of Standards of Training, Certification and Watchkeeping - International Maritime Organization IMO). The BRM/ERM courses are designed to enable all maritime personnel on/off shore to develop their existing knowledge and understanding of human and technical resources in an operational maritime environment. During the course the crew gain experience in handling ships under various conditions, improve communication quality, improve quality of decisions and contribute to the bridge team during ship maneuvering in normal and emergency conditions more effectively. Recent advances in technology have positioned simulators as powerful tools for creating more realistic, experiential learning environments and thereby helping organizations meet the BRM training challenges. A training simulator is a tool for creating a more realistic learning environment, providing the trainer with a virtual medium through which various types of knowledge, skills and attitudes can be acquired. Antai (2002) defines training as "the systematic development of employees' knowledge, skills and attitudes that are required for an organization to meet its goals." Knowledge refers to factual information and skills refer to the learned capacity to perform some type of task. Unlike knowledge, skills typically include a physical component that must be developed through practice and feedback.
Maritime Operations AS offers four different training options leading to BRM certification, depending on the seafarer's previous education. All four courses teach theory and link it to practice through simulator training. A questionnaire with 46 items was distributed to 317 seafarers who attended the courses between April 2013 and March 2014 resulting in a total of 112 completed questionnaires. Results indicate that 77 % of the variation of "Change in behavior as a result of the BRM course" was explained by the combination of increased skills, change in attitudes, and increased knowledge and understanding. One can conclude that using simulations in BRM courses have great potential as a medium to create highly-relevant training contexts where the bridge teams are active participants in a learning process that creates specialized and adaptive knowledge and skills.

Keywords: Crew- training, maritime safety, maritime training

1. INTRODUCTION

One of the major causes for marine casualties is human error (Hanzu-Pazara , Barsan & Arsenie, 2008; Petkov, Todorov, Takov, Petrov, Stoychev, Vladimirov & Chukov. 2004; O'Connor & Flin 2003; O'Connor, 2011). Perrow (1999) and Hetherington et al. (2006) suggest that ship-owners and regulating bodies should place more emphasis on team training with focus on training in non-technical skills. Bridge and engine room resource management (BRM/ERM) courses are now becoming mandatory to gain certificatation according to STCW 2010 (The Convention of Standards of Training, Certification and Watchkeeping - International Maritime Organization IMO). The BRM/ERM courses are designed to enable all maritime personnel on/off shore to develop their existing knowledge and understanding of human and technical resources in an operational maritime environment. This paper assesses BRM training courses offered by Maritime Operations AS in Ålesund, Norway. The courses leading to BRM certification teach theory and link this theory to practice through simulator training. Antani (2002) define training as "the systematic development of employees' knowledge, skills and attitudes that are required for an organization to meet its goals" and Cannon-Bowers, Salas, Tannenbaum & Mathieu (1995) define team training as: "Team-training is defined as a constellation of content (i.e., the specific knowledge, skills and attitudes that underlie targeted teamwork competencies), tools (i.e., team task analysis, performance measures) and delivery methods (i.e., information, demonstration and practice-based learning methods) that together form an instructional strategy." Bridge Resource Management (BRM) intends to reduce the risk of marine casualties by training a ship's bridge crew to anticipate and respond to their ship in changing situations. BRM addresses bridge officers' knowledge, skills and attitudes and brings teambuilding, communication, leadership, and decision-making, into the larger picture of organizational and regulatory management since 1970. Commercial and military aviation have used Crew Resource Management (CRM), the aviation version of BRM. BRM courses are a more recent initiative, adapted directly from the aviation model. Simulator-based training courses comparable with the CRM courses used in the aviation industry were introduced in shipping primarily to train the skills of passage planning, and the importance of the Master/Pilot relationship (Gyles & Salmon 1978). Even earlier, as a result of a number of radar-assisted collisions in the 1950s, simulators were used in shipping for training in the interpretation of radar information. These passage planning and radar information training courses have been developed into the BRM courses that are conducted today on many simulators world-wide. If the definition of CRM as used in the aviation industry (Salas, Prince, Bowers, Stout, Oser, Cannon-Bowers, 1999) is employed changing cockpit with bridge, the following definition of BRM is created:

> "a set of instructional strategies designed to improve teamwork on the bridge by applying well tested training tools (i.e., performance measures, exercises, feedback mechanisms) and appropriate training tools (e.g., simulators, lectures, videos) target at specific content (i.e. teamwork, knowledge, skills and attitudes)." (Salas et al. 1999, p163).

A maritime training simulator is mainly a tool for creating a more realistic learning environment in the implementation of BRM, providing the trainer with a virtual medium through which various types of knowledge, skills and attitudes can be acquired. Knowledge refers to factual information and skills refer to the learned capacity to perform certain types of task. Unlike knowledge, skills typically include a physical component that must be developed through practice and feedback. According to Carson-Jackson (2010) simulation for optimal use of crew resources on the bridge has become a very useful tool in education, and is an effective teaching method for transferring theoretical knowledge into practical applications.

According to some research, the use of BRM is not completely positive and may include problems of coordination and communication between crewmembers. Therefore, failures related to poor shared mental models and shared situation awareness in the bridge team might occur. Chauvin et al. (2013) reports that "failures in BRM are involved in more than 1 out of every 3 collisions investigated. BRM is a contributory factor of accidents when it does not play its role as a "barrier" to prevent accidents" (p35). In a review paper on CRM which looks at 34 articles Salas, Wilson, Burke & Wightman (2006) present evidence that CRM training is effective at some levels (e.g., attitudes). CRM training seems to be only one of a number of factors influencing practice and effectiveness of behavior. CRM can enhance learning, and change behavior in a simulated environment; however, one cannot answer with certainty as to whether CRM training has an effect on safety (Salas et al. 2006). O'Connor (2011) evaluated the effectiveness of the US Navy's BRM training assessing the attitudes and knowledge of human factors that contributed to accidents in a high risk organization. He compared Surface Warfare Officers who have had no BRM training with officers that have had BRM training and found that BRM training had no significant effect on the attitudes and knowledge of the officers. He concluded that for this sample of navy officers BRM training was not having the impact on knowledge and attitudes that were typical for the Crew Resource Management training reported in aviation. He proposed that the main reason might be that the content of the training was not based upon a needs assessment among the officers (the content of the course). Haerkens, Kox, Lemson, Houterman,van der Hoeven & Pickkers (2015) indicate that when CRM is implemented in hospitals there is an improved perceived safety climate and improved clinical outcome such as a reduction in complication rate and mortality in critically ill patients. In view of these results and absence of deleterious side effects for the patients, they argue that similar to aviation, widespread implementation of CRM in the intensive care units is justified, even without higher levels of evidence obtained from randomized clinical trials.

Figure 1 shows the conceptual model of the study and illustrates five hypotheses which are to be empirically tested.

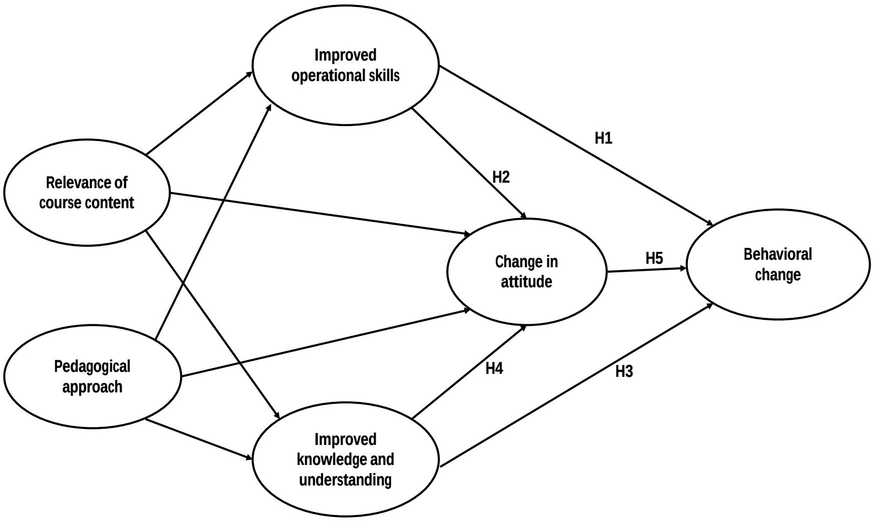

Figure 1. Conceptual evaluation model for simulator training

The five hypotheses below have to be seen in connection to each other. The Theory of Reasoned Action (Ajzen & Fishbein, 1977) and Theory of Planned Behavior (Ajzen, 1991) provide us with a conceptual framework including knowledge, skills and the influence of attitudes on behaviors. According to the theories (Ajzen, 1991 and Fishbein, 2000) intention is the immediate antecedent of actual behavior and intention is in turn determined, amongst other factors, by the attitude towards the behavior. Wilson, Kraft & Dunn (1989) and Neal, Griffin, & Hart (2000) found that knowledge predicted behavior, compliance and participation. Bentler & Speckart (1981) found that attitudes influenced behavior both directly and through behavioral intentions. Salas, DiazGranados,Weaver & King (2008) conclude that "Team training works", however, one should pay attention to the elements of the training design and delivery, ensuring that the trainees gain the necessary knowledge, skills and attitudes (KSAs) to become good team members and make use of their knowledge and skills. Krug & Frush (2007) identified poor teamwork as a factor that threatened the safety in emergency situations. Trainers and educators often refer to these three categories as KSA (Knowledge [cognitive], Skills [psychomotor], and Attitudes [affective]). This taxonomy of learning behaviors may be thought of as "the goals of the learning process." That is, after a learning episode, the learner should have acquired a new skill, knowledge, and/or attitude. The cognitive domain involves knowledge and the development of intellectual skills (Bloom, Engelhart, Furst, Hill & Krathwohl 1956). This includes the recall or recognition of specific facts, procedural patterns, and concepts that serve in the development of intellectual abilities and skills. The affective domain (Krathwohl, Bloom & Masia, 1973) includes the manner in which we deal with things emotionally, such as feelings, values, appreciation, enthusiasms, motivations, and attitudes. The psychomotor domain includes physical movement, coordination, and use of the motor-skill areas. Development of these skills requires practice. Hence, we hypothesize that:

H1: Improved operational skills among crew lead to a more positive perception of behavioral change

H2: Improved operational skills among crew lead to a more positive perception of intended change in attitude

H3: Improved knowledge and understanding lead to a more positive perception of behavioral change

H4: Improved knowledge and understanding lead to a more positive perception of intended change in attitude

H5: Change in attitude among crew leads to a more positive perception of behavioral change

According to Schein process, intervention activities are designed to assist individuals and groups to examine, diagnose, and act upon their behavior and interpersonal relationships. The ideal end-result of these activities is improved team skills and effectiveness, knowledge and competence and attitudes which in turn lead to change in behavior/behavioral intentions (Schein, 1969; 1999).

2. MATERIALS AND METHOD

A questionnaire with 46 items was distributed to 317 seafarers who attended the courses between April 2013 and March 2014 resulting in a total of 112 completed questionnaires. The conceptual model consisted of six latent variables each of which was measured with multiple items on a scale from 1(strongly disagree) to 7 (strongly agree). The question items and constructs/factors are listed in Table 1.

Table 1. Constructs/factors, indicators, mean, standard deviation, loadings and t-values

Indicators/variables	Mean	SD	Loadings	T-value#
Relevance of course content				
Communication was a very useful topic	6.28	0.85	0.842	13.355***
Situational awareness was a very useful topic	6.11	0.85	0.844	12.172***
Cultural differences was a useful topic	5.61	1.01	0.722	8.477***
Decision making was a useful topic	6.01	0.97	0.797	8.242***
The "human element" was a useful topic	6.00	1.10	0.824	18.684***
The theoretical teaching worked well	5.97	0.98	0.761	9.509***
Pedagogical approach				
Instructions during simulator training worked well	5.79	1.09	0.832	14.786***
The preparation before the simulator exercise was very useful	5.51	1.20	0.826	18.898***
The discussions after the simulator exercise were very useful	6.03	1.09	0.818	16.896***
It is very important to use a simulator when practising co-operation	6.01	1.20	0.855	23.051***
A combination of theory and practice on the simulator was very useful	6.03	1.03	0.865	19.317***
Improved operational skills				
After the course				
my skills in how to cooperate has improved	4.92	1.17	0.921	47.868***
my skills in how to communicate has improved	5.18	1.19	0.897	35.596***
the bridge/engine crew work better as a team	4.46	1.14	0.876	31.447***
my decision making skills in critical situations have improved	4.83	1.21	0.919	51.264***
my decision making skills under pressure have become better	4.72	1.30	0.913	51.192***
Improved knowledge and understanding				
I gained a better understanding of				
the thinking process of the people that I work with	5.40	1.10	0.840	24.932***
the importance of joint situational awareness in the bridge team	6.04	1.05	0.910	33.990***
the importance of precise communication aboard	6.20	1.04	0.882	21.143***
the importance of good planning	5.89	1.13	0.865	19.382***
Change in attitude				
After the course I took into consideration conditions I had not thought about before	5.26	1.09	0.894	41.759***
After the course I gained a more positive attitude towards cooperation	5.16	1.20	0.891	40.549***
My colleagues claimed they had had an "aha" experience concerning how we behaved towards each other	4.59	1.27	0.825	25.689***
Behavioural change				
I feel that the course has				
had a positive effect on safety aboard	5.06	1.14	0.847	22.531***
led to new attitudes aboard	4.68	1.14	0.882	26.521***
led to me doing things differently	4.76	1.11	0.914	52.210***
led to safer operations aboard	4.79	1.16	0.888	39.183***

*# Based on 1000 bootstrapping samples ***Significant at $p < 0.001$ (two-tailed test)*

Structural equation modeling (SEM) is a methodological tool that helps in running multiple regressions between variables and latent variables of which LISREL, AMOS and Mplus are the most popular of SEM software packages. Partial Least Square (PLS) (Wold, 1975) is a SEM technique that can simultaneously test the measurement model (relationship between indicators or manifest variables and their corresponding constructs or latent variables) and the structural model (relationships between constructs). Recently, the use of PLS has increased (Hair, Hult, Ringle & Sarstedt, 2014). This study used PLS to evaluate the proposed theoretical model. PLS has the capacity to deal with complex models with a high number of constructs, indicators and relationships (Barclay, Thompson & Higgins, 1995; Hair, Hult, Ringle & Sarstedt, 2014) which makes its application in our study an ideal analytical technique. The method is not covariance based but variance-based. Compared to covariance-based SEM (BSEM), PLS offers many benefits with respect to distribution requirements, type of variables, sample size and the complexity of the model to be tested (Chin & Newsted, 1999). Psychometric properties of the measures were assessed by first performing an exploratory factor analysis with Varimax rotation. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.883 and Bartlett's test of Sphericity was significant at the 0.0001 level, indicating that the data matrix sufficiently correlated to the factor analysis. Further analysis was performed by the use of PLS software application SmartPLS (Ringle, Wende & Becker, 2014). All constructs in this study were operationalized as reflective measures. We assessed the measurement model in terms of item reliability, internal consistency and discriminant validity. Using the rule of thumb of accepting items with loadings of 0.707 or more, though loadings of at least 0.5 are acceptable (Barclays et al. 1995), all the indicators were above 0.707 as shown in Table1. Internal consistency was examined using Fornell & Larcker's (1981) composite reliability index. In our model the composite reliability index for all constructs exceeded the acceptable value of 0.7 (Hair, Anderson, Tatham & Black, 1998) with all constructs above 0.900. Discriminant validity indicates the extent to which a given construct is different from other latent constructs. Fornell & Larcker (1981) suggest the use of Average Variance Extracted (AVE) such that a score of 0.5 for the AVE indicates an acceptable level. Table 2 shows that the average variance extracted by our measures range from 0.639 to 0.820, all above the acceptable value of 0.5. A comparison of the square root of the AVE (diagonal values) with the correlations among the constructs meets Fornell & Larcker's (1981) criterion in support of discriminant validity. The correlation between behavioral change and improved operational change is the highest (0.864). However, further assessment of collinearity statistics shows there was no problem with multicollinearity. Convergent and discriminant validity was also achieved by examining the construct/factor loadings and cross loadings, which shows that all constructs were more strongly correlated with their own measures than with any other constructs suggesting good convergent and discriminant validity.

Table 2. Discriminant validity coefficients

	1	2	3	4	5	6
Change in attitude	**0.870**					
Behavioral change	0.740	**0.883**				
Improved knowledge and understanding	0.706	0.668	**0.875**			
Improved operational skills	0.744	0.864	0.710	**0.905**		
Pedagogical approach	0.574	0.610	0.728	0.651	**0.839**	
Relevance of course content	0.638	0.668	0.738	0.663	0.807	**0.800**
Mean	5.000	4.821	5.884	4.823	5.871	5.995
Standard deviation	1.031	1.004	0.943	1.087	0.943	0.767
Composite reliability	0.903	0.934	0.929	0.958	0.923	0.914
AVE	0.757	0.780	0.766	0.820	0.705	0.639

Bold numbers on the diagonals shows the square root of the AVE, numbers below the diagonal represent construct correlations

3. RESULT AND DISCUSSION

In the sample the median age is 40 (from 21 to 66 years); almost 70 % worked on offshore vessels, 85 % were officers, 62. 5 % attended the course together with other members from the same crew. Almost 53 % of the respondents reported that they had experienced highly stressful situations which the BRM course helped them tackle. Between 88% and 97% of the respondents evaluated the theory part of the course including themes such as communication, decision-making, situational awareness, cultural differences and the human elements as useful and important. Most of the respondents (77.7 %) reported that they had improved their communications skills as a result of the course while 64.3 % reported that their decision-making skills had improved. Debriefing was evaluated as an especially important part of the course since around 96 % of the respondents reported that debriefing after each training session was useful or very useful.

The structural model represents the relationships between constructs or latent variables that were hypothesized in the conceptual model. Since the primary goal of PLS is prediction (Duarte & Rapaso, 2010; Hair et al, 2014), the effectiveness of a theoretical model is established by the strength of each structural path and the combined predictability (R^2) of its exogenous constructs

(Chin, 1998). The results of the structural model are shown in Figure 2 with variance explained for each dependent construct.

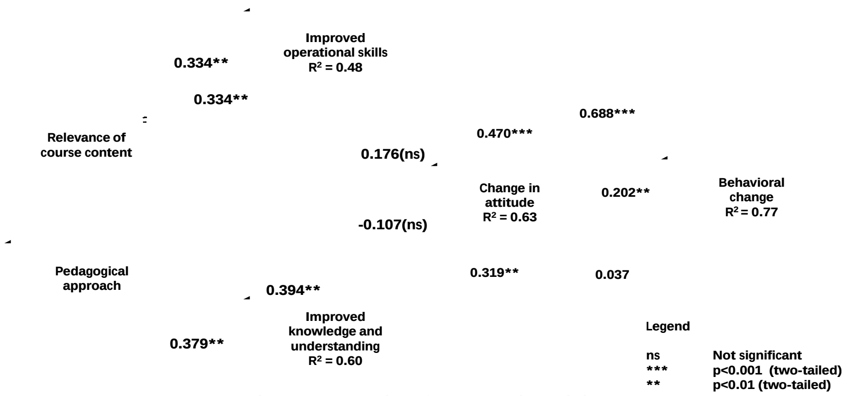

Figure 2. Results of structural model

The estimation and assessment of structural model path coefficients was performed using SmartPLS3. Assessment of the path coefficients was done by bootstrap analysis in SmartPLS3 to assess the significance of the path coefficients. Table 3 shows the results of the path analysis.

Table 3. Path coefficients (Sample size=112)

Path			Coeff.	T-value#
Change in attitude	→	Behavioral change	0.202	2.767**
Improved knowledge and understanding	→	Change in attitude	0.319	2.666**
Improved knowledge and understanding	→	Behavioral change	0.037	0.473
Improved operational skills	→	Change in attitude	0.470	5.195***
Improved operational skills	→	Behavioral change	0.688	9.918***
Pedagogical approach	→	Change in attitude	-0.107	0.851
Pedagogical approach	→	Improved knowledge and understanding	0.379	3.252**
Pedagogical approach	→	Improved operational skills	0.334	2.570**
Relevance of course content	→	Change in attitude	0.176	1.365
Relevance of course content	→	Improved knowledge and understanding	0.433	3.570***
Relevance of course content	→	Improved operational skills	0.394	3.101**

*# Based on 1000 bootstrapping samples, *** p<0.001, ** p<0.01 (two-tailed)*

The effect of improved operational skills on behavioral change (H1) is significant at 0.001(two-tailed). The hypothesized relation between improved operational skills among and change in attitude (H2) is significant (β=0.470, p< 0.001). However, the effect of improved knowledge and understanding on perception of behavioral change (H3) is insignificant (β=0.037, p>0.05). Improved knowledge and understanding has a positive significant effect on change in attitude (H4; β=0.319, p<0.01). The hypothesized relation between change in attitude and behavioral change (H5) is significant (β=0.202, p< 0.01). Thus, improved operational skills' effect on behavioral change has the highest effect size (f^2=0.77), followed by improved operational skills' effect on change in attitude (f^2 =0.26) and the lowest effect size for the effect change in attitude on behavioural change (f^2=0.07). In assessing the path coefficients, effect sizes are used to gauge whether a predictor latent variable has a weak, medium or large effect at the structural level. Values of 0.02, 0.15 and 0.35 are considered as weak, medium and large respectively (Hair, Ringle & Sarstedt, 2011; Hair, Hult, Ringle & Sarstedt, 2014).

In the current context, with expensive specialized vessels and platforms with high workloads, the acquisition of knowledge, attitudes and skills can be difficult in terms of available time, cost effectiveness and safety (Håvold, Nistad, Skiri & Ødegård, 2015). The Bridge Resource Management (BRM) course which involves the use of simulators appears to be a valuable course which provides the needed skills, change in attitudes and behavior which is required by crew to perform efficiently and safely especially in very 'demanding conditions' at sea. The relevance of course content (highest mean value of 5.995, Table 2) and the pedagogical

approach (mean value of 5.871, Table 2) brought about improved operational skills and increased knowledge and understanding to crewmembers who participated in the course. Relevance of course content in terms of how to communicate effectively, how to be aware of situations on board, how to relate with other crew members and make decisions were considered to be very useful topics on this course (see mean values of items, Table 1). The pedagogical approach which involves discussions after the simulator training, a combination of theory and practice on the simulator, and the use of the simulator in practical training were considered as very important pedagogical approaches in disseminating knowledge and providing the skills that are required for effective operations on board. The use of simulators provides better and more realistic situations. For example, the use of simulation is required by law for airline pilots in many countries. Offshore seafaring yet lacks such a requirement. However, the need to improve offshore safety has made the use of simulators in training seafaring crew a necessity in order to provide realistic situations for participants on such training programs. Simulations have a great potential as a ''low cost'' medium to create relevant training contexts where trainees, students, employees are participants in a learning process (Håvold et al, 2015, p.143). The outcomes of the BRM training course include improvement and acquisition of skills in communication, cooperation, decision-making and working as a team.
Outcomes in terms of an increase in knowledge and understanding with specific reference to improvements in gaining better understanding of the thinking process of other crewmembers, planning and more effective communication between crewmembers cannot be underemphasized. In terms of change in attitude and behavior, the BRM course is indisputably an important and effective way to bring about those desirable attitudinal and behavioral changes. The BRM course is an effective way of changing attitude (mean value of 5.000, Table 2). The structural model (Figure 2) shows that most of the 63% variation in change in attitude is explained by improved operational skills and improved knowledge and understanding. Relevance of course content and the pedagogical approach explains 48% variation in improved operational skills and 60% in improved knowledge and understanding respectively. Behavioral change has 77% of its variation explained by improved operational skills, change in attitude and improved knowledge and understanding. The significant effect of change in attitude on behavior is consistent with the Theory of Reasoned Action (Ajzen & Fishbein, 1977) and Theory of Planned Behavior (Ajzen, 1991). Attitudes are indicators of behavior and effectiveness, as they reflect the cognitive aspects of the concepts espoused in training (Fishbein & Ajzen, 2010). Attitudes may not be perfect indicators of behavior, but the findings suggest that in order to bring the desired change in attitudes, the acquisition of knowledge and understanding and increased skills (in other words, improvement in skills) has a profound influence on changing attitudes. When people have the necessary skills, they are more able to act on their intentions. Hence, without the necessary skills, intention will not predict behavior. Thus, the acquisition of skills is very important. The evaluation of training programs such as those discussed in this study can contribute to improvements in course program design. It can help to know which factors to consider in order to provide effective training for participants. Course content and the pedagogical approach are important predictors of improved operational skills and improved knowledge and understanding while improved operational skills are significant predictors of behavioral change.

4. CONCLUSIONS

Team training works! "Careful attention to all elements of the training design and delivery will ensure that trainees gain the necessary KSAs to be a good team member and can maximize their use of these skills on the job, thereby enhancing both their own working conditions and patient safety." The use of evaluation and the assessment of BRM simulator training programs can help pinpoint the key success factors that should be given prioritized attention in the design of such training programs. Training programs are very important strategic tools that can be employed to provide the needed skills to participants, to help bring about the necessary changes in attitudes and behavior especially in the demanding situations which occur in seafaring. The use of cross-sectional correlational design used in this study means that the various hypotheses used in evaluating the training program was done at a point in time and this may not be useful in demonstrating causality. Secondly, attitudes are dynamic and change over time; hence a longitudinal design may be useful in providing further insights in the evaluation of such training programs over some considerable period of time. Thirdly, interesting possibilities for further research could involve a cross cultural crew (e.g. Norway and Brazil) since more vessels are now operating in the Brazilian shelf. Multicultural teams can provide interesting moderating factors to help provide alternative explanations for some of the issues that have been discussed in this study.

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6. REFERENCES

Ajzen, I. (1991). The theory of planned behavior. *Organ. Behav. Hum. Decis. Process*. 50, 179–211.

Ajzen, I. &Fishbein, M. (1977). Attitude– behavior relations: a theoretical analysis and review of empirical research. *Psychol. Bull.* 84, 88–91.

Antai, A.S. (2002). *Management of human resources*. Calabar: Pyramids Publisher.

Barclays, D., Thompson, R. and Higgins, C. (1995) The partial least squares (PLS) approach to causal modeling: personal computer adoption and use as an illustration, *Technology Studies*, 2 (2), 285-309.

Bentler, P.M., Speckart, G. (1981). Attitudes ''cause'' behaviors: a structural equation analysis. *J. Pers. Soc. Psychol*. 40, 226–238.

Bloom, B.S. (Ed.). Engelhart, M.D., Furst, E.J., Hill, W.H. & Krathwohl, D.R. (1956). *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain.* New York: David McKay Co Inc.

Cannon-Bowers, J.A., Salas, E., Tannenbaum, S.I. & Mathieu, J.E. (1995). Toward theoretically-based principles of training effectiveness: A model and initial empirical investigation. *Military Psychology,* 7, 141-164.

Carson-Jackson, J. (2010). A simulator instructor's handbook - The learning game. London: The Nautical institute

Chauvin, C., Lardjane, S., Morel, G., Clostermann, J-P. & Langard, B. (2013) Human and organisational factors in maritime accidents: analysis of collisions at sea using the HFACS. *Accid Anal Prev* 59(0):26–37. doi:10.1016/j.aap.2013.05.006.

Chin, W. W. and Newsted, P. R. (1999) Structural equation modeling analysis with small samples using partial least squares, In: Hoyle, R. H. (Ed.), *Statistical strategies for small sample research*, Thousand Oaks: Sage (pp. 307-341).

Duarte, P. A. and Rapaso, M. L. (2010), A PLS model to study brand preference: an application to the mobile phone market. In: Vinzi, V. E., Chin, W. W., Henseler, J. and Wang, H. (Eds.) *Handbook of partial least squares – concepts, methods and applications*. Berlin: Springer (pp. 449 -485).

Fishbein, M. (2000). The role of theory in HIV prevention. Special Issue. AIDS Impact. *In: 4th International Conference on Biopsychological Review*, vol. 81, pp. 59–74.

Fishbein, M and Ajzen, I. (2010), *Predicting and changing behavior: the reasoned action approach*, Psychology Press, New York.

Fornell, C. and Larcker, D. F. (1981) Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, 18 (1), 39-50.

Gyles, J.L. & Salmon, D. (1978). Experience of Bridge team Training using the Warsash Ship Simulator. *Proc First Int Conf. on Marine Simulation MARSIM* pp 1-26 Nautical Institute.

Haerkens, MHTM., Kox, M., Lemson, J., Houterman, S., van der Hoeven, JG. & Pickkers, P. (2015) Crew Resource Management in the Intensive Care Unit: a prospective 3-year cohort study. *Acta Anaesthesiologica Scandinavica* doi: 10.1111/aas.

Hair, J. F., Hult, G. T. M., Ringle, C. and Sarstedt, M. (2014) *A primer on partial least squares structural equation modeling (PLS-SEM)*, Sage Publications.

Hair, J. F., Anderson, R. E., Tatham, R. L. and Black, W. C. (1998) *Multivariate data analysis* (5th ed.). London: Prentice Hall International.

Hair, J. F., Ringle, C. M. and Sarstedt, M. (2011) PLS-SEM: Indeed a silver bullet*, Journal of Marketing Theory and Practice,* 19, 139-151.

Hanzu-Pazara R., Barsan, E. & Arsenie, P. (2008). Reducing of maritime accidents caused by human factors using simula-tors in training process, *Journal of Maritime Research*, Volume 5, No 1, 2008, ISSN 16974840, Spanish Society of Maritime Research, Santander, Spain.

Hetherington, C., Flin, R. & Mearns, K. (2006). Safety in shipping: the human element. *J. Safe. Res.* 37 (4), 401–411.

Håvold, J. I., Nistad, S., Skiri, A & Ødegård, A. (2015), The human factor and simulator training for offshore anchor handling operators, *Safety Science*, 75, 136-145.

Krathwohl, D.R., Bloom, B.S. & Masia, B.B. (1973). *Taxonomy of Educational Objectives, the Classification of Educational Goals. Handbook II: Affective Domain.* New York: David McKay Co., Inc.

Krug, S.E. & Frush, K. (2007) Patient safety in the pediatric emergency care setting. *Pediatrics* 120:1367–1375.

Neal, A., Griffin, M.A., Hart, P.M. (2000). The impact of organizational climate on safety climate and individual behavior. *Safety Sci*. 34, 99–109.

O'Connor, P., Flin, R. (2003) 'Crew resource management training for offshore teams'. *Safety Science*, 41 (7):591-609.

O'Connor, P. (2011). Assessing the effectiveness of bridge resource management training. *International Journal of Aviation Psychology* v21(4) 357-374

Perrow, C. (1999). Normal Accidents: Living with high risk technologies, Marine Accidents, 170–231. Princeton University Press, Princeton, New Jersey.

Petkov, G., Todorov, V T., Takov, T., Petrov, V., Stoychev, K., Vladimirov, V. I. & Chukov, I. (2004). Safety investigation of team performance in accidents. *Journal of Hazardous Materials*, Volume 111, Issues 1–3, 26 July 2004, Pages 97-104.

Ringle, C. M., Wende, S., and Becker, J-M. (2014) SmartPLS 3. Hamburg: SmartPLS. Retrieved from http://www.smartpls.com.

Salas, E., Prince, C., Bowers, C.A., Stout, R.J., Oser, R.L., Cannon-Bowers, J.A., (1999). A methodology for enhancing crew resource management training. *Human Factors 41* (1), 161–172.

Salas, E., Wilson, K. A., Burke, C. S. & Wightman, D. C. (2006). Does crew resource management training work? An update, an extension, and some critical needs. *Human Factors* Summer;48(2):392-412.

Salas, E., DiazGranados, D., Weaver, S.J, & King, Heidi MS (2008). Does Team Training Work? Principles for Health Care Academic Emergency Medicine 15:1002–1009.
Salas, E., Rosen, M.-A., Shawn Burke, C.S., Nicholson, D. & Howse, W.R. (2007). Markers for enhancing team cognition in complex environments: the power of team performance diagnosis. *Aviation, Space and Environmental Medicine* 78, B77–B85.
Schein, EH. (1969). *Process consultation: Its role in organization development*. Reading, MA: Addison-Wesley.
Schein, EH. (1999). *Process consultation revisited: Building the helping relationship.* Reading, MA: Addison - Wesley.
Wilson, D.T., Kraft, D. & Dunn, S.D. (1989). The disruptive effects of explaining attitudes: the moderating effect of knowledge about the attitude object. *J. Exp. Soc. Psychol*. 25, 379–400.
Wold, H. (1975) Path models with latent variables: The NIPALS approach, In Blalock, H. M. Aganbegian, A., Borodkin, F. M., Boudon, R. and Capecchi, V. (Eds.), *Quantitative Sociology: International perspectives on mathematical and statistical modeling,* New York: Academic Press (pp. 307−357).

Management of chemicals in micro-firms in Cyprus – Results from a Nationwide Survey

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Abstract

Management and safe storage of chemicals in micro-firms (<10 employees) is a critical issue due to their lack of resources and the limited – in certain cases – knowledge on the subject. It is also an under-researched area in the international safety literature. While there is limited, yet comprehensive, literature and survey results focusing on Small and Medium Enterprises (SMEs), there is very little evidence on micro firms. This paper is based on a nationwide survey with the cooperation of the relevant health and safety authority among micro-firms in several economic sectors. Micro-firms comprise a major percentage of business firms in a small economy like Cyprus. The survey involved the workers and the owners/managers of the firms, but also obtained information for compliance and safety performance of the particular firms from safety inspectors. The proposed approach overcomes potential problems of common method bias when all data are obtained from the same group of respondents. Safe storage and management of chemicals is a sensitive issue with potentially catastrophic consequences at human, company, as well as, societal level. Micro firms employing a small number of employees tend to portray certain types of safety behavior that reflect the degree of close relationships between the workers and management. Employees and employers – due to the small size of the firm – tend to develop a "sense of belonging" with the firm and sometimes undermine safety rules. In addition to that, it is reported, in literature that the role of the manager in a micro firm is decisive. The financial crisis has added to that by adding extra costs, fewer employees, more stress in the workplace and an increased possibility of accident or mismanagement of chemicals. The paper – a part of a wider nationwide survey to collect information on the management and storage of chemicals in micro-firms – deals in a holistic way with information related to employees, employers and their role, strategies and attitudes towards safe storage and management of chemicals in the workplace. It is work-in-progress and at a later stage, further to appropriate analysis, will yield information regarding employees as well as employers in micro firms. The paper presents only the results related to the perceptions of employees and safety inspectors. Information was collected on demographic characteristics of firms and major influencing factors of safety performance such as employee participation in safety decisions, worker willingness to use personal protection measures, and safety training. The analysis of data has produced some interesting results showing the relationship between good practices on the one hand and safety performance on the other, even in micro-firms. The safety compliance measure, an index comprising safety and chemicals regulations compliance aspects assessed by the health and safety inspectors, has a positive and statistically significant correlation with views of employees on access and use of safety information on chemicals. The employer interest and consultation measure was not found a statistically significant predictor of safety compliance in the regression model. The results also present the current situation with regards to the safe management of chemicals.

Keywords: compliance, consultation, employees, employers, safety

1. INTRODUCTION

Firms in various economic sectors produce, store, and/or use chemicals. Some examples include the paint, printing, and pesticides industries. Management of safety from exposure of workers to hazardous chemicals is a serious issue (Niskanen et al, 2014). The consequences of an accident could have a significant, sometimes even devastating impact on the firm and the individual. Adverse consequences of an accident for the firm include compensation costs, loss of production time, and negative reputation. The impact of accident for employees includes fall in their morale, personal and social costs, and risk for continuation of employment for the accident victim (Vinodkumar and Bashie, 2009). While most attention is frequently directed to the short term adverse effects of chemicals, the chronic effects should not be overlooked (Sadhra et al, 2002).

The present study focuses on a particular category of firms with special problems in the management of safety regarding the production and/or use of chemicals, that is the micro-firms defined here as those with fewer than 10 employees (Cunningham et al, 2014). While accidents in such firms are perceived as being of lower scale and therefore importance they are significant, since there is usually a large number of micro-firms in the economy and form a relatively neglected category from an inspection point of view (Cowley et al, 2004).

Accident prevention in micro-firms is of particular importance since relative lack of knowledge and familiarity with chemicals leads to deficiencies in the use and safe storage of chemicals in such firms. Risk assessment systems, hazard management systems, and worker exposure monitoring and reporting systems are either non-existing or in a primitive form in comparison with larger firms (Balsat et al, 2003). The approach to accident prevention is largely reactive and ad hoc rather than proactive and planned (Hasle and Limborg, 2006). There are, however, increasing pressures, even on micro-firms to comply with laws and regulations in order to avoid fines, protect their reputation, and show social responsibility to their employees and the wider community.

The sources of information of micro-firms for safe storage and handling are mainly external, especially suppliers, but also safety inspectors and to a smaller extent consultants (Walker and Tait, 2004). The dependence on suppliers for information, including provision of material safety data sheets (MSDS), makes the links in the supply chain of particular importance in the study of management of chemicals in micro-firms (Laird et al, 2011). The compliance to safety rules and legislation, and especially the preparation and maintenance of MSDS in the local language, are viewed as a difficult to bear bureaucratic burden by small firms and even more so by the micro-firms (Balsat et al, 2003).

Some of the characteristics of micro-firms can be summarized as follows:

- Small size, informal task division, and lack of clear role responsibility
- Sense of belonging of employees due to the family nature of micro-firm
- Informality and close social relationships affecting views of safety issues
- Financial instability and survival concerns
- Limited resources capability and resource slack, especially money and managerial time
- Ability of the owner/manager to directly influence business decisions.

The above characteristics are important because they lead to special challenges and needs of micro-firms (Laird et al, 2011). Such needs include the cost-effective and practical advice, which is easy to convert to meaningful and especially effective action (Oldershaw, 2003).

The management of chemicals in firms has been widely studied, especially the technical aspects of handling chemicals and systems for prevention of accidents (Bragatto et al, 2015). Social and behavioural factors and informal aspects of the management of chemicals are equally, if not more, important and interact with the technical safety features (Harms-Ringdahl et al, 2000). Even the limited studies on such factors are mainly focused on large firms, especially in industrially advanced countries and to a much lower extent on small firms. The lower end of small firms that is micro-firms are severely under-represented in the literature. The present study attempts to close this gap. There are differences in safety patterns between micro-firms and other categories of small firms and therefore business size matters (Micheli and Cagno, 2010, Legg et al, 2015).

The specific characteristics of micro-firms as mentioned above, especially the close inter-personal relationships of management and employees, and the expectation that employee attitudes are more homogeneous and therefore easier to be captured is an additional reason for this study (Luria and Yagil, 2010).

The main research objectives of the paper include:

- Understand perceptions and beliefs of employees about chemical risks
- Current management of hazardous chemicals in micro-firms and collaboration of workers and managers
- Compliance practice to safety rules and procedures in relation to hazardous chemicals
- Differences in perceptions, knowledge, and practice of owners/managers, employees, and safety inspectors
- The effect of various organizational variables on safety outcomes (like compliance and proactive safety activities)

The current paper focuses mainly on the views of employees and their involvement in safety practices, but also their perceptions about management commitment and priority given to safety versus production targets. It also investigates their safety behaviour in the workplace including the extent of involvement in information gathering on chemical risks, comprehension of such information, and application for the proper handling of chemicals. Compliance of the firm to safety and chemicals regulations, as a major barrier to accidents in the workplace, is an essential aspect of safety performance and a major output variable for this study (Dahl and Olsen, 2013).

The research is expected to lead to identification of potential types of suitable preventive intervention practices like training, information provision, safety audits, monitoring and reporting systems and their relative importance, and increased learning from near misses and accidents.

The context of research is Cyprus a small European island country. The social and economic context, especially the legal and regulatory framework of the country, have an important impact on the management of chemicals in micro-firms (Walters, 2006). The legal structure about protecting the health of workers from chemicals in Cyprus is briefly summarized here as a useful background for the current study.

In Cyprus there is a major regulation for chemical substances and the safety of the workers, namely Chemical Substances Law 78/2010. This legal framework encompasses the main EU directives, REACH (2007) and CLP (2008). REACH is *"the Regulation on Registration, Evaluation, Authorization and Restriction of Chemicals"* and has been put into play on the 1st of June 2007. It aims to ensure a high level protection of the human health and the environment from the risks arising from the use of chemicals, the promotion of alternative testing methods, the free circulation of substances on the internal market and the enhancement of competitiveness and innovation (EC, 2006). CLP – Regulation 1272/2008 has been put into force on January the 20th 2009 and focuses on classification, labeling and packaging aiming at ensuring that the same hazards are described and labelled the same around the world, as directed by the Globally Harmonized System (GHS). The EU suggested a transition period until CLP – Regulation completely took over the older EU regulations; that was the 1st of December 2010 for substance classification and labelling to be consistent with the new rules and the 1st of June 2015 for mixtures to abide by the new CLP directive (2008).

In addition to the above directives, the Chemical Substances Law 78/2010 of the Cyprus government is acting as an umbrella ensuring that a) hazardous chemical substances and mixtures are always in the appropriate packages, b) they are labeled correctly in terms of safety, exposure limits and protective measures to be taken by workers for their personal safety and health and the safety of the environment, c) the professionals using hazardous substances are obligated by this law to keep a Safety Data Sheet in Greek, d) the restrictions for production, importing, exporting and distributing specific hazardous substances and mixtures are not being compromised, e) all chemical substances available on the market are registered by the CLP standards, and f) relevant information regarding the hazardous chemicals that are on the Cypriot market has been notified to the European Chemicals Agency (ECHA).

Section 2 below describes the materials and methods, while section 3 the analysis of results and their discussion, and finally section 4 the conclusions and some recommendations based on the findings.

2. MATERIALS AND METHODS

2.1 Sample

The paper is based on the results of a study on safety management in micro-firms in Cyprus. The survey tool (questionnaire) was divided in 3 sections: the employer, the employee, and the labour inspector. In this way, the labour inspector as an independent observer would confirm (or not) the statements of the employer and employee. For every organization, a questionnaire was filled by the employer, one employee, and the labour inspector that administered the questionnaire and observed the workplace. A survey was conducted among 60 micro-firms (employing less than 10 employees) from several economic sectors with the help of the Department of Labour Inspection, Cyprus. 48 questionnaires were returned. The sample is representative of the main economic sectors of Cyprus (Manufacturing (other than chemical) 33.3%, Chemical industry 26.8%, Services 29.4%, Others 10.5%). The sample is small therefore the study has only an exploratory character. Micro-firms are notorious for their reluctance to participate in surveys (Lamm 2014).

A pilot study was conducted among ten micro-firms to test whether the questions of the questionnaire were easily comprehended by the respondents. Based on this pilot study re-wording of some questions was made in order to increase clarity and comprehension. For example in the question of accidents at the workplace the qualification of reporting only those that kept the employee three days away from work had to be added.

The Department of Labour Inspection had an active participation in questionnaire design and data collection. Confidentiality and the fact that this data collection was completely independent from the inspection duties of the inspectors were emphasized. Although the method of delivery of questionnaires by labour inspectors has admittedly introduced some potential bias in the interviewee responses, it was the only feasible approach for access to micro-firms in Cyprus, which are notoriously reluctant in providing information to researchers. The inspectors then filled in their answers to questions regarding to indicators of safety performance and chemicals management of the firm after the visit.

Questions were asked to employees about the provision of training on health and safety issues, the provision of individual safety protection measures and their participation in safety and chemicals management related decisions. There were also questions on the perceived safety conditions and occurrence of accidents (which kept employees for more than 3 days away from work) in the last 12 months. Finally questions were asked about the employee role in proper handling of chemicals and the availability of safety information. The research complied with the guidelines of our university for human research ethics.

2.2. Variable measures

A safety performance measure for the firm was constructed in order to be used as the dependent variable. It is a simple summative index (safety compliance) comprising two safety performance aspects, assessed by the health and safety inspectors. The two items of the index were based on the following questions answered by the safety inspectors:

1. Does the firm comply with the law and regulations about chemicals?
2. Does the firm comply with health and safety law and regulations?

In both cases they were asked to “Grade compliance on a scale of 1 minimum to 10 maximum”
The Cronbach’s alpha reliability of the summative scale at 0.83 is quite good. The fact that this measure is based on judgement of safety inspectors, while the independent variables are based on responses of employees is an advantage of the research design since it avoids the common method bias.

Safety compliance cannot be tested for association with the occurrence of serious accidents in the firm because there were no accidents in the last 12 months in the sample firms. Serious accidents – according to Cypriot Law - are those requiring an absence of the employee for more than three days from work.

Some of the independent variables as use of chemicals in the production process of the firm, everyday use of chemicals by the employee, study of the material safety data sheets, and willingness to follow instructions for proper use of chemicals were measured as dichotomous (binary) variables (Yes = 1, No = 0). Access to chemicals safety data, perceived safety conditions in the workplace, perceived employer interest in health and safety issues and "Breach of safety regulations in order to meet production targets" are each measured by a single five step scale from not at all to very much. Extent of safety training was measured by taking into account the number of hours of training regarding proper use of chemicals (5-10, 10-20, and over 20 hours).

A scale was constructed for the "perceived consultation and interest in safety of the employer" by employees. It is based on the following four items and has a high Cronbach's alpha reliability of 0.91.

- Employer/employee consultation on chemicals
- Employer interested in employee protection from chemicals
- Awareness of employer views on protection from chemicals
- Appreciation of my views on chemicals management

A second scale was constructed for "access and use of safety information on chemicals" by employees. It is based on the following three items and has an acceptable Cronbach's alpha reliability of 0.69.

- Access to chemicals safety data
- Label information adequacy
- Study of chemicals labels

Descriptive statistics was initially used for some of the results and then zero order correlation was used in order to explore the relationships between the dependent and independent variables by calculating the Pearson r coefficient. Multiple regression was used to determine the relative influence of the independent variables on safety compliance.

3. RESULTS AND DISCUSSION

Due to limited space the article reports only some of the descriptive results. The employee respondents are mainly males (76%) against 24% females. Their answers on length of training for proper use of chemicals show that the majority of companies (56.7%) provide minimal training 5-10 hours, but a significant percentage over 20 hours with only 8.1% providing 10-20 hours of training.

There is no significant correlation between safety compliance and OHS policy existence, and surprisingly no significant correlation also between safety compliance and training, employee willingness to follow safety guidelines and employee willingness to use personal protection measures. There is, however a significant relation ($r = 0.35$ $p<0.05$) between safety compliance and "employee consultation about chemical management" as reported by owners/managers. Some similarities between the views of employers and employees are noteworthy. For example there is a moderate and statistically significant correlation ($r = 0.51$ $p<0.01$) between "consultation on chemicals management" as perceived by employees and "consultation" as reported by employers. The latter variables are not however statistically correlated with the "compliance of employees to information provided by material safety data sheets" as reported by the inspectors. Finally there is a statistically significant correlation between information provided on proper use of chemicals as reported by employers and as reported by employees ($r = 0.30$ $p<0.05$).

Subsequently multiple regression analysis was conducted in order to determine the relative contribution of each predictor to the outcome variable safety compliance (sumcomplianceins). Two demographic variables company age, and employee years of experience (as a proxy for work experience), and the two scales on "perceived consultation and interest in safety of the employer" (employerconsult) and "access and use of safety information on chemicals" (labelchem). Table 1 presents the abbreviations used in the analyses. Table 2 the descriptive statistics and Table 3 zero-order correlations, while Tables 4, 5, 6 illustrate the results of regression analysis. The assumptions of linear regression for normality, linearity, homoskedasticity, and lack of collinearity were checked with the appropriate diagnostic tests (mainly inspection of appropriate histograms, residual scatter plots, and normal probability plots) and it was confirmed that they are met.

In the regression model the R square is 0.48, (adjusted R square 0.32). Only the variable "access and use of safety information on chemicals" (labelchem) was statistically significant in the regression model: beta = 3.28, p<0.01.

***Table 1** – Abbreviations of variables used during the analyses*

Variable description	**Variable Abbreviation**
perceived consultation and interest in safety of the employer	employerconsult
safety information on chemicals and use by employees	labelchem
years of employment at the firm	Years Employment
Compliance of the firm with the law and regulations (about chemicals and health and safety)	sumcomplianceins
Years the company has operated for	Company Age

Table 2 – Descriptive Statistics

	Mean	**Std. Deviation**
employerconsult	170.667	342.053
labelchem	107.209	336.880
Years Employment	3.02	.901
sumcomplianceins	129.362	345.407
Company Age	4.62	.834
N		**45**

***Table 3** – Correlations*

		1	**2**	**3**	**4**	**5**
employerconsult [1]	Pearson Correlation	1	.481**	.315*	.274	.086
	Sig. (2-tailed)		.001	.035	.076	.593
	N	45	41	45	43	41
labelchem [2]	Pearson Correlation	.481**	1	.343*	.583**	.115
	Sig. (2-tailed)	.001		.024	.000	.485
	N	41	43	43	41	39
Years Employment [3]	Pearson Correlation	.315*	.343*	1	.380**	.440**
	Sig. (2-tailed)	.035	.024		.009	.003
	N	45	43	49	47	45
sumcomplianceins [4]	Pearson Correlation	.274	.583**	.380**	1	.316*
	Sig. (2-tailed)	.076	.000	.009		.039
	N	43	41	47	47	43
Company Age [5]	Pearson Correlation	.086	.115	.440**	.316*	1
	Sig. (2-tailed)	.593	.485	.003	.039	
	N	41	39	45	43	45

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4 – Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.696[a]	.484	.415	260.442	2.068

a. Predictors: (Constant), Years Employment, employerconsult, Company Age, labelchem

b. Dependent Variable: sumcomplianceins

***Table 5** – ANOVA*

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	190.795	4	47.699	7.032	.000b
	Residual	203.490	30	6.783		
	Total	394.286	34			

a. Dependent Variable: sumcomplianceins

b. Predictors: (Constant), Years Employment, employerconsult, Company Age, labelchem

***Table 6** – Regression Model Coefficients*

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	3.425	3.106		1.103	.279	-2.919	9.769					
	employerconsult	-.001	.143	-.001	-.004	.997	-.292	.291	.320	-.001	.000	.776	1.288
	labelchem	.527	.161	.534	3.278	.003	.199	.855	.656	.514	.430	.649	1.540
	Company Age	.316	.584	.081	.541	.592	-.877	1.510	.293	.098	.071	.778	1.286
	Years Employment	.818	.643	.214	1.273	.213	-.494	2.131	.515	.226	.167	.609	1.643
a. Dependent Variable: sumcomplianceins													

There is substantial agreement between the views of managers and employees on the issue of “perceived consultation of employers and employees” as shown above by the statistically significant correlation between the relevant variables and also on provision of information on proper use of chemicals. In contrast many literature sources refer to differences in views on safety issues between employees and owners/managers in small firms (Hasle and Limborg, 2006). Frequently owners/managers blame employees for accidents considering them responsible for their own safety in the workplace (Laird et al, 2011).The demographic variables years of employment or tenure of the employee (a proxy for work experience) and company age (a potential proxy for experience at company level for safe handling of chemicals) although individually positively correlated with compliance of the firm to safety regulations are not statistically significant in the regression model.

The results of regression analysis show that the variable “Perceived employer interest in safety and consultation” is not a statistically significant predictor of safety compliance. This variable reflects the views of employees regarding consultation of management with employees on protection from chemicals, the perceived interest of employer in protection of workers from chemicals, management commitment to safety, and importance attached to employee views by management. It is an indirect measure of safety leadership as perceived by employees (Dahl and Olsen, 2013). More positive views were expected to be associated with higher safety compliance of the firm, but this was not the case. Similarly Hambach et al (2011) report distrust of workers in chemical firms towards management from their focus group based study. In contrast Walters and Nichols, 2006 refer to the importance of consultation of management with employees on health and safety issues in small chemical firms. Niskanen et al, 2014 report positive views of workers’ organizational safety and health (OSH) representatives in chemical industry in general (mainly small and medium size firms) regarding engagement, willingness to collaborate with, and trust to management.

Positive views on “access and use of safety information on chemicals” by employees as summarized by the relevant variable are positively associated with higher safety compliance.

Safety communication is considered as an important factor for safety performance. Brown et al, 2006 have found that workers in the printing industry criticize management for lack of interest for employees, provision of little health and safety information, and inadequate training provided to them. Sadhra et al, 2002 from a study among small electroplaters have found that workers learn more from one another than from material safety sheets or other available written material. The sources of information (formal and informal) and the role of exchange of information with peers in the family atmosphere of the micro-firm is an issue worthy of further investigation in the context of micro-firms.

Limitations of the current study include the small sample size, its cross–sectional survey nature and the selection of firms from different economic sectors instead of concentration on chemical industry. It is also possible that some of the replies reflect the desirable and socially acceptable behaviour rather than the actual one. Agreement between additional questions on similar issues do not show however a large extent of this effect.

4. CONCLUSIONS

The most interesting finding of the study is that the variable representing the perceptions of employees regarding access and active use of safety information on chemicals has a positive association with safety compliance. The cross-sectional nature of the study does not allow to conclude whether positive views of employees on availability and use of information on chemicals leads to higher compliance of the firm to regulations or whether high compliance leads to positive employee views on safety information issues. Views of employees on employer's interest in protecting workers from chemical risks, consultation and commitment to safety were not found significantly related to safety compliance as independently judged by safety inspectors in the regression model.

The findings suggest that good practices like provision of information on chemicals and motivation of employees to read the relevant information and especially act accordingly taking the necessary precaution measures and using the appropriate personal protection equipment seem to be a proper intervention strategy in micro-firms using chemicals. The key issue is how to design realistic intervention strategies to match the informal atmosphere and the resources and safety capabilities of micro-firms in order to increase their effectiveness.

5. REFERENCES

Balsat A, de Graeve J, Mairiaux P. (2003) A structured strategy for assessing chemical risks, suitable for small and medium-sized enterprises *Annals of Occupational Hygiene*, 47(7), 549– 556.

Bragatto, P., Ansaldi, S. and Agnello P. (2015) Small enterprises and major hazards: How to develop an appropriate safety management system *Journal of Loss Prevention in the Process Industries* 33, 232-244.

Brown TP, Rushton L, Williams HC, English JS. (2006) Intervention development in occupational research: An example from the printing industry. *Occupational and Environmental Medicine* 63(4), 261–266.

Cowley, S., Else, D. and LaMontagne A. (2004). Increasing the adoption of OHS risk controls in small businesses: Can social marketing help to achieve change*? J Occup Health Safety* -Aust NZ 20(1), 69-77.

Champoux D, Brun JP, (2003) Occupational health and safety management in small size enterprises: an overview of the situation and avenues for intervention and research, *Safety Science* 41, 301–318.

Cunningham, T.R., Sinclair, R., Schulte, P., (2014). Better understanding the small business construct to advance research on delivering workplace health and safety. *Small Enterprise Res*earch 21(2), 148–160.

Dahl O. and Olsen E. (2013) Safety compliance on offshore platforms: A multi-sample survey on the role of perceived leadership involvement and work climate. *Safety Science* 54, 17–26.

Hasle P, Limborg HJ. (2006) A review of the literature on preventive occupational health and safety activities in small enterprises, *Industrial Health* Vol. 44(1):6-12.

Hambach, R., Mairiaux P, Francois G, Braeckman L, Balsat A, Van Hal G, Vandoorne C, Van Royen P, and van Sprundel M *(2011)* Workers' Perception of Chemical Risks: A Focus Group Study *Risk Analysis,* 31(2)*,* 335-342.

Harms-Ringdahl L, Jansson T, and Malmén Y (2000) Safety, Health and Environment in Small Process Plants—Results from a European Survey *Journal of Safety Research*, 31(2), 71–80.

Hopkins, A. (2011). Risk-management and rule-compliance: Decision-making in hazardous industries. *Safety Science,* 49, 110-120.

Laird, I., Olsen, K., Harris, L.-A., Legg, S., & Perry, M. (2011). Utilising the characteristics of small enterprises to assist in managing hazardous substances in the workplace. *International Journal of Workplace Health Management,* 4(2), 140–163.

Lamm, F. (2014) The challenges of researching OHS of vulnerable workers in small businesses. *Small Enterprise Res*. 21(2), 161–179.

Legg S.J., K.B. Olsen, I.S. Laird, P. Hasle, (2015) "Managing safety in small and medium enterprises", *Safety Science* 71, pp.189-186.

Luria, G. and Yagil D. (2010) Safety perception referents of permanent and temporary employees: Safety climate boundaries in the industrial workplace *Accident Analysis and Prevention* 42, 1423–1430

Micheli, G.J.L., Cagno, E., 2010. Dealing with SMEs as a whole in OHS issues: warnings from empirical evidence. *Safety Science* 48, 729–733.

Niskanen T. Louhelainen K. and Hirvonen M. (2014) Results of the Finnish national survey investigating safety management, collaboration and work environment in the chemical industry *Safety Science* 70, 233–245.
Oldershaw, P. 2003 Editorial: Control Banding Workshop, 4–5 November 2002, London *Ann. Occup. Hyg*., 47(7), 531–532
Olsen, K., Harris, L.-A., Laird, I.S., Legg, S., Perry, M., & Hasle, P. (2010). Differential intervention strategies to improve the management of hazardous chemicals in small enterprises. *Policy and Practice in Health and Safety, 8* (2), 57-76.
REGULATION (EC) No 1907/2006 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC
Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006
Sadhra S, Petts J, McAlpine S, Pattison H, MacRae S. (2002) Workers' understanding of chemical risks: Electroplating case study. *Occupational and Environmental Medicine*, 59, 689–695.
Sinclair, R. C. and Cunningham, T. R. (2014). Safety activities in small business. *Safety Science*, 64, 32-38.
Sørensen, O.H., Hasle, P., Bach, E., 2007. Working in small enterprises – is there a special risk? *Safety Science* 45, 1044–1059.
Tabachnick*,* B. G*., &* Fidell, L. S. (*2006*). Using Multivariate Statistics (5th ed). Boston, MA: Allyn and Bacon.
Vinodkumar, M.N., Bhasi, M., 2009. Safety climate factors and its relationship with accidents and personal attributes in the chemical industry, *Safety Science,* 47(5), 659–667.
Walker, D and Tait, R. (2004). Health and safety management in small enterprises: an effective low cost approach. *Safety Science*, 42, 69-83.
Walters, D. (2006) "The efficacy of strategies for chemical risk management in small enterprises in Europe: evidence for success?" *Policy and Practice in Health and Safety*, 4(1), 82-116.
Walters, D and Nichols, T. (2006) Representation and consultation on health and safety in chemicals: an exploration of the limits to the preferred model , *Employee Relations*, 28(3), 230-254.

Challenges Transferring Regulatory Regimes. The Norwegian - Brazilian case

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Abstract
The paper addresses challenges that occur when elements of a regulatory regime developed under certain historical contexts in one region are transferred to other national contexts. On February 11, 2015, there was a serious explosion on the Floating, Production, Storage and Offloading unit (FSPO) Ciade de Sau Mateus on the Brazilian continental shelf. Nine workers died in the accident. The explosion was, however, not powerful enough to affect the large amount of oil that was stored on the vessel, which could have resulted in further fatalities and potential large oil spill. The FSPO was owned and operated by the Norwegian company BW Offshore that produced oil for the state owned Brazilian company - Petrobras. Accordingly, the accident put attention on the relationships between the Norwegian and Brazilian petroleum industry and how Norwegian experiences have been used in developing an offshore sector in Brazil.
Through a comparative analysis, the paper discusses similarities and differences in relation to regulatory challenges overseeing the Norwegian and the Brazilian offshore sector. In order to accomplish such an analysis, the paper also relates cases of the Brazilian regulatory system to relevant cases of the U.S and British regulatory system.

Keywords: Petroleum industry, Social Context, Governmental role, Local content, Safety

1. INTRODUCTION

When Brazil established an independent regulatory institution related to petroleum activities in 1997, the regulatory approach in the Norwegian offshore oil sector was one of the main models. Together with the regulatory regime in Britain, the Norwegian regulatory regime has developed a status as “industrial best praxis” when it comes to regulation of petroleum activities offshore. The main reason for this is the fact that more than 30 years have passed since Norway has had a large accident. The statistics show that work-related fatalities in the sector are rare. There was not a single fatality between 2009 and 2015. Other statistical figures that compare lost time due to incidents and other safety related indicators between countries show a more complex picture. This does not undermine the general positive picture as it can be interpreted as simply a consequence of effective report systems. However, during the last decade there have been near misses that under more unfortunate circumstances might have turned into catastrophes (IRIS 2011). It is difficult to determine just what it is about the Norwegian safety system that makes it work. Since the efficiencies of a safety system can be related to specific context, important pillars in a system can erode unnoticed. Accordingly, the challenge is even higher if one transforms a part of a system that work in one country to other countries where contexts are very different.
Context is also important when it comes to safety. The relevant contexts can be very concrete such as laws, regulations, and formal institutions, such as the Norwegian Petroleum Agency (PSA), and therefore easy to define. Context can also consist of more vague factors such as power structure, tacit knowledge, and even more general, culture. The international petroleum industry is experienced in transferring huge packages of technological solutions that are organized in certain structures. However, the industries will also, to a large degree, be shaped by the social, cultural and political relations in the country where they operate. Since regulatory regimes are tied to the local state, regulation must be related to other regulatory traditions that dominate the host country. These dimensions all have their own history. The paper, therefore, addresses challenges that occur when elements of a regulatory regime developed under certain historical contexts in one region are transferred to other national contexts. The paper is based on findings from the ongoing projects “Robust Regulatory Regimes” and “Defences against Major Accidents” (Funded by Norwegian Research Council).

2. HISTORICAL BACKGROUND

Even though Latin America has a long petroleum history, with Mexico and Venezuela being among the largest producers in the world for long periods of time, the Brazilian oil industry has a distinct historical background in the sense that it first became a large producer after oil was found on the Brazilian continental shelf in the 1960s (Randall 1993). The most important reference point in the development of the Brazilian oil sector has therefore not been other Latin American countries, but the development in the other two largest offshore oil producing regions, i.e. the North Sea and the U.S. part of the Gulf of Mexico. Even though the Brazilian state oil company has had an almost monopolistic position as owner and formal operator since it was established in 1953, it has to a large degree relied on the international offshore supply and service industry for difficult technological tasks. Given the size and advanced nature of the operation, the dependency of the international supply and service industry enhanced after exploration and production of petroleum started offshore. This meant that it was the same international industry that operated in both Brazil and Norway when drilling started offshore in the mid-1960s. The parallel development was such that companies sometimes could even move key equipment and personnel back and forth, crossing the Atlantic and the Equator.

However, since oil was first found offshore in the Garoupa-field in Brazil in 1968 and at the Ekofisk-field in the Norwegian part of the North Sea in late 1969, there have been important differences between Brazil and Norway that have had significant effects on safety issues. First there are some very basic weather conditions that have influenced technological decisions from the pioneer period in the 1960s up to today: All installations operating in the North Sea have to be robust enough to handle a cold, stormy winter season. Platforms have to be designed for a so called “100-year’s wave” up to 30 meters. The Brazilian continental shelf does not have the same climate and waves seldom reach more than 7 meters. That is a bit higher than in the U.S. outer continental shelf in the Gulf of Mexico. However, unlike U.S., Brazil did not have to take into account hurricanes.

Another major difference between Norway and Britain on one side, and Brazil on the other was that the oil companies operating in the North Sea during the 1970s and 1980s found a series of large reservoirs of oil and gas, while the finding rate in Brazil was much lower (BP 2015). Several of the largest findings in the North Sea, like Brent Spar, Statfjord, Murchison, were on water depths from 150 meters and below. The size of the findings and the fact they were found in politically safe areas far from more politically turbulent oil-producing countries in the Middle East, led to an intense investment boom. In Norway and Britain, a new industry was built from scratch during a very short period. This, combined with the fact that the industry was operating on the very edge of what was technologically possible, had also profound consequences for safety. Both the Norwegian and the British continental shelf experienced a series of accidents. In Norway, between the 1960s and 1978 there were 82 fatalities related to offshore activities. The worst accident occurred in 1980 when the Alexander Kielland platform capsized, causing 123 deaths. Britain had a similar accident rate and experienced its worst accident in 1988 when a blow-out led to an explosion and fire at the Piper Alpha platform, causing 167 deaths (Woolfson, Foster, Beck 1997, Paterson 2014).

Investments in offshore installations in Brazil did not really take off until there were significant oil findings in the Campos basin in the mid-1970s. The findings were not as big as the largest findings in the North Sea. When several of them were producing in the mid-1980s, Brazil produced 1/3 of what Norway and 1/5 of what Britain produced at the same time. What is important in relation to safety is that the Brazilian fields were generally found in shallow waters. With a lag of time of about five years, less wave heights, more shallow water, and a less intense investment boom, the Brazilian offshore sector had the advantage of being able to use technologies that had been proven effective under more challenging circumstances in the North Sea. This did not mean that exploration and production of oil from offshore installations in Brazil was an easy task. In Brazil, as in Norway, there was strong desire to make sure that construction of installations was made locally. In the Campos basin many of the basic metal structures that were in use, such as jackets and platform-decks, were constructed at local yards.

2.1 First Accidents

Parallel to Norway, the first serious incident in relation to offshore petroleum activities in Brazil occurred when the first drilling rig was towed over the Atlantic. Another serious accident happened when a jacket for first production installations on the Gouropa-field was to be installed in 1980 (C.T. da Costa Fraga (et. Al.) OTC 15219. 2003. p.2). The jacket was constructed based on experience from the North Sea. However, when the installation was placed on the seabed outside Brazil, part of it sank and made the entire installation tilt. In the same year, the process plant on the same installation collapsed. After these incidents the engineers concluded that different seabed conditions, wave, and stream conditions had to be taken more seriously when designing and constructing installations.

The most serious accident in the first phase of the Brazilian offshore oil history occurred when a production installation on the Enchova field in August 1984 experienced a blowout. The Platform caught fire after an explosion. Forty-two workers were killed in the event, most of them because a life boat collapsed when it reached water after having been released from the platform. In April 1988 the same platform experienced a new blowout (Maduro & Reunolds, 1989). This time the evacuation went well but the platform collapsed however from a heavy fire.

In the 1990s, Brazil caught up with the North Sea and the Gulf of Mexico in the sense that oil was found on deeper waters. The breakthrough for Brazil as a deep-sea producer happened when oil was found in the Barracuda field (300 meter and down) and the Marlim field (800 meter and below) in the late 1980s. The real technological challenge was not the exploration drilling, but the installation of production wells and the related installation adjusted to such conditions. However, due to Brazil's debt problems, heavy inflations, and long periods of economy crises and stagnation it was difficult for Brazil to promote any kind of protective industrial policy from the mid-1980s into the 1990s. Brazil had given up most of its ambitions to develop a local supply and service industry. This meant that even though the Brazilian continental shelf was about to become an important technological laboratory for offshore oil technology, it was mainly firms with historical roots in the offshore activities in the North Sea and the Gulf of Mexico that dominated. Initially, U.S. firms received most of the contracts. When Petrobras in the early 1990s during the development phase on the Barracuda and the Marlim fields established technical standards for sub-sea structures, they chose to use the U.S. API standard (Oil & Gas Journal 1994). The main rationale for introducing technical standards was to reduce cost and make sure that operations ran as smoothly as possible. However, making equipment and installations fit together and become more robust also had safety implications.

In the late 1990s and into the 2000s, Norwegian firms played an increasingly important role in the deep sea segment of the Brazilian industry. The hazards in relations to petroleum production offshore increase for every extra meter drilled into the ground. These dangers are further related to extreme temperatures (i.e. extra cold in deep waters, potential extra warm the deeper in to the ground), as well as extreme pressure. This was clearly demonstrated by the Deepwater Horizon accident. The main technological breakthrough, though, was the ability to operate the equipment from above. As long deep sea activities were regulated by the technological standards set by the dominating operator Petrobras, Norwegian firms also had to rely on U.S.-developed API standards. However, the very competitive edge of many Norwegian firms was, to a large degree, influenced by a stricter Norwegian regulation regime. Most new fields on the Norwegian shelf in the 1990s were on depths between 150 and 350 meters. These depths made it possible but dangerous for divers to operate. In the early 1990s, Norway introduced new regulations that in praxis restricted diving beneath 180 meters. Major operators and supply and service firms were therefore forced to quit operate installations for BOPs, wellheads, manifolds, etc., on the seabed either from automated steering systems on platforms or from remote operated vessels (ROVs). Norwegian firms operating in Brazil had to adapt to the API standards that were in use in Brazil. However, many firms used installations and equipment that were developed to adapt to stricter safety requirements that also were adjusted to the Norwegian technological standard, NORSOK. This was particular the case for drilling rigs and supply ships active in Brazil. It was also the case for some of the standardised equipment on board FSPOs, even if these were usually registered in flag states.

In the late 1990s and the early 2000s, offshore activities in Brazil competed with the U.S outer continental shelf in the Gulf of Mexico to have the world record both in drilling and operative production installations on deeper water. The Roncador field, which was found in 1996, covered an area with water depths between 1500 and 1900 meters. It was here that Brazil experienced one of its most serious offshore accidents when, in March 2001, an explosion and a following fire led to a total collapse of the platform. (Petrobras 2001) Eleven people lost their lives. The platform was originally constructed as a drilling rig. When the construction was finished at an Italian yard it was the largest semi-submersible drilling rig ever built. When production on Norwegian oil fields started up in the 1990s and 2000s, the typical strategy would be to construct entirely new installations for the purpose of production only. Due to constant financial constraints, the typical strategy for Petrobras would be to start production early, often with installations that were originally constructed for drilling only, and adapt them to production

purposes. This strategy was a way to create cash flow that circumvented the governmental formal budget procedures. When the P 36 was converted to a production platform, it was the largest semi-submersible production platform in the world.
The production from the Roncador field was taken up again when a Floating, Production, Storage and Offloading unit (FSPO) began production in 2002. In the same manner as large gravity production platforms, it became a symbol of the technological style on the Norwegian continental shelf from the late 1970s and into the 1990s, the use of FPSOs on the Brazilian have some of the same symbolic meanings. No other offshore oil region in the world can boast the same concentration of large FPSO's (FSPO.com), which has a total of 30 vessels. In the U.S. part of the Gulf of Mexico, where the water depths and environmental conditions are similar, FSPOs are seldom used. The reason is a general scepticism among many actors in the U.S oil industry regarding the storage of a large amount of oil in the same place since the Exxon Valdez Accident in 1989. Typical, it was Petrobras who operated a large oil field from an FSPO in the U.S Gulf of Mexico (Caskade & Chinook fields). The actual PSPO, BW Pioneer, was owned and operated by the same Norwegian company BW Offshore that operated the FSPO Cidade de São Mateus that experienced a serious accident in 2015.
The use of FPSO, with equipment able to withstand extreme pressure, has been the main solution after oil from 2007 was found in pre-salt layers. Located in areas with water depths down to 2000 meters and more, and in geological zones placed more than 7000 meter below the sea, oil petroleum activities in pre-layers have taken the oil industry to new challenging ground, where safety implications have not yet been fully explored. When an explosion occurred on the Cidade de São Mateus in February 2015, it was the worst incident ever on an FSPO. Nine of the vessel's 76 crew members died. However, with a depth of 760 on the Camarupim field where the vessels were operating, the potential challenges were not as great as in the much deeper pre-salt field. Luckily, and partly due to safety systems on board, the fire did not spread. A total collapse of the installation such as the Allexander Kielland/Piper Alpha/P-36/Deepwater Horizon type was therefore not experienced

3. REGULATION IN NORWAY

When offshore oil activities began in Brazilian waters in the 1960s, responsibility for safety was left to an internal department in Petrobras. This department conducted enquiries of accidents as well as qualified and monitored procedures and technical standards regulating both the oil companies and the suppliers. This kind of self-regulation from an operative state institution is not unique to Brazil. It used to be the norm in most countries where state oil companies operated. In Norway a similar regulation system was used in the state railway system until 1997. However, in 1972, when it was clear that the petroleum sector offshore where to become an important part of Norwegian industry and economy, an independent regulatory institution was established. The Norwegian Petroleum Directorate (NPD) was established the same year as was the state oil company Statoil. The NPD was, from the start, responsible for regulating both resource allocation and safety. Since the maximum amount of resource rent on one side and safety on the other to some extent may involve contradictory interests, the two departments from 1978 had to report to different ministries. It was not before 2004 that the two departments became two different independent institutions: the NPD and Petroleum Safety Authority (PSA).
The regulatory philosophy in NPD was unique compared to other regulatory traditions in Norway. The fact that offshore petroleum activities in Norway were a totally new and quickly expanding industry contributed to such an uniqueness. Instead of building on other established institutions, NPD was developed from scratch and was located in Norways' new oil capital Stavanger, not near established state institutions in the capitol, Oslo. It took some time and several serious accidents before the NPD acquired sufficient knowledge and authority to confront the industry in a way that actually influenced behaviour and technology. In the early 1980s, the internal control system was developed. The internal control system was a combination of self-regulation and prescriptive regulations, the Working Environmental Act from 1977, and an adaption of modern principles in safety science such as the system approach and risk analyses. When the NPD opted for a system based on performance based instead of prescriptive regulation, it was a response to the continuous development of new technologies and new kinds of installations in the sector. The NPD found that it was impossible to follow up the development of new technologies with the existing system of prescriptive rules and detailed auditing procedures.
However, the system that was developed was different from pure self-regulation in the sense that it was made very clear that it was always the operator's responsibility to operate safe. That

meant that operators had established their own procedures and technical standards when necessary. The self-regulation element did not mean that the NPD was a weak regulatory authority. Companies have always had to prove their focus on safety in extensive documentation. When the regulatory system was fully developed, the ideal role of the NPD was said to be to audit the companies' safety system, not conduct detailed inspections of technical equipment. Typically, when civil servants from the NPDs and later PSA, visited offshore sites it was described as part of audits, not inspection. A typical audit would involve several civil servants in the NPD, last for several months, and involve document analyses, interviews, and inspection, resulting in a report published openly on PSAs webpage (Ryggvik 2014, PSA.com). When all operators had to perform risk analyses it was considered to be an important part of the companies' safety systems. This was at the same time a requirement in the NPD/PSAs regulations. The internal control principle was enforced in several resolutions from 1995 when the regulator made specific demand towards the orientation of the companies' management systems [SAM-forskriften 1995, Kgl res. 27. Juni 1997 and Styringsforskriften (the steering regulation) of 3. September 2002]

The offshore safety system reflects the underlying philosophy of the Working Environmental Act in two ways. First, companies operating on the Norwegian shelf have to accept trade unions as legitimate counterparts. Concerning safety companies have to establish Health and Safety Committees. Several committees and institutions of a more corporative type where workers representatives (unions), companies and relevant government representatives cooperates on everything from safety issues to the forming of technological standards were also established. Second, the Act from 1977 was important in the sense that it clarified the importance of improving technology instead of focusing on workers behaviour in enhancing safety. Hence, the underlying philosophy was that technology had to adapt to humans, not that humans had to adapt to existing technology. This was made particularly clear in the so-called steering regulation.

The last revision of the Norwegian regulation system offshore happened in the early 2000s. This was a time with low oil prices and a focus on cost cutting, which created a tense atmosphere between unions and companies. The conflict ended after the creation of a series of new corporative institutions. Facilitated by the Norwegian Petroleum Authority, the Regulatory Forum and Safety Forum were established. These new institutions formalized the tripartite partnership between public agencies, industrial actors, and labour unions.

3. REGULATION IN BRAZIL

When Brazil, based on Law 9,478 from 1997, established the Acencia Nacional do Petrolero, Gas natural e Biocumbustiveis (ANP), it was part of a larger reform process. The main goal of the reform was to create a counter power towards Petrobras inside the Brazilian state apparatus while opening up the Brazilian oil sector for foreign oil companies. Safety was a secondary issue. By creating separate regulatory authority, Brazil copied the basic structure of offshore regulations in Norway, UK, and U.S. However, like in Norway with NPD in the 1970s, it took some time for the safety department in ANP to develop the necessary knowledge and authority to influence an industry where activities took great leaps into the unknown. Also similar to Norway in the early years, there were many uncertainties regarding the division of labour concerning responsibilities between ANP and other Brazilian regulatory institutions. ANP had to coordinate its activities with the Ministry of Labor, standards from Marine Authority, Regulation and licensing from IBAMA - Brazilian Institute of Environment (offshore), and Health Surveillance Agency (ANVISA). To reduce and control the overlap of responsibilities the group "Operação Ouro Negro" (Black Gold Operation) was established so the related authorities changed information and resources (email: Luciano da Silva Pinto Teixeira, ANP).

It was not before the P 36 accident in 2001 that work to develop a regulatory safety framework gained momentum. This finally resulted in a regulatory framework introduced in 2007 (Resolution No 43, 6th December 2007). The Brazilian system copied all of the three major offshore oil regulatory systems confirming that operators had an overall responsibility of safety and a responsibility when contractors conducted activities. At least in theory, the Brazilian system copied the Norwegian and partly UK orientation towards performance-based regulations. Like in Norway and Britain, there was a strong focus on the regulations for operators performing risk analyses. Like in Norway, and unlike offshore regulation in the U.S., Brazil's regulations cover issues like the content of management systems, culture, and involvement of workers. However, unlike Norway, there were no strong requirements for oil companies to document all relevant safety data such concrete technical information, as well as more general information like workers involvement and the kinds of safety management system that were in use. This means that when safety personnel in ANP visit installations, they tend to perform inspections focusing on the actual technical equipment rather than the more general form of audits that is typical for the Norwegian system. Likewise, the Brazilian regulation did not have an equivalent to the underlying philosophy in the Norwegian Work Environment Act and the mentioned Norwegian steering regulations where it is made clear that companies in their safety system should focus on robust technological solutions (installations as well as necessary barriers if something goes wrong).

In Brazil trade unions have played a much more important role in the development of the oil sector than in the U.S where unions have been almost non-existent on offshore installations. In Brazil unions have had particularly strong position inside Petrobras (Braathen 2014). But, like in the U.S, unions have been weaker when it comes to offshore activities. This is partly because much of the actual work offshore is performed by contracted firms, like BW Offshore, which operated a field in production for Petrobras. In such companies, unions tend to be weaker. Since the first years under President Vargas in the 1930s, Brazil has had laws that institutionalized trade unions. In the late 1970s trade union mobilization from below also became an important political force in Brazil. But the focus for unions was mainly basic demands like wages, work hours, pensions, etc. When conflicts became political in the oil sector it was issues such as the privatisation of Petrobras and opening for foreign participation that were at the forefront. Brazil did not have any kind of tripartite arenas where workers and employers cooperated on safety issues and other issues relevant to the development of the industry. This was also reflected in ANPs regulations. The paragraphs in the regulations that address work relations are vague. They might as well accept the kind of involvement from workers in behaviour-based safety systems that, up until the Deep Water Horizon accident, had a central place in the U. S. system, as opposed to the more collective cooperation between unions and companies that characterizes the Norwegian system.

An event that typically initiated activities in the abovementioned forums (Regulatory Forum and Safety Forum) in Norway was the Deepwater Horizon accident in 2010. The different forums came forward with proposals for adjustments in safety regulations and technical standards that the system quickly took into account. Many criticised the Brazilian system for not doing the same. This criticism got momentum in the Brazilian public sphere during the blowout on a field operated by Chevron just a few months after the accident in the Gulf of Mexico. Chevron was using a rig owned and operated by Transocean, the very same company that was involved in the accident on the Macondo where BP was the formal operator. As in Norway, technical standards were important when it came to slowing detailed safety issues. However, due to the dominance of foreign companies, it was in praxis the U.S. API-standard that, where in use on the Brazilian continental shelf, did Brazil do any work to develop its own technological standard.

4. GENERAL PRINCIPLES OF REGULATORY REGIMES

A regulatory regime consists of rules and enforcement mechanisms, and includes everything from overall policy to concrete implementation, stakeholders, and agencies at various levels, as well as all formal and informal mechanisms that keep the regime together. A certain amount of stability and durability over time will thus characterize a regime, although dynamic, changing processes and interactions between elements are important topics in regime studies. The persistence of a regime will be continuously tested because stakeholders will try to conquer or gain control over the regime.

A way of describing the legal part of the leeway within a function based regulatory framework is presented in figure 1. The two left columns show the two main categories of rules; legally and non-legal binding norms with examples of sub-categories. The right column shows examples from the Norwegian offshore regime. The Petroleum Act and the Working Environment Act are the laws and the main regulations that form the legal binding rules. Guidelines, etc. from the regulator and recognised industrial standards as well as company- and project specific requirements are the non-legal rules. As a “linking-pin” between the legal and non-legal rules is pasted the legend “Legal standards”. The term is aimed at words or phrases in a law referring to norms or standards that are not defined in the law itself. Such norms are developed within a particular professional community and are following prevalent norms and “best practice” and attitudes in society.

Function-based regulation needs some form of discretionary criteria that are considered as legal standards and provide some special interpretation challenges. The term "legal standard” refers to words or phrases in a law claim that stipulates a scale or norm beyond the law, i.e., a particular practice, widespread attitudes in the community, professional standards, etc. Since these conditions and phenomena change over time, the content of the legal requirement embedded in the law will similarly change over time. The underlying measure of the legal standards is based on the issues, terminology, and solutions that are understood in the professional and scientific community. Through stakeholder involvement in the process of developing these norms, the use of legal standards may enjoy greater legitimacy than rules based on legal terminology and legal text. The use of legal standards aims to achieve an appropriate regulation of complex fields in constant development. It can also be seen as an expression of respect for the importance of expert knowledge to ensure the safety and quality in key areas of society. Legal standards probably safeguard the goal of combining flexibility, innovation, and technological development with safety and quality better than prescriptive rules fully formulated in laws and regulations.

Table 1. *Hierarchy of norms with legal standard as "linking-pin"*

Hierarchy of norms	Main group	Examples from Norwegian offshore regime	Examples from Brazilian offshore regime
Legally binding norms	Laws	Petroleum Act, Working Environment Act	Law 9,478 from 1997
Legal standards	By-laws (regulation)	The Framework Regulation (Royal Decree) Regulations regarding (1) Management, Activity, (2) Information and (3) Installation passed by the Petroleum Safety Authority (PSA)	Resolution No 43, 6th December 2007.
Non-legal binding norms	Regulatory guidelines	Guidelines to the regulation, Letters of interpretation	
	Industrial standards "Best Practice"	Specific standards developed on the NCS (NORSOK), Recognized global or regional industry standards (ISO), company specific requirements and guidelines, project specific requirements and specifications, etc.	Specific standards, developed by Petrobras in cooperation with mainly foreign supplier (often copy of U.S. API-standard) Petrobras specific contracts requirements.

As shown in table 1, there is an important distinction between legally binding norms, i.e., laws, regulations, and decisions, and norms that are not legally binding. Non-legally binding standards are guides to laws and regulations, measures that are not statutory, and industry norms and standards of various kinds. Maintaining authority through governmental actors such as PSA implies it is exercising its legitimate power through legally binding rules and following up with sanctions. Strong governmental agents can exercise power by binding up companies and suppliers and thereby reducing the scope that occurs in the space of legal standards. In the Norwegian safety regime, there has traditionally been an established balance of power and trust. The way this is done has great significance for how risk is managed, safety is maintained, and how development and change occur.

A consistent application of a function-based regulation requires a comprehensive and systematic review as to how the various provisions are to be understood and how the appropriate standards should be used to meet the requirements. Procedures must provide relationships between laws and regulations and technical/professional standards to comply with the laws and predictability in relation to supervisors' evaluations. For the regulatory authorities and inspectors this can be a demanding and comprehensive system to keep up to date, and it requires that the standards keep pace with developments and new knowledge. Comprehensive guidelines may also be an excuse for companies to not take responsibility in monitoring and implementing newly recognized expertise and scientific knowledge.

5. DISCUSSION

In a long historical perspective, given the extreme expansion under extreme circumstances, the Brazilian oil sector has gone through since the early 2000s, one might have expected even more serious accidents on the Brazilian continental shelf. In 2014 the ANP was responsible for regulating around 70 drilling rigs, 140 production units, and 300 different types of vessels, from simple to very advanced supply and service vessels. The Brazilian offshore oil activities surpassed the Norwegian continental shelf both yearly production and activities measured in number of workers. Both the number of fatalities and serious incidents show that there were elements in the safety system that worked less efficiently than the safety system in Norway. Hence, even if the Brazilian oil sector was living through a challenging phase, there was a problem that needed to be fixed.

5.1 Norway and Brazil: nationals and foreigners

When the Norwegian regulators gradually built up their competence and authority vis a vis the oil industry, the general understanding was that foreign oil companies, which at the time dominated as operators, did not take safety issues serious enough. Hence, when the authorities introduced strict regulations, there was an element of nationalism. The regulator could always count on significant support from both politicians and civil society in general when the "foreign" industry was to be confronted. Under such circumstances, Norwegian oil companies that were struggling to take over as the dominant operators made an effort to present themselves as particularly concerned about safety. Foreign companies that wanted to keep their position had to do the same.

In Brazil the foreign–national dichotomy has been a central theme in relations to oil policies. However, for the regulatory institution ANP the dominant counterpart when struggling to establish real authority was the local, national oil company Petrobras. Even in the 2000, after the Brazilian oil sector opened up for foreign oil companies, Petrobras continued to be operator for around 90 per cent of the country's production. In such a context, ANP had a more difficult task in opposing the dominating operator's informal political power than NPD had in Norway towards Statoil.

5.2. Norway and Brazil: companies, workers and public awareness

Different from industrial plants onshore, the actual exploration and production of oil and gas takes place out of the public's sight. This remoteness opens up a possibility for the oil companies to operate partly outside the social structures and formal democratic procedures. Serious events, when covered by media, however, visualise potential risk of the industry. Norway does not seem to be particularly different from Brazil in the sense that that major events in the form of large accident that have become headlines in media have also turned public attention to what is going on offshore, and put pressure on the industry to perform better when it comes to safety.

Both Brazil and Norway confirm the general truth in the history of safety that large accidents tend to mobilise the public, actors in the industry and authorities, and initiate changes and improvements. In this sense, the offshore oil sector's major challenge is, paradoxically, that large accident happens too seldom. Offshore oil technology has in the last 40 years been constantly evolving. Safety systems based on the experience of one serious accident might not be of much help when the technology ten years later has changed or is being used in finding and producing petroleum reserves in very different geological formations. A focus on risk analyses that have become important for both the Norwegian and the Brazilian offshore industry have partly compensated for that. However, there might be other circumstances (falling oil prices, less interesting geological prospect, political turmoil etc.) where the element of self-regulation in a performance-based safety system is not working for regulatory authorities who often want to be ahead of developments. The Deepwater Horizon accident proved that a safety indicator like lost time accident is not of much help in indicating where the potential for major accident related to process operation is large (Hopkins 2013, US CSB 2015). In the U.S, after the accident, the new U.S. authority BOMERE, will be maintained with a system relying on government authorities inspecting offshore installations regularly. The Norwegian and the Brazilian systems have to compensate for the fact that many operations will be left to themselves, without government oversight, with the responsibility to uncover where problems might occur. In Norway, unions, safety representatives, and the different parts of the tripartite system have played a very important part. With enforced power from regulations workers' safety representatives are an extended arm of the regulatory authority. In offshore installations in Brazil there are no similar combinations of enforced counter power and corporative cooperation.

5.3 Norway and Brazil: Institutional dependence or independence

It is general accepted that institutional independence is important for both regulatory authorities' credibility and their efficiency. For Brazil, with the government's recent large deficit as a consequence of overinvestment and cost overruns in offshore oil sector, the contradictory role of regulation production and safety in the same institution can seem particularly unfortunate. It is, however, important not to put too much emphasis on formal institutional set ups. The Norwegian experience shows again how the historical context in the form of underlying power relations, subjective factors such as attitude of key personnel in the relevant institutions, and general expectation in the society at any time in history play have great significance. It took some time to educate regulators on the necessary skills to effectively audit and survey the oil industry. In the late 1970s, these regulators confronted the same kind of challenges that Brazil has experienced recently, with large deficits on the state budget and a strong pressure from both companies and interest groups within the state to get production on stream as soon as possible. The major improvements in safety came in the 1980s and 1990s, at a time when state finances was in a much better state. There is no strong indication that the final breakup of the NPD in two separate institutions in 2004 in itself has improved safety. Separation of institutions is no guarantee against the possibility for regulators to relax on strict, costly safety measures in difficult economic periods. Once again the historical context is important: When the NPDs headquarter was placed in the new oil city Stavanger instead of the country's capitol Oslo, it was an important factor in defining the new institution's independence and willingness to confront an industry that essentially was foreign. However, in a situation where activities are reduced, such nearness can create an affiliation to the industry and its workers that can make regulators more cautious in introducing necessary measures that, in worst case scenario, might lead to activities being closed down.

5.4 Norway & Brazil: Governmental legitimacy

A regulatory regime rests on the assumption that the involved parties have a common interest in that the system is maintained and that conflicts of interest that may arise naturally will be solved without exercising power that would threaten the foundation of trust between the involved parties. Hale (2014) emphasizes how relatively few players or agents and a transparent institutional structure makes it easier to establish relationships of trust between the different parties. Institutional transparency refers to one of the basic prerequisites for the regime to work - namely the existence of legitimate arenas for co-operation and negotiations. The basic foundations of the robustness of both the Brazilian and the Norwegian regimes are the abilities to take institutional action, facilitate information exchange and encourage dialogue and negotiation between a limited numbers of participants. In some cases this can lead to constructive cooperation for the development of regulations and meet the requirements of professional anchoring and democracy.

Maintaining authority, e.g., through governmental actors such as PSA, may reduce their vulnerability through an exercise of legitimate power through legally binding rules and following up with sanctions. Strong governmental agents can exercise power by binding up companies and suppliers and thereby reduce the scope that occurs in the space of legal standards. In Norway, the regulatory practices and strategies involve comprehensive, frequent, and multifaceted patterns of interaction between the authorities and the industry (Kringen, 2014a), and the equilibrium of the tripartite process leads to a balance of power within those interactions. However, there have been threats to the equilibrium and disturbance of the balance of power. Different views among employers and unions of the risk level have previously led to union activism and to conciliation by the regulator who restored the balance partly by threatening the employers with a return to prescriptive regulation.

5.5 Norway and Brazil: Technical standards

A final issue, which makes it difficult to assess the Brazilian safety system offshore, is the industry's use of technical standards. Since Brazil, to such large degree, has been relying on the international offshore supply industry, one might expect that actual operations to a large degree have been influenced by the kind of technological solutions and work praxis's the companies have been bringing with them. Hence, safety on the Brazilian continental shelf will be indirectly influenced by safety systems and technical standards developed elsewhere. The

U.S. API standard, which to some degree has been used in Brazil, is considered to be less strict than the Norwegian NORSOK-standard. However, there are also vessels and installation in use in Brazil where Norwegian owners have ordered special equipment constructed in accordance with the NORSOK- standard. One hypothesis is that since these companies are international they will tend to adapt their safety standards to the one of the large offshore markets that have the strictest regulations. In that way, the company will be able to use the same technologies and the same key personnel. This will mean that safety in Brazil can be heavily influenced by standards in Norway, among others. Another hypothesis might be that companies, because of intense competition, will always tend to choose the shortest and the less costly way. To conclude how such concrete, but important issues are influencing the Brazilian safety system, more research is needed.

6. CONCLUSIONS

When Brazil established an independent regulatory institution to oversee oil related activities in 1997, the regulatory approach in the Norwegian offshore oil sector was one of the main models. As opposed to the prescriptive regulatory system in the U.S. and Gulf of Mexico, Brazil chose to rely on the Norwegian/British performance based system. However, important formal, informal, and contexto-related elements of the Norwegian and British system were not implemented into the Brazilian petroleum sector.

The international petroleum industry is experienced in transferring huge packages of technological solutions that are organized into certain type of organisational structures, etc. However, when a national regulation system tries to influence such a dominant technological system, it is not only formal institutional set ups concrete regulations in the form of laws that matter. The actual outcome will, to a large degree, be shaped by the social, cultural, and political relations in the country where the systems meet.

7. REFERENCES

Austerhaug et al (2011) Læring av Gullfaks C. (Learning of Gullfaks C) IRIS report 153.

BP Statistical Review of world energy 2015,

Braathen E.,(2014) “The Pre-Salt of Life? ,Social and political struggles surrounding Brazil’s newfound oil reservoirs”

C.T. da Costa Fraga, F. A. Borges, C Bellot, R. Beltrao, M. I. Assayag, Petroleo Brasilere S. A. (2003) ,”Camps Basin 25 Years of Production ant its Contribution to the Oil Industry. OTC 15219, Houston, Texas May

Det Norske Veritas, Report OLF/NOFO -Summary of differences between offshore drilling regulations in Norway and U.S. Gulf of Mexico. Report No.: 2010-1220. August 2011.

Forskrift for styring i petroleumsvirksomheten (styringsforskriften). Fastsatt av Oljedirektoratet 3. september 2001.

Forskrift for systematisk oppfølging av arbeidsmiljøet i petroleumsvirksomheten (SAM-forskriften). Fastsatt av Oljedirektoratet 8. mars 1995.

Freudenburg, W.R & Gramling R, *Blowout in the Gulf, The BP Oil Spill Disaster and the Future of Energy in America*, London 2011.

Hale, A. (2014). Advancing Robust Regulation: Reflections and Lessons to Be Learned. In Lindøe, P. H., Baram, M. & Renn, O. (Eds.) Risk Governance of Offshore Oil and Gas Operations. New York: Cambridge University Press (pp. 403-424).

Hopkins, Andrew (2012) *Disastrous Decisions: The Human and Organisational Causes of the Gulf of Mexico Blowout.*

International Regulators’ Forum, Offshore Safety (IRF), Country Publication Data. www.irfoffshoresafety.com/conferences.

Kringen, J. (2014). Contested Terrains in Risk Regulation: Legitimacy Challenges in Implementation Processes. In Lindøe, P. H., Baram, M. & Renn, O. (Eds.) Risk Governance of Offshore Oil and Gas Operations. Cambridge University Press

Lindøe, P., Baram M & Renn, O (2014) (eds.) *Risk Governance of Offshore Oil and Gas Operations*, Cambridge 2014.

Lov om arbeidervern og arbeidsmiljø m.v., 4. februar 1977

National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, Deep Water, The Gulf Oil Disaster and the Future of Offshore Drilling. Washington DC 2011,

Oil & Gas Journal, Standardized wellheads proven economical for subsea operations, 05/02 1994

Paterson, J. ”Health and safety at work offshore”, (2000) i James Paterson and Greg Gordon (eds.), *Oil and Gas Law, Current Practice and Emerging Trends.*

Petrobras, P-36 Inquire Commission, Final Report

Petroleumstilsynet, Deepwater Horizon-ulykken, – vurderinger og anbefalinger for norsk oljevirksomhet, Hovedrapport. 2011.

Randall, L. (1993) *The Political Economy of Brazilian Oil,* Praeger, London.

Rausan M. & Øien K., ” Risikoanalyse. Tilbakeblikk og utfordringer.” i Lydersen (red.), 2004,

Ryggvik H. & Smith-Solbakken, Marie.(1997) *Norsk Oljehistorie, Bind 3*

Ryggvik, H. (2000) *Adferd, teknologi og system. En sikkerhetshistorie,* Trondheim.

United States Coast Guard, Report of Investigation into the Circumstances Surrounding Explosion, Fire, Sinking and Loss of Eleven Crew Members Aboard the Mobile Offshore Drilling Unit Deepwater Horizon in the Gulf of Mexico April 20–22, 2010

Vinnem J.E., ”Risk indicators for major hazard on offshore installations”, *Safety Science 95*, 1142–1153

W.P. Maduro, Petrobras, and Jim Reunolds, Smith Intl. Inc. Enchova Blowout: Record Relief Time, SPDE/IADC Drilling Conference 18717. 1989.

Woolfson, C. Foster, J. Beck M. (1997) *Paying for the Piper, Capital and Labor in Britain’s Offshore Oil Industry*, London

A sociotechnical perspective on risk regulation and tripartite system in the Norwegian petroleum industry

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Abstract
This paper applies a sociotechnical perspective on tripartite collaboration in the Norwegian petroleum industry by highlighting developments and challenges related to the regulation of risk and issues of power and trust. The paper is based on findings from the ongoing projects “SAF€RA STARS - Socio Technical Safety Assessment within Risk Regulation Regimes”, and “Robust Regulatory Regimes. Defences against Major Accidents” (Funded by SAF€RA and NRC-Norwegian Research Council). During nearly 45 years of oil and gas production, the Norwegian petroleum industry has established a risk regulation regime following the Nordic welfare model of a tripartite system of collaboration, egalitarian values, and mutual trust among the main actors. Through close interactions between the Norwegian government, the oil companies, the supplier industry, and the labour unions, the shaping of the regulatory framework has been characterised by shifting alliances, power relations, trust, and distrust. Focusing events (such as accidents and near misses) have created arenas for policy change, but have also influenced the relationships between the involved actors and created institutional settings for risk and safety regulation. From a sociotechnical perspective, risk regulation of the petroleum industry consists not only of rules and enforcement mechanisms, but also of the institutional environment from overall policy to concrete implementation. This provides a wider picture of how to develop and enforce safety for high-risk technological systems, which includes relations between stakeholders and agencies at various levels, as well as the institutional and organisational structures and processes that keep the regime together.

Keywords: power; trust; safety; institutional structures; focusing events

1. INTRODUCTION

European and U.S. risk-regulating regimes are commonly characterised by a command-and-control structure, where a top-down approach foresees that high-risk industries (the regulated) comply with the rules set down by the regulator. Rules are reinforced by legal sanctions in case of non-compliance. Norway, on the other hand, has developed a different regulatory structure for its petroleum industry that mirrors the Nordic welfare state model. The Norwegian risk-regulating regime promotes a symmetrical partnership between public agencies and industrial actors, which involves labour unions (the so-called tripartite regulatory system), in parallel with the asymmetric role of sanctioning the industry for law violations. Principles of enforced self-regulation (functional regulations) are followed, thereby relying on the capability of the industry to manage its own risks according to accepted norms and standards. Thanks to this tripartite regulatory system’s long-lasting cooperation in monitoring risk and improving safety and reliability, the Norwegian petroleum industry has been characterised by a certain amount of stability and durability. However, such processes are vulnerable due to the comprehensive, frequent, and multifaceted patterns of interaction among government, operators/suppliers, and labour unions. Functional risk regulation requires a balance of power and mutual trust among the intervening actors, which sometimes becomes challenging during periods of technological innovation and organisational changes that impact safety.
Applying a sociotechnical approach to risk regulation within the Norwegian petroleum industry, we analyse the extent of different views on risk among the Norwegian government, petroleum operators/suppliers, and labour unions, whether this differentiation may jeopardize the foundations of the tripartite regulatory system, and implications for safety.
The aim of the paper is threefold:

1. What characterises the development and challenges of the risk regulatory regime and tripartite system within the sociotechnical framework of the Norwegian petroleum industry?
2. How are focusing events influencing and challenging the sociotechnical character of the Norwegian petroleum risk regulation regime?
3. How are issues of power and trust affecting the sociotechnical character of the Norwegian petroleum industry?

The remainder of the paper will elaborate on these issues. First, we will outline the sociotechnical-systems approach, including important concepts, and the sociotechnical framework of "the Nordic Model". We will then discuss the development and challenges of the Norwegian tripartite regulatory system, focusing events that have influenced and challenged the sociotechnical character of the Norwegian petroleum risk regime, and the important issues of power and trust. Finally, we outline how the use of a sociotechnical approach can provide a wider picture of how to develop and enforce safety in high-risk industries. The paper is based on findings from the ongoing projects "SAF€RA STARS - Socio Technical Safety Assessment within Risk Regulation Regimes", and "Robust Regulatory Regimes. Defences against Major Accidents" (Funded by SAF€RA and NRC-Norwegian Research Council).

2. SOCIOTECHNICAL SYSTEMS APPROACH

In this section, we will briefly describe the evolution of the concept "sociotechnical system". According to Davis et al. (2014), sociotechnical-systems thinking grew out of work conducted at the U.K. Tavistock Institute of Human Relations (Trist and Bamforth, 1951; Emery and Trist, 1960; Trist et al., 1963; Trist, 1981). Researchers at the Institute reflected on the importance of adding to the technical framework of production, the so-called human factor inside a work system (industry or organisation). The idea of sociotechnical system was designed to cope with the theoretical and practical problems of working conditions in industry, in particular the introduction of new machines into coalmines. The researchers argued that technology could not be an independent and autonomous variable since it is strictly related to and influenced by social aspects, such as human working conditions, and political and economic structures. Thus, the sociotechnical term was coined to describe the reciprocal interrelations between technology and humans. The term "system" was taken from general systems theory, which describes a system as a set of elements related to each other, with functions that transform the system over time. These studies were the foundation for the sociotechnical systems theory (van Eijnatten, 1997), and sought to overcome the challenge of analysing elements of a system separately by embracing its complexity and interdependencies between the technical (hard or structural) and the social (behavioural) aspects. Furthermore, they sought to explain the changes of the workplace in terms of ways of organising work, technology and practices (Davis et al., 2014; Klein, 2014).

Several disciplines (sociology, psychology, engineering, cognitive engineering, ergonomics, management, and political sciences) have enriched sociotechnical systems research, and over the years researchers have formulated different models in order to develop a unifying concept of a "sociotechnical system", e.g., Smith and Carayon-Sainfort's work system model (1989), Rasmussen's vertical model (1997), and Wilson's model of interactions (2000). In the 1970s, the notion of "high-risk" (or "safety critical") systems were grouped into an independent category that included industries such as nuclear, aviation, marine, and petroleum (Le Coze, 2013). The notion of a sociotechnical system has been successfully applied in order to understand risks, disasters, and the prevention of accidents in complex technological systems (Nævestad, 2009). Furthermore, disaster research has shown how risks and disasters derive from interactions in interrelated technical and social elements of technological systems (Turner and Pidgeon, 1997). This is an argument for understanding safety in relation to social relations, processes, and structures (or networks) where the system plays a role in generating trust and discouraging misconduct (Granovetter, 1985; Vaughan, 1999), but also where political, regulatory, and power issues can contribute to system failures (Sagan, 1993, 1994; Perrow, 1999). According to Vaughan (1999), it is important to link an organisation's environment (political, economic, legal, demographic, and cultural dimensions), to the organisational characteristics (structure, e.g. centralisation/decentralisation; processes, e.g. power plays, feedback loops; tasks, e.g. routines and interface with technology) and individuals (cognitive practices, influence of social context on choice). Based on this perspective, safety is the result of implementation of functions to be understood through technological designs and tasks, as well as structural features of organisations and cognitive, cultural, and power issues at several nested layers of analysis (micro-meso-macro) (Le Coze, 2013).

Power is an important concept in a sociotechnical view on risk and safety. A definition of power is “a persons’ ability to achieve his/her will, despite resistance from others”. Moreover, power and trust are interrelated concepts. Trust can be considered as a contrast to power, meaning that those who receive trust can act in a way that is not in accordance with the trust-giver’s will and interests (Grimen, 2009). One who has trust is empowered, and giving trust implies a transfer of power from the trust-giver to the trusted. Consequently, an analysis of trust in a system where actors relate to each other automatically implies that the power relations must be an integrated part of the discussion.

3. THE SOCIOTECHNICAL FRAMEWORK OF THE NORDIC MODEL – GOVERNANCE, INSTITUTIONS AND PRACTICES

“The Nordic model” refers to institutional frameworks that organise and regulate negotiations, wealth distribution, and conflict resolution in the Nordic countries. In terms of regulation, the Nordic model involves a high degree of formalized industrial relations. This implies a centralised organisational structure, and, at the same time, a trinity of cooperation among employers, employees, and the government concerning economic policy, exchange of information, and consultations at different levels of the industries. This institutional integration has supported a national system, organising the collective negotiations between employers and employees. Moreover, it has contributed to the institutionalisation of petroleum companies according to the formal and informal rules of the Norwegian institutional setting.

In terms of safety, the Nordic model is embodied in the tripartite collaboration. A common feature within the tripartite system is the in-house use of an “Occupational Health and Safety Organisation” that offers three different collaborating structures. First, Safety Committees provide opportunities for employers and employees to meet and discuss important issues. Second, there are independent and autonomous “institutions”, as Safety Representatives, and third, there are a number of experts on occupational health and safety who may be called upon in disputes, either as an in-house service or external consulting expertise. Hence, safety and optimal working environment is one of the cornerstones of the model.

No-blaming regulatory cultures appear to correspond well with these contextual factors. Key features of the Nordic welfare model are also reflected in the health and safety regulations. The Norwegian petroleum industry covers a complex group of actors, technologies, and natural resources. Risks range from minor injuries, to long-term health impairments, to major accidents. Responsibilities are distributed at all levels in the industrial value chain (Kringen, 2014). According to Engen (2014), in the context of the sociotechnical system of the Norwegian petroleum industry, institutional aspects of technology and the Nordic model can be expressed through the following figure (Figure 1).

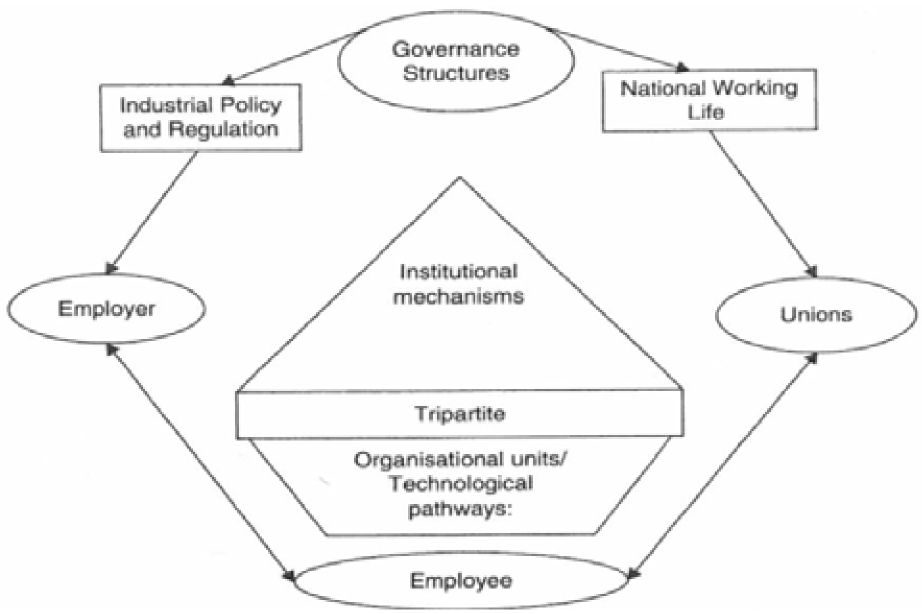

Figure 1 – The sociotechnical system of the Norwegian petroleum industry.

This figure conveys a broad institutional perspective on industrial policy, regulation, working life, and technological pathways. The integrated organisational unit – department, installation, plant, and the like – follows traditional sociotechnical models of risk regulation wherein organisational units combine the technical production system with a safety management system (Olsen and Lindøe, 2009). The diamond-like figure in the middle illustrates feedbacks where information and effects from industrial policy and risk regulation are handled through a complex set of institutional mechanisms. These institutional mechanisms consist of actors, i.e. companies, labour unions, employers' associations, and governmental organisations, and are constituted by their mutual relationships (Engen, 2014).

4. THE REGULATORY REGIME AND TRIPARTITE SYSTEM OF THE NORWEGIAN PETROLEUM INDUSTRY – DEVELOPMENT AND CHALLENGES

The first aim of this paper is to describe and discuss the development and challenges of the risk regulatory regime and tripartite system within the sociotechnical framework of the Norwegian petroleum industry.

The sociotechnical systems approach provides a framework for analysing the linkages and relationships between different social and technical aspects. The potential value of applying such an approach is that it provides a structured and systematic way of analysing a variety of complex systems, problems, and events (Davis et al., 2014). As mentioned in the previous section, the working regulation in the Nordic countries is characterised by a trinity of cooperation among employers, employees, and the government concerning economic policy, exchange of information, and consultations at different levels of industries, i.e. a tripartite system. The institutional strength of the tripartite system for the Norwegian offshore petroleum industry was fortified in 1977 when the working conditions offshore were subjected to the same legal framework as the working conditions onshore. The Working Environment Act of 1977 gave employees in Norway extended privileges in general, and became a powerful instrument for offshore workers in terms of influencing safety and security regulations. A safety deputy, for instance, had the same power as the platform manager to stop the production stream if there was any suspicion of technical or organisational irregularities that could increase the risk of undesirable incidents.

Lindøe (1992) states that the introduction of the "internal control-system" in the 1980s, which was based on the philosophy of enforced self-regulation and goal-setting (function-based) legislation, strengthened the robustness of the Norwegian regulatory system. When self-regulation is used to assure safety, enterprises are obliged to identify and assess risks and hazards embedded in their operations (Lindøe et al., 2006). Internal control gives companies a personal responsibility to monitor and implement an updated safety management system. Organisations have an incentive to comply with principles of internal control because the regulatory process can focus on desired outcomes, rather than regulating detailed processes, with regulatory intervention as a last resort. In cases of breach or dissatisfaction, the regulatory body can escalate its enforcement process with more serious consequences for the regulated organisation. Some regulatory systems are linked to licensing privileges (including the regulatory system for the Norwegian Petroleum activities) where a license to trade or conduct an activity is conditional on compliance with formal or procedural norms such as having "effective" internal control. The sanction of withdrawing a license is usually a last resort and an outcome of extensive prior negotiation (Power, 2007).

The introduction of the internal control regulations has partly been a response to the complex and dynamic nature of the petroleum industry. The traditional model of regulation from above, through specified command and control rules, has been challenged in several ways. Prescriptive rules proved difficult in terms of keeping up with the dynamic technological developments and the complexity of hazards and their causes. The traditional regulations did not sufficient address risks related to long-term exposures, combined effects of several hazards, psychosocial strain, etc. In the Norwegian petroleum industry, the tripartite system is clearly expressed in the formal institutions facilitated by the Norwegian Petroleum Safety Authority (PSA), i.e. the Regulatory Forum and the Safety Forum, which are forums for discussing overall priorities and critical issues, and developing regulations, as well as more specific and practical questions (Kringen, 2014b). These institutions formalise the partnership between public agencies and industrial actors (Lindøe et al., 2011, Lindøe et al., 2014), and thus constitute an important formal part of the sociotechnical structure of the petroleum system.

The experience gained through the last few decades indicates that the adoption of internal control as the principle for risk regulation of the Norwegian petroleum industry is regarded as a success because it permits more flexible and efficient regulatory supervision. However, this regulatory approach also creates challenges. The function-based regulatory regime creates a hierarchy of overlapping norms, which has developed into a complex system of rules and regulations, legal standards, industrial standards, internal company standards, as well as codified “best practices”. This array of documentation (for companies) is further challenging aspects of the robustness of the Norwegian regime. To master such complexity requires knowledge and skills, and therefore gives power to those who possess this knowledge and skill, i.e. those handling and navigating in the system. For those firms who do not handle complexity, this can easily develop into distrust towards those who possess knowledge. Complexity thus creates an imbalance between power and confidence, as those with competence get increased power, while those who lack knowledge may respond with distrust. Such a disparity can further develop where there is a significant scope in which to apply industry standards or other "best practices". Labour unions in Norway are experiencing an increasing lack of knowledge while, at the same time, a reduction in their confidence in the function-based system (Engen et al., 2013).

Regulatory requirements for internal control represent an indirect form of government where results ultimately may be produced by the companies instead of the government itself, and where the companies are held accountable. These outcomes create challenges for the regulator. The regulator may choose between different roles or strategies, and thereby be exposed to different expectations from the companies. Such mix of roles induces an important challenge of the function-based legislation, which is reflected in what we might describe as the inspector's dilemma. The Engen-report from 2013 (Engen et al., 2013), states that the actors of the Norwegian petroleum industry respond positively to a regulatory regime based on functional requirements. However, the regulatory regime of the Norwegian petroleum industry was developed under circumstances very different from the ones we have today. In the 1970s, oil companies were competing to get a foothold in this new, promising region. The general political trends pointed towards protectionism and as much national influence as possible (Ryggvik, 2000). According to Hale and Baram (1998), the new era of free trade and globalization causes constant reorganising and change for companies trying to seize opportunities and to reduce costs and increase competitiveness. As an example, the Norwegian petroleum industry went through major changes of reorganising, downsizing, and merges during the late 1990s, which, according to some, affected the safety level of the industry (Ryggvik, 2000).

Thus, even though the safety regime for the Norwegian petroleum industry has been in the forefront in developing purpose- and goal-based regulations, the change from a prescriptive regime to more functional regulation in the Norwegian petroleum industry has been demanding on everyone concerned. The regime rests on the assumption that the involved parties have a common interest in maintaining the system, and that the conflicts of interest that may arise will naturally be solved without threatening the foundation of the trust between the involved parties. How much power each of the involved agents actually will possess will vary depending both on their perception of the risk and on the character of the event. The Norwegian regulatory regime opens up for politicisation of the safety field and it becomes a political “battlefield”. This happens when different groups have different interests in the field and the groups have the formal power to protect their interests and use this power directly in the decision-making processes. The leeway of function-based regulatory regimes creates a space where the relationships between the actors are characterised by struggle and bargaining - conflicts and co-operations, and thus continuously exposed to politicisation (Rosness and Forseth, 2014).

Such politicisation is not a problem in itself, but may affect the robustness of the regime, for example where such processes end up questioning the legitimacy of governmental agents, such as the PSA. Politicisation may, in other words disturb, trust and power relations. Politicisation of the Nordic model is thus problematic because decisions may be made on the basis of "random" policy, and may encourage intervention without clear theoretical or normative grounds. According to Engen et al. (2013), the strength of the tripartite regulatory system is that collaboration is a very potent instrument when it is necessary to change the sociotechnical system. At the same time, collaboration will be undermined if the balance of power is upset or certain actors dominate the process and gain power at the expense of other actors.

5. FOCUSING EVENTS

The second aim of this paper is to discuss how focusing events are influencing and challenging the sociotechnical character of the Norwegian petroleum risk regulation regime. Risk regulation and inspection strategies emerge from different sources. Some are global trends while others are results of disasters or major industrial accidents within hazardous industries. Such events mobilise public opinion, environmental organisations and politicians, and initiate legislative processes with new regulations being implemented at different institutional levels: globally, nationally, and within industrial sectors (Slovic, 2000)

The Alexander L. Kielland accident in 1980 induced an overall goal of simplifying and enhancing the efficiency of risk regulation on the Norwegian Continental Shelf (NCS). The accident underlined the importance of being able to establish and maintain a high level of safety with clear regulatory boundaries. Hence, the regulatory regime that was established consisted of two elements: A single agency, at that time the Norwegian Petroleum Directorate (NPD), was assigned responsibility to draw up detailed regulations and to make overall safety and working environment assessments. Formal agreements with the pollution control authorities for the natural environment and with the health authorities for health-related issues were also negotiated and implemented. Coordination and support between many different governmental agencies represented a new approach to administration and differed from the common model, which implied that single agencies were responsible for their individual aspects of safety and working environment.

This coordination of supervision gradually revealed the need for developing a joint set of regulations based on a number of overall considerations, including safety and the working environment, the natural environment, and occupational health. The industry's response was not only that the reform represented a clear simplification and efficiency enhancement, but the more integrated health, safety, and environment (HSE) regulations also made it possible, and stimulated to a greater degree, participation and collaboration in influencing risk regulation in general. The regulator could now supervise the business on a more unified basis. However, the challenge became to handle collaboration issues and possible conflict of interests across government agencies through formal procedures and agreements in order to ensure that the system functioned well in practice.

However, the regulatory regime established after Alexander Kielland was challenged from many directions. In 1993, a Norwegian cost-efficient program was introduced denoted NORSOK (an abbreviation for "NORsk SOkkels Konkurranseposisjon", in English "The competitive situation of the Norwegian Shelf). NORSOK represented a break with the infant industry policy of the 1970s and 1980s, and a political shift from an active and interventionist oil policy to a more passive one that sought to link various actors rather than dictating terms to them. NORSOK introduced a process that allowed both the petroleum companies and main suppliers to enjoy greater freedom when choosing technological concepts, sub-suppliers, location of bases, headquarters, etc.

The incidents and number of accidents, however, increased during the 1990s. In the 1990s several trends in the risk picture could be identified: First, an increase in major hazards related to problems with gas leakage, and second, increased risk and uncertainty regarding the safety level for floating installations. This was mainly related to new technology. The Norne accident in 1998, a helicopter accident at the Norne field in the Northern part of the North Sea, clearly illustrated the high-risk arena of shuttle traffic by helicopters. There were also increased accidents related to the activities of service vessels and increased vulnerability caused by increased use of ICT systems, automation, and reduced manning on the installations (Engen, 2014).

New contractual relations implied that the oil companies became less responsible for design and accomplishments of the development projects, and less responsible for general HSE. The increased economic pressure combined with lack of knowledge and experiences in risk and safety management created new vulnerabilities and reduced robustness in the sociotechnical system. This put pressure on the glue that characterised the governance structure and institutional mechanism of the Nordic model. During the first decade after the millennium, there was only one substantial incident on the NCS, namely the Snorre A incident. Snorre A is a floating installation in the north of the North Sea and operated by Statoil. In 2004, a gas leakage was discovered and the platform was evacuated. The investigation report showed afterwards that it was only a minute away from igniting and causing a very serious accident. The Snorre A incident created a lot of attention in the media, but there was no serious debate about whether the ground principles in the Norwegian regulation model should change. Statoil was, however, challenged, both from the PSA and the unions, to improve their procedures concerning compliance and learning. Several internal organisational programs where introduced, but these programs were, to a certain degree, overshadowed by the merger between the two biggest Norwegian oil companies, Statoil and Hydro Oil & Gas, in 2007.

The next focusing event took place between December 2009 and May 2010, when the Gullfaks C field, operated by Statoil, was subjected to several critical incidents with leakages of hydrocarbons from wells. The investigation showed that at least one of the incidents was only minutes away from becoming a full-scale disaster. An independent research institute made an assessment, and the strong Norwegian environmental group, Bellona, used the report as an indication that Norway should adapt EU regulations as soon as possible in order to avoid future major oil pollution. In this case, Bellona proposed a major critique towards not only Statoil, but also towards the PSA and thus the Norwegian regulatory regime in general. The Gullfaks C incident became a focusing event on the NCS that triggered the Norwegian government to start to evaluate the regulatory regime's robustness.

Gullfaks C took place in the international context of Deep Water Horizon, which fortified the incident as a focusing event and created further momentum, media, and NGO pressure, not only in Norway, but also among most European countries. After the Deep Water Horizon disaster, members of the EU Parliament asked how robust the existing risk regulatory approaches for offshore HSE regulation were among the member states. The authorities and industry in Norway and U.K. formed groups to review and assess lessons learned and make necessary recommendations with regard to well control and safe offshore operations. In the U.K., some instances rapidly declared that offshore regulatory standards, as exemplified by the "Safety Case Regime", were superior to those that were found in the Gulf of Mexico at the time of the Deep Water Horizon disaster. Both in the U.K. and in Norway, the reaction towards those who wanted to use the focusing event as an engine for regulatory change was unambiguous; the functionality and robustness of the North Sea regulatory regimes was the best way of organising safety, which implied that redesign towards more standard prescriptive directions was not applicable.

6. THE IMPORTANCE OF POWER AND TRUST IN THE TRIPARTITE RELATIONSHIP

The third aim of the paper is to discuss how issues of power and trust are affecting the sociotechnical character of the Norwegian petroleum industry. As mentioned in section 4, while the tripartite relationship is based on trust between the parties, of equal importance to the tripartite relationship is the balance of power (Engen, 2014). The Nordic model implies strong unions, strong and competent oil companies, and strong competent governmental institutions (Ryggvik, 2014; Lindøe et al., 2012). In order to use the leeway of the function-based risk regulations in a best possible way, the key players have to trust each other. Companies have to trust that employees and contractors will perform work according to agreements. Inspectors must trust that the oil companies have the right quality systems and procedures in place for safe work both in themselves and towards their suppliers. Unions have to trust that the government has established the right kind of supervision and control chains for the companies and suppliers.

As previously mentioned, trust and power are interrelated concepts, and the relevance of a power approach is further enhanced by two empirical characteristics of the petroleum industry. Petroleum is an international industry with large investments, potential gains, and substantial risks, as well as operational and technological challenges. In such settings, conflicts of interest and politicization between those involved can obviously be substantial. At the same time, the institutionalised system of collaboration between employers, unions, and government are vital to the Norwegian regime. Governmental authorities regard these traits as vital in the petroleum industry and they serve as a cornerstone in efforts to establish and develop a high level of safety in the petroleum industry. The challenge within this leeway is, therefore, to strike a balance between giving trust and executing power. The question is whether the leeway is defined too widely, and whether the Norwegian regulatory regime requires more clearly defined and restricted rules and procedures.

Trust means that the people and organisations that interact with each other act in expected ways. Furthermore, to rely on another means that one expects that the person or organisation will, for example, use the functions-based system and framework of norms in a way that is in accordance with the rules and overall objectives. However, displaying trust in others also makes oneself vulnerable in relation to the same "other". The other might act differently than expected and opposite to one's own interests and desires. In this way, there is a vulnerability built into the function-based regime, as a potential risk and thus a threat to the robustness of the system. This also opens up a space where games of power and politicization unfold. The regime rests on the assumption that the involved parties have a common interest in maintaining the system and that the conflicts of interest that may arise naturally will be solved without exercising power, which would threaten the foundation of trust between the involved parties (Hale, 2014). Accordingly, the term "dialogue" is frequently used to encapsulate the relations between the authority and the industry. However, the term is ambiguous as high stakes are involved for the primary duty holders in possibly compromising their reputation, including their attractiveness as (future) licence holders (or contractors) (Kringen, 2014b).

Rosness and Forseth (2014), have denoted the relationships within the sociotechnical system of the Norwegian petroleum regime as a shifting between boxing and dancing. The boxing and dancing metaphor refers to both the vulnerability and to the strength of the Norwegian regime - namely due to the actual existence of legitimate arenas for cooperation and negotiations. The foundation of the robustness of the Norwegian regime is the ability to take institutional action, facilitate information exchange, and encourage dialogue and negotiation between limited numbers of participants. In some cases, this can lead to constructive cooperation for the development of regulations and allow it to meet the requirements of professional anchoring and democracy. However, the coin has two sides. In certain situations, such close and intimate dialogue between opponents may also produce conflicts of interest. Accordingly, we have a regime or institutional framework where the same constellations that make up the strength of the regime also make up its vulnerability. Some political issues can easily undermine the existing trust between the parties and immediately ruin the climate of cooperation. In such contexts, it is a demanding role for the governmental agency to act as a navigator and mediator in the leeway and space of action the function-based regulations create. The ability to handle the role of facilitator is also to determine the degree of the robustness of the regime in general.

Over the last 10 to 15 years, we have seen several examples where the parties have used their power base in a way that has reduced their trust in each other, and in some cases turned into distrust and blocking of the cooperation. As an example, different views among employers and unions of the risk level have previously led to union activism and to conciliation by the regulator who restored the balance partly by threatening the employers with a return to prescriptive regulation. This particular conflict was resolved by initiating the RNNP project (Trends in Risk Level in the Petroleum Activity) in 2001, which brought in independent researchers to study the risks and trends and establish sufficient consensus. Another example is the introduction of the NORSOK programme by the Norwegian government in the 1990s to improve the competitive abilities of the Norwegian petroleum industry. There was a need to encourage implementation of new technology and organisational designs, new contractual arrangements, and improved procedures for accomplishing and launching development projects. However, the NORSOK programme changed the sociotechnical character of the Norwegian petroleum industry by challenging the practices of the Nordic model. The merger of Statoil and Hydro in 2007 also upset the power balance in the tripartite collaboration. The merger increased the domination Statoil possessed over the technological pathways and towards the regulatory authorities concerning risk regulation and safety. These practices survived, however, despite new technological directions and alterations in governance structures and institutional mechanisms. Even though different types of safety regulation systems, new technologies, and economic pressure are continuously challenging the principles of the Nordic model, it seems that the basic principles remain intact. The discussion about the NORSOK programme shows how the explanation lies in the interdependency and balance of power between the parties (Engen, 2014).

Hence, the means to reduce vulnerabilities of fragile trust relationships and/or build robustness is through power relations and the exercise of power. In the Norwegian safety regime, balancing between power and trust is also balancing between functional and prescriptive regulation. The way this is done in the future will have great significance for how risk is managed and robustness is maintained, and for how development and change may occur in the Norwegian petroleum regime.

7. CONCLUSIONS

In this paper, we have applied a sociotechnical perspective on the risk regulation regime and tripartite collaboration of the Norwegian petroleum industry. Sociotechnical theory makes explicit that technology cannot be considered an independent and autonomous variable since it is strictly related to and influenced by social aspects, such as human working conditions and political and economic structures. From a sociotechnical perspective, risk regulation of high-risk technological systems such as the Norwegian petroleum industry, consists not only of rules and enforcement mechanisms, but also of the institutional environment from overall policy to concrete implementation. We have highlighted developments and challenges related to regulation of risk in the sociotechnical system and issues of power and trust. We have also shown that different focusing events (accidents and near misses) have influenced and challenged the sociotechnical character of the Norwegian petroleum risk regulation regime.

Furthermore, we have discussed the extent of different views concerning risk among the Norwegian government, petroleum operators/suppliers, and labour unions, and whether this differentiation may jeopardize the foundations of the tripartite regulatory system, and its implications for safety.

The function-based character of the risk regulatory regime and tripartite system of the Norwegian petroleum industry guarantees a large degree of autonomy for employers and companies, which they can use to design their safety practices in directions they feel appropriate. Such autonomy can be advantageous for employers in several ways, not least financially. Similarly, the employee side has vested interests in the regime since it gives them relatively large possibilities of influence. Such influence is provided through the formal forums for collaboration that have been established through the Nordic Model. Thus, the Norwegian regime has given employees more power than other regulatory regimes. However, the various groups' use of force to protect their interests in the safety field represents a type of politics that can be challenging for the regime because it can weaken its academic integrity, among other reasons.

At any time the challenge within the leeway of the function-based regulatory system is to balance between giving trust and executing power. Conflicts between parties in the Norwegian tripartite system are solved through extensive laws and systems of agreements. Historically speaking, the Nordic model implied that employers supported unions and their professional activities to a certain degree. Moreover, employers have often been forced to de-emphasise short-term profit goals to advance longer-term managerial objectives. The success of this policy may be explained by the strength of the unions in national and local political processes. From this perspective, we may say that the Nordic model has functioned as a stabilising factor in Norwegian politics and society. In relation to the Norwegian petroleum sector, the Nordic model has formed and shaped the political strategies concerning the balancing of a growing resource economy with other economic sectors, the balancing of a public and private sector, and finally, how to consider challenges created by the fact that petroleum is a non-renewable and exhaustible resource (Engen et al., 2015).

A sociotechnical perspective conveys a broad institutional perspective on industrial policy, regulation, working life, and technological pathways (Olsen and Lindøe, 2009). Information and effects from industrial policy and risk regulation are handled through a complex set of institutional mechanisms. These institutional mechanisms consist of actors, i.e. companies, labour unions, employers' associations, and governmental organisations, and are constituted by their mutual relationships (Engen, 2014). Thus, the use of a sociotechnical approach to risk regulation can provide a greater picture of how to develop and enforce safety in high-risk industries.

8. REFERENCES

Bang, P., & Thuestad, O. (2014). Governmental enforced self regulation. The Norwegian case. In Lindøe P. H., Baram, M., & Renn, O. (Eds.) *Risk Governance of Offshore Oil and Gas Operations*. New York: Cambridge University Press (pp. 243-273).

Davis, M.C., Challenger, R., Jayewardene, D.N.W., & Clegg, C.W. (2014). Advancing socio-technical systems thinking: A call for bravery. *Applied Ergonomics,* 45, 171-180.

Engen, O. A., Hagen, J., Kringen, J., Kaasen, K., Lindøe, P. H., Selnes, P. O., & Vinnem, J. E. (2013). Tilsynsstrategi og HMS-regelverk i norsk petroleumsvirksomhet [The Norwegian safety regime for the petroleum industry], Report, 27 August.

Engen, O. A. (2014). Emergent Risk and New Technologies. In Lindøe, P. H., Baram, M. & Renn, O. (Eds.) *Risk Governance of Offshore Oil and Gas Operations*. New York: Cambridge University Press (pp. 340-359).

Engen, O.A., Gressgård, L.J., Hansen, K., & Lindøe, P., (2015). Tilsyn i Grensesnittene-rammebetingelser som tilnærming i tilsynsarbeidet [Inspections in the intersections-approaching external conditions in the inspections process]. Report for the PSA, Unpublished.

Hale, A. R. & Baram, M. (1998). Safety management: the challenge of change. Oxford: Pergamon.

Emery, F. E. & Trist, E. L. (1960). Socio-technical Systems. In Churchman, C. W. & Verhulst, M. (Eds.) *Management Science, Models and Techniques*, Vol. 2. Pergamon (pp. 83-97).

Granovetter, M. (1985). Economic action and social structure. *American Journal of Sociology,* 91, 481-510.

Hale, A. (2014). Advancing Robust Regulation: Reflections and Lessons to Be Learned. In Lindøe, P. H., Baram, M. & Renn, O. (Eds.) *Risk Governance of Offshore Oil and Gas Operations*. New York: Cambridge University Press (pp. 403-424).

Klein, L. (2014). What do we actually mean by 'sociotechnical'? On values, boundaries and the problems of language. *Applied Ergonomics,* 45, 137-145.

Kringen, J. (2014). Contested Terrains in Risk Regulation: Legitimacy Challenges in Implementation Processes. In Lindøe, P. H., Baram, M. & Renn, O. (Eds.) *Risk Governance of Offshore Oil and Gas Operations*. New York: Cambridge University Press (pp. 274-308).

Kringen, J. (2014b). Liability, blame, and causation in Norwegian risk regulation. *Journal of Risk Research,* 17(6), 765-779.

Le Coze, J.C. (2013). New models for new times. An anti-dualist move. *Safety Science,* 59, 200–218.

Lindøe, P. (1992). Internkontroll: krysspress mellom byråkratisk kontroll og aktiv medvirkning. Institutt for organisasjons- og arbeidslivsfag. Trondheim, Norges Tekniske Høgskole. Dr. ing., PhD thesis.
Lindøe, P. H., Olsen, O. E., & Lie, T. (2006). Systematic Occupational Health and Safety Management in Complex Industrial Settings. *Applied Ergonomics* (CD-ROM), 6. ISSN 0003-6870.
Lindøe, P., Engen, O.A & Olsen, O.E. (2011). Reponses to accidents in different industrial sectors*. Safety Science,* 49, 90-97.
Lindøe, P., Baram, M., & Patterson, J. R. (2012). Risk Regulation – an assessment of US, UK, and Norwegian approaches. Paper presented at ESREL. Helsinki, Finland.
Lindøe, P. H., Baram, M. & Renn, O. (2014). *Risk Governance of Offshore Oil and Gas Operations*. New York: Cambridge University Press.
Nævestad, T.O. (2009). Mapping Research on Culture and Safety in High-Risk Organizations: Arguments for a Sociotechnical Understanding of Safety Culture. *Journal of Contingencies and Crisis Management,* 7(2), 126-136.
Olsen, O. E. & Lindøe, P. (2009). Risk on the ramble: The international transfer of risk and vulnerability. *Safety Science*, 47,743-755.
Perrow, C. (1999). *Normal Accidents*, 2nd ed. Princeton: Princeton University Press.
Power, M. (2007). *Organized Uncertainty: Designing a World of Risk Management*. Oxford: Oxford University Press.
Rasmussen, J. (1997). Risk management in a dynamic society: a modelling problem. *Safety Science,* 27 (2/3), 183–213.
Rossness, R. & Forseth, U. (2014). Boxing and Dancing: Tripartite Collaboration as an Integral part of a Regulatory Regime. In Lindøe, P. H., Baram, M. & Renn, O. (Eds.) *Risk Governance of Offshore Oil and Gas Operations.* New York: Cambridge University Press (pp. 309-339).
Ryggvik, H. (2000). Offshore safety regulations in Norway: From model to system in Erosion. NEW SOLUTIONS: A*. Journal of Environmental and Occupational Health Policy,* 10 (1-2), 67-116.
Ryggvik, H. (2014). Inspections, Independence and Intelligence. In Lindøe, P. H., Baram, M. & Renn, O. (Eds.) *Risk Governance of Offshore Oil and Gas Operations*. New York: Cambridge University Press (pp. 382-402).
Sagan, S. (1993). *The Limits of Safety*. Princeton: Princeton University Press.
Sagan, S. (1994). The perils of proliferation. *International Security,* 18, 66-107.
Slovik, P. (2000). *The perception of risk*. Risk, society, and policy series. London: Earthscan Publications.
Smith, M. J. & Carayon-Sainfort P. (1989). A balance theory of job design for stress reduction. *International Journal Industrial Ergonomics,* 4, 67-79.
Trist, E.L. & Bamforth, K.W. (1951). Some social and psychological consequences of the longwall method of coal-getting: an examination of the psychological situation and defences of a work group in relation to the social structure and technological content of the work system. *Human Relations*, 4(1), 3-38.
Trist, E.L., Higgin, G.W., Murray, H., & Pollock, A.B. (1963). Organizational Choice. London: Tavistock.
Trist, E.L. (1981). The Evolution of Socio Technical Systems. *Occasional Paper*, 2, 1-67. Toronto, ON: Ontario Ministry of Labour.
Turner, B. & Pidgeon, N. (1997). *Man-Made Disasters*. Oxford: Butterworth-Heinemann.
van Eijnatten, F.M. (1997). Development in socio-technical systems design (STSD). In Drenth, P.J.D., Thierry, H., de Wolff, C.J. (Eds.) *Handbook of Work and Organizational Psychology*. Organizational Psychology, Vol. 4. Sussex, UK: Lawrence (pp. 61-88).
Vaughan, D. (1999). The dark side of organizations. Mistake, Misconduct, and Disaster*. Annual Review of Sociology,* 25, 271-305.
Weick, K.E. (2004). Normal Accident Theory as a Frame, Link and Provocation. *Organization and Environment,* 17(1), 27-31.
Wilson, J.R. (2000). Fundamentals of ergonomics in theory and practice. *Applied Ergonomics,* 31(6), 557-567.

An engineering or human approach? A study into employee's perceptions regarding the effectiveness of occupational road safety initiatives

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Abstract
Background and Aims: A range of risk management initiatives are increasingly being introduced in many motorised countries to improve occupational fleet safety, including: driver training, driver monitoring via intelligent transport systems, education and awareness, purchasing safer vehicles, etc. Such interventions often incorporate frameworks aligned with safety culture and climate, in an attempt to maximise safety outcomes. However, considerable variation has been documented with interventions' ability to create lasting behavioural change, and the frequency of application is not always based on scientific evidence regarding effectiveness. While research has shown that community perception of road safety countermeasures do not always align with evidence, employees' perceptions regarding the effectiveness of fleet interventions has been almost entirely overlooked. This is a critical oversight as employees' beliefs and acceptance levels (as well as the perceived organisational commitment to safety) can ultimately influence levels of effectiveness, and this study aimed to examine such perceptions in Australian fleet settings. *Method:* 679 employees sourced from four Australian organisations completed a safety climate questionnaire as well as provided perspectives about the effectiveness of 35 different safety initiatives. These initiatives were based on best practice in industry reports as well as countermeasures that had previously been empirically evaluated in the literature. These included: monitoring driver behaviour, signing commitment cards and encouraging self-monitoring of driving behaviours. *Results:* Countermeasures that were perceived as most effective were a mix of human and engineering-based approaches: (a) purchasing safer vehicles, (b) investigating serious vehicle incidents and (c) practical driver skills training. In contrast, least effective countermeasures were considered to be: (a) signing a promise card, (b) advertising a company's phone number on the back of cars for complaints and compliments and (c) communicating cost benefits of road safety to employees. It is noteworthy that some of these initiatives are regularly implemented. No significant differences in employee perceptions were identified based on age, gender, employees' self-reported crash involvement or employees' self-reported traffic infringement history. Perceptions of safety climate were identified to be "moderate" but were not linked to self-reported crash or traffic infringement history. However, higher levels of safety climate were positively correlated with perceived effectiveness of some interventions. *Conclusion*: Taken together, employees believed occupational road safety risks could best be managed by the employer by implementing a combination of engineering and human resource initiatives to enhance road safety. This paper will further outline the key findings in regards to practice as well as provide direction for future research.

Keywords: Safety culture, climate, occupational road safety, interventions.

1. INTRODUCTION

Compared to general motorists, a relatively small body of research has focused on fleet drivers, particularly individuals who drive company sponsored vehicles (Davey et al 2007; Freeman et al., 2009; Newnam et al., 2002, 2004; Sullman et al., 2002; Xie & Parker, 2002). This may be considered surprising given that professional drivers not only have different driving demands, but they also have higher exposure to risk (Öz, Özkan, & Lajunen, 2010) and are disproportionately represented in crash statistics. In fact, occupational driving crashes are the most common form of injury or death in Australian workplaces (Haworth et al., 2000), with 40% of all worker fatalities over the past 11 years (2003-2013) resulting from vehicle collisions (Safe Work Australia, 2014). This effect is not confined to Australia, but rather, similar findings have been reported in the United Kingdom (Maycock et al., 1996) and in the United States (Bureau of Labor Statistics, 2006). The largest proportion of the research has been directed towards examining fleet drivers' self-reported driving behaviours, which is usually measured via the Driver Behaviour Questionnaire (Reason, et al., 1990). This research has demonstrated that company drivers have a greater risk of accident involvement (Newnam et al., 2002; Sullman et al., 2002), due not only to higher levels of exposure to the road environment, but also as a result of time and scheduling pressures and other distractions (Stradling et al., 2000). This has resulted in a growing view expressed both in industry and the corresponding road safety literature that there is a need to create a proactive "fleet safety culture" that has a strong foundation based on corporate policies, processes and procedures (Darby, Murray & Raeside, 2009).

Interventions
Within Australia, organisational intervention strategies have historically been applied in a "post hoc" manner due to an increase in numbers or severity of work-related vehicle crashes or incidents (Wishart & Davey, 2004). That is, most organisational intervention strategies have historically been implemented in reaction to an increase in numbers or severity of work-related vehicle crashes or incidents (Wishart & Davey, 2004) and fail to proactively address problems or incidents before they occur. Additionally, organisations have traditionally adopted a "one size fits all" approach to intervention strategies that often involves an overreliance on driver training, generally based on enhancing driver skills and not targeting specific driver behaviours or organisational influences (Davey, Freeman, Wishart & Rowland, 2008). However, some research has been conducted into the effectiveness of fleet interventions, briefly reviewed below.

> Driver Training: The effectiveness of driver training in fleet settings remains relatively unknown, despite it being the most widely implemented fleet intervention (Darby et al., 2009; Haworth et al., 2000). Preliminary research provided limited evidence of effectiveness (Brown et al., 1987) as it has been suggested that the approach focuses too much on skill improvement at the expense of judgement and decision-making (Christie, 2001). Rowland, Wishart and Davey (2005) argued that an emphasis on strategies to improve the driving skills of drivers reinforces the perceptions of organisational management that the driver, more specifically a lack of driver skills and ability, is primarily to "blame" for work-related incidents/crashes. This may in fact not be the case in many incidents. Nevertheless, research on general motorists has demonstrated the approach can improve driving skill if it involves formal instruction and extensive practice (Groeger & Clegg, 2000; Groeger & Brady, 2004).

> Various Organisational Interventions: Advancements in Occupational Health and Safety legislative frameworks have also resulted in an increasing presence of employer obligations in the workplace (Haworth et al., 2000). This has subsequently enhanced the focus on driver safety management approaches (Haworth et al., 2000). Newnam and Watson (2011) categorised these risk management approaches into: (a) crash reporting databases and (b) driver recruitment and training. While the utilisation of crash databases is useful in regards to benchmarking, the approach is often reactive and is of little use to develop proactive interventions (Davey et al., 2008). Driver recruitment processes often involve confirming that the applicant has a valid licence and collecting information about driving history (Newnam & Watson, 2011), which arguably should also be undertaken at on-going intervals throughout an employee's contract.

> Behaviour Modification: The use of incentives has also proven popular within fleet settings, with many of the approaches being modelled off operant conditioning e.g., providing incentives. Some preliminary research has indicated there is merit in the approach for reducing crashes (Gregersen et al., 1996) as well as seat belt usage (Mortimer et al., 1990). Safety awareness programs have also been trialed, and have proven effective but outcome measures are dependent upon self-reported data (Newnam & Watson, 2009).

Organisational fleet safety interventions are not limited to the above approaches. Rather, a range of risk management initiatives have been introduced in many motorised countries (including Australia, New Zealand, the United States of America, Ireland, Sweden and the United Kingdom) that include: management education and awareness; policies relating to the management of journeys, drivers and vehicles; safe vehicle selection and maintenance; driver training; driver monitoring; awareness campaigns; risk assessments; post-incident investigations; assessments of health and fitness to operate vehicles; conferences, seminars and workshops; incident data recording; safe driving awards; group discussions; competency based licence testing; and programs focussing on vehicle maintenance, fatigue management, driving hours, and driver health (Haworth, Greig, & Wishart, 2008; Murray, 2007). Banks, Davey, Biggs and King (2010) conducted a document review of empirical studies pertaining to occupational road safety initiatives. From the 19 initiatives reviewed, only six initiatives were found to be positively associated with occupational road safety both during and after the intervention period (Banks et al., 2012). These were: a pay rise; driver training; group discussions; enlisting employees as community road safety change agents; safety reminders; and group and individual rewards. However, it should be noted that quantifying the level of effectiveness has yet to be undertaken. While others have argued that a holistic approach is necessary. More specifically, this could include the systematic identification and management of the risks associated with fleet drivers, development of appropriate intervention/improvement strategies, and maintaining continuous monitoring and review of the risks (Rowland et al., 2005). Furthermore, it has also been suggested that theoretical development in the work-related driving arena has been limited (and similar to the application of interventions), has been anecdotal and data driven (Newman & Watson, 2011).

Importantly, there is some preliminary evidence that indicates community perception of road safety countermeasures do not align with evidence, but rather, appear to suffer from a misunderstanding of behaviour change principles and crash causation (Watson, 1997). Therefore, there may be a disconnect between perceptions of the effectiveness of fleet interventions (as well as the subsequent implementation of initiatives) and actual empirical evidence regarding the efficacy of countermeasures to improve road safety. Furthermore, while previous research has focused heavily on drivers' perceptions of safety (Wills et al., 2006) as well as self-reported attitudes and behaviours (Wishart et al., 2011), it has generally neglected drivers' perceptions regarding the effectiveness of different fleet interventions. This may prove to be a significant oversight, as research has suggested that employees' beliefs may facilitate or act as a barrier when implementing organisational initiatives (Weiner, Amick, & Lee, 2008). It may yet be proven that individuals are more likely to accept initiatives that they believe will assist them in achieving a goal and to resist initiatives that they believe have limited effectiveness and/or are not appropriate in their organisation (Banks et al., 2010). More broadly, the impact of attitudes on behaviour is well documented within the Theory of Planned Behaviour (Riebl et al., 2015) and the powerful influence of attitudes as well as expectations is no more clearly evidenced than in the placebo effect (Maybeck et al., 2002). Furthermore, positive attitudes towards an initiative have been proven to increase usage (Celebi, 2015) and it may yet be proven that the limited effectiveness of in-vehicle monitoring systems for teenager drivers (Farmer et al., 2010; Lotan & Toledo, 2005) is related to low levels of acceptance.

Safety Culture and Climate

There is some evidence that creating a strong "safety culture" can have a positive effect on improving road safety by reducing fleet collisions (Gregersen et al., 1996; Newman et al., 2004; Wills et al., 2006), although it is also noted that traffic safety culture is a relatively new concept and there is no consensus regarding the nature of the concept nor how it should be defined (Edwards et al., 2014). The concept of safety culture first emerged in the International Nuclear Safety Advisory Group's (INSAG) report on the 1986 Chernobyl nuclear power plant disaster, which indicated that a lack of safety culture contributed to the incident. A complete review into the evolution and development of safety culture is beyond the scope of the current paper (see Guldenmund, 2000; Zohar, 2010), but in its simplest terms, the concept may be defined as "the assembly of underlying assumptions, beliefs, values and attitudes shared by members of an organisation, which interact with an organisation's structures and systems and the broader contextual setting to result in those external, readily-visible, practices that influence safety" (Edwards et al., 2013; p.77). The concept has a lengthy history of application in organisational safety over the past 25 years, but it has only recently emerged in the traffic safety literature (Edwards et al., 2014). Nevertheless, preliminary research has provided positive results regarding the influence of safety culture. For example, Öz et al. (2010) explored the self-reported driving behaviours of 230 male professional drivers and reported those with low work orientation scores (e.g., culture) reported significantly more DBQ related-violations than those with high scores for work orientation.

A further extension of the safety culture concept is that of *safety climate*, which refers to employees' shared perceptions of management's commitment and operations with regards to fleet safety practices, policies and procedures (Banks, Davey & Brownlow 2006; Wills, Watson

& Biggs, 2004). As such, fleet safety climate forms part of the broader concept of safety culture, but focuses primarily on workers' perceptions and thus represents a psychological construct (Wills et al., 2006). Preliminary research has identified a number of general dimensions that may impact fleet safety climate including: management commitment; work demands and pressure; trusting relationships including communication and support; appropriateness of safety rules as well as safety training (Banks, et al., 2006; Wills, et al., 2004; Wills, Watson & Biggs, 2006). In regards to impacts on safety performance, there is some evidence for a relationship between safety climate and safety outcomes in regards to: self-reported current driver behaviour and future driving intentions at work (Wills, Watson & Biggs, 2009); incident rates (Mearns, Whitaker & Flin, 2003); and self-reported safety behaviours and injury outcomes (Huang, Zohar, Robertson, Garabet, Lee & Murphy, 2013). For example, Wills et al. (2009) found that both individual factors (e.g., safety attitudes) and organisational factors (e.g., safety climate perceptions) influenced current driving behaviours as well as future driving intentions. Newnam et al. (2008) also reported that among a sample of fleet drivers, both individual factors and organisational safety values can influence safety outcomes. Despite this research, it has been suggested that few theoretical or conceptual advances have been made within the fleet safety domain (Newnam & Watson, 2011), and research rarely uses such frameworks to explore work-related driving issues. Nevertheless, given the possible links between safety climate and safety outcomes, it is suggested that fleet safety climate may be related to occupational road safety outcomes, and thus worthy of further exploration (Banks, Freeman & Davey, 2014).

Taken together, empirical evidence is lacking into the effectiveness of a range of fleet interventions as well as how theoretical constructs such as safety culture and climate can be combined with organisational initiatives to enhance safety outcomes. Arguably, one of the first steps is to examine employees' perceptions regarding various occupational road safety initiatives and explore what factors influence such perceptions.

2. MATERIALS AND METHOD

A total of 679 employees sourced from four Australian organisations completed an on-line questionnaire. Participation was confidential and anonymous. The organisations included private and public, profit and not-for-profit organisations, and contained either medium or large vehicle fleets. These organisations were responsible for a combined workforce of approximately 42,000 and a combined fleet of approximately 19,000, which operated in both rural and urban environments. A convenience sampling approach was utilised with a minimum of 100 participants being sampled from each of the four organisations. Participants ranged in age from 18 years to 65 years ($\underline{M}$ = 42, $\underline{SD}$ = 11). A relatively even distribution of male (58 percent) and female (42 percent) participants was achieved. All participants reported regularly driving a vehicle for occupational purposes. Crash involvement and demerit point history (e.g., fines) were examined via participants reported frequency of such events over the past 12 months. The largest proportion of the sample had not been involved in a crash (84.5%, n = 574), with 9.6% (n = 65) being involved in one crash and 1.9% (n = 13) being involved in more than one crash. In regards to fines, 87.5% (n = 594) had not received a fine in the last year, while 7.1% (n = 48) received one fine and 1.5% (n = 10) received more than one fine.

A questionnaire was developed that required participants to rate 35 fleet safety-based initiatives in regards to how effective they perceived they would be in improving road safety in their organisation. Initiatives were selected based upon: (a) a review of interventions proposed to be best practice in industry reports (Anderson, Plowman, Leven, & Fraine, 1998; Haworth et al., 2008; Haworth, Tingvall, & Kowadlo, 2000; Health and Safety Executive, 2000; Murray, 2007; Murray, Newnam, Watson, Davey, & Schonfeld, 2003); and (b) initiatives that had been previously empirically evaluated (Banks, Davey, Biggs & King, 2010). Identified initiatives that have been previously researched included: group discussions to identify safety problems and brainstorm solutions (Gregersen et al., 1996), safe driving goal setting, (Ludwig, 2000) signing a promise card commitment to drive safely (Ludwig & Geller, 1991), monitoring driver behaviour with in-car data recorders (Wouters & Bos, 1999), and encouraging self-monitoring of driving behaviour (Olson & Austin, 2000). The questionnaire was piloted with both managers and employees. Participants were required to rate initiatives on a five-point Likert scale ranging from very ineffective to very effective. The descriptions of the initiatives used in the questionnaire can be viewed in the results section in Table 1.

A 36 item fleet safety climate scale developed in previous research (Banks et al., 2006) was also utilised. The items were consistent with existing fleet safety climate measures such as the Safety Climate Questionnaire – Modified for Drivers [SCQ-MD] which has previously been validated with industry samples (Wills et al., 2009). Participants' responses to the items required them to indicate how much they thought the practices applied to their organisation. Items were measured using a five-point scale ranging from one representing never to five representing always. All factors were calculated such that higher scores indicated safer perceptions.

3. RESULTS AND DISCUSSION

3.1 Perceived Effectiveness

Descriptive analysis revealed that the initiatives perceived by employees to be most effective in managing occupational road risks were multifaceted. The top five initiatives were considered to be: (a) making vehicle safety features standard, (b) practical driver training skills, (c) investigation of serious driver vehicle incidents, (d) making cruise control a standard vehicle feature and (e) targeting safety assistance to high risk drivers. As a result, the countermeasures perceived to be most effective were a combination of technology and human factors. However, it is noteworthy that only "making vehicle safety features standard" reached a mean score above 4 indicating consensus that the approach was "effective." Additionally, there has yet to be a cumulative body of evidence that indicates the initiatives (particularly practical driver training skills) actually improves fleet safety. Between groups analysis revealed no significant differences between the three highest ranked items, although a top ranked items (e.g., making vehicles safer) was ranked significantly higher than the fifth ranked item (e.g., targeting safety assistance) $t(679) = 8.19$, $p < .01$. In contrast, the least effective initiatives were considered to be: (a) signing a promise card, (b) advertising company phone numbers on vehicles, (c) consideration of driving competence in staff recruitment, (d) communicating cost benefits of road safety e.g., fuel efficiency, and (e) presenting comparisons of vehicle incident statistics between depots. No significant differences in employee perceptions were identified based on age, affiliated organisation, gender, employees' self-reported crash involvement or employees' self-reported traffic infringement history. The means and standard deviations for all 35 initiatives are presented below in Table 1.

Table 1 - Employee perceptions of initiative effectiveness

Occupational Road Safety Initiative	Mean	SD
Making vehicle safety features standard e.g. passenger airbags	4.02	1.11
Practical driver skills training	3.94	1.25
Investigation of serious vehicle incidents	3.89	1.09
Making cruise control a standard vehicle feature	3.69	1.23
Targeting safety assistance to high risk drivers	3.66	1.14
Marking low visibility walls and objects with hazard colours	3.60	1.21
Recording vehicle incidents and identifying high risk employees and vehicles	3.59	1.16
Assessing competency before being cleared to operate vehicles in difficult areas	3.57	1.22
Medical screening for problems that will affect driving e.g. vision	3.53	1.25
Journey planning to avoid high risk situations e.g. animals at dusk	3.49	1.19
Vehicle inductions for all drivers	3.48	1.22
Awareness communication on work related road risks e.g. emails, posters	3.46	1.01
Employee input in selection of vehicles	3.44	1.27
Individual incentives for safe driving	3.44	1.27
Presenting genuine personal stories about serious crashes in your organisation	3.43	1.19
Making 'lights on' during driving a standard vehicle feature	3.39	1.30
Documenting vehicle maintenance	3.39	1.10
Provision of driver safety information	3.38	1.02
Checking driver's licences are current every 12 months	3.30	1.35
Group incentives for safe driving	3.27	1.21
Individual feedback on driving behaviour	3.27	1.13
Development and promotion of work related road safety policy	3.25	1.01
Including driving behaviour in performance assessments	3.21	1.21

Safe driving goal setting	3.15	1.10
Encouraging self-monitoring of driving behaviour	3.09	1.06
Individual consequences for unsafe driving	3.07	1.03
Making speed-limiters a standard vehicle feature	3.06	1.36
Group discussions to identify safety problems and brainstorm solutions	3.00	1.12
Group feedback on driving behaviour	3.00	1.17
Monitor driver behaviour with in-car data recorders	2.93	1.32
Presenting comparisons of vehicle incident statistics between depots	2.92	1.20
Communicating cost benefits of road safety e.g. fuel efficiency	2.87	1.13
Consideration of driving competency in staff selection process	2.87	1.18
Advertising organisations phone number on vehicles for complaints & compliments	2.81	1.36
Signing a promise card commitment to drive safely	2.37	1.17

3.2 Safety Climate

A factor analysis of the Fleet safety climate scale extracted five factors that were: (a) management commitment; (b) work demands; (c) trust; (d) appropriateness of rules; and (e) communication. The observed reliability coefficients for each of the factors were above the acceptable cut-off level of .70 (De Vaus, 2002). Examples of items loading on each of the factors are provided below.

- Management commitment: “Management are committed to motor vehicle safety” and “Management are committed to driver safety”;
- Work demands: “Safety rules relating to the use of motor vehicles are followed even when a job is rushed” and “Time schedules for completing work projects are realistic”;
- Appropriateness of Rules: “Safety rules relating to the use of motor vehicles are always practical” and “Safety rules relating to the use of motor vehicles can be followed without conflicting with work practices”;
- Trust: “Employees trust management” and “Management trust employees”;
- Communication: “An effective documentation management system ensures the availability of safety procedures relating to the use of motor vehicles” and “safety policies relating to the use of motor vehicles are effectively communicated to workers”

Mean and standard deviation scores were calculated for the overall fleet safety climate questionnaire as well as for each of the five extracted factors. The mean overall fleet safety climate score was 3.33 (SD = 0.67), which on a five point likert scale, suggests a perceived “moderate” level of organisational support for safety. Mean scores remained relatively consistent across the five factors. More specifically, the scores were as follows: Factor One - management commitment (M = 3.47, SD = 0.88); Factor Two - work demands (M = 3.13, SD = 0.89); Factor Three – trusting relationships (M = 3.15, SD = 0.89); Factor Four - appropriateness of rules (M = 3.55, SD = 0.72); and Factor Five - communication (M = 3.27, SD = 0.80).

3.3 Safety Performance

A series of analyses were undertaken to determine the impact of safety climate and perceived initiative effectiveness on driving performance e.g., crashes and fines. In regards to aberrant driving behaviours, no significant differences were identified between crash involvement or incurring fines and self-reported safety climate. This may be considered unsurprising given the small number of employees who reported being involved in a crash or receiving a fine, which may in part be dependent upon the 12 month time period. Pearson’s correlations revealed that higher perceptions of management commitment were positively associated with awareness communication regarding risks (r = .20**), setting a goal of safe driving (r = .21**) and promotion of road safety policy (r = .21**). Higher reports of work demands was positively associated with including driver behaviour in performance assessments (r = .24**) and enforcing individual consequences for unsafe driving (r = .22**). For trusting relationships, communicating the benefits of cost benefits was positively associated with this factor (r = .21**) and signing promise cards (r = .19**). Having appropriate rules was positively correlated with performance assessments (r = .17**) while communication was related to promoting awareness (r = .20**), goal setting (r = 2.23**) and having safety policies (r = .21**). Not surprisingly, higher inter-correlations were identified between the five safety climate factors e.g., communication and management commitment (r = .78**).

4. CONCLUSIONS

This study aimed to examine employees' perceptions regarding various occupational road safety initiatives and determine whether a higher presence of safety climate influenced such perceptions. In regards to perceptions, a range of engineering/technology as well as human factors initiatives were considered moderately effective, such as purchasing safer vehicles, investigating serious vehicle incidents and practical driver skills training. It is noteworthy that research has yet to conclusively determine whether such approaches are in fact effective at improving road safety. More specifically, while utilising safer vehicles and investigating incidents makes intuitive sense, research has yet to demonstrate that increasing driver training skills and targeting safety assistance for high risk drivers actually improves safety outcomes. Of interest is that some of the initiatives that were considered least effective, were countermeasures currently widely undertaken in Australia, such as "advertising company phone numbers on vehicles". Additionally, monitoring driver behaviour with in-car data recorders was considered the sixth least effective initiative, which is surprising given that in-vehicle monitoring systems are: (a) being increasingly embraced within the fleet industry and (b) beginning to produce positive results (Horrey et al., 2012). In regards to the latter, a number of preliminary trials have reported improvements in fleet safety (Toledo & Lotan, 2006) including a reduction in crashes (Lehmann & Cheale, 1998; Musicant et al., 2007; Toledo et al., 2008; Wouters & Bos, 2000). This finding may be explained by the human propensity to display negative attitudes towards interventions they have little exposure to (Aletraris, Shelton, & Roman, 2015). Further research is required into fleet drivers' acceptance of installing technology in vehicles, as research is identifying that user acceptance is a multifaceted concept that can influence program success e.g., Technology Acceptance Model (Regan et al., 2014). The lack of research into user acceptance of in-vehicle systems is a critical oversight given the increasing implementation of the technology in Australia.

In regards to the influence of safety climate on perceptions of initiative effectiveness as well as self-reported aberrant driving behaviours, the findings were mixed. On the one hand, expected correlations were found between factor loadings of safety climate and the perceived effectiveness of initiatives e.g., trusting relationships and communicating cost benefits of safety to employees. On the other hand, a clear link was not identified between safety climate and self-reported crash involvement or incurring fines. This could be due to the small percentage of the sample who were actually involved in such incidents in the 12 months, or the finding could also reflect on-going difficulties conceptualising and operationalising safety culture and climate. While the difficulties associated with measuring the nature and impact of safety culture are well documented in the literature (Edwards et al., 2013; Guldenmund, 2000), the concept is increasingly being utilised to direct the implementation of safety initiatives (Edwards et al., 2013). Finally, further research is needed to determine the organisational processes that both facilitate and maximise a collective motivation to improve safety. Preliminary research has demonstrated that institutional forces can positively influence employees' general perceptions of initiatives in the workplace (Susskind et al., 2014) and employee's perceived effectiveness of interventions actually impacts upon safety outcomes (Matlow et al., 2012). Taken together, continued research to both identify and enhance the processes that increase intervention acceptance and the corresponding effectiveness of actual fleet interventions can only assist in reducing the burden of road crashes. This research has demonstrated that while the relationship between perceived effectiveness of interventions and safety climate is not always clear, workers may be willing to participate in a range of engineering and human-factor initiatives.

5. REFERENCES

Aletraris, L., Shelton, J., & Roman, P. (2015). Counselor attitudes toward contingency management for substance use disorder: effectiveness, acceptability, and endorsement of incentives for treatment attendance and abstinence. *Journal of Substance Abuse Treatment,* available online: http://dx.doi.org/10.1016/j.jsat.2015.04.012

Anderson, W, Plowman, B, Leven, B. & Fraine, G. (1998). *Workplace Fleet Safety System.* Brisbane, Australia: Queensland Transport.

Banks, T., Davey, J., & Biggs, H. (2012). Employee perceptions regarding the effectiveness of occupational road safety initiatives. *In Occupational Safety in Transport Conference,* 20-21 September 2012, Crowne Plaza, Gold Coast, QLD.

Banks, T., Davey, J., Biggs, H. & King, M. (2010). A Review of the Effectiveness of Occupational Road Safety Initiatives. In: Dorn, L. and Matthews, G. and Glendon, I. (eds.) *Driver Behaviour and Training* Vol IV. Ashgate, Farnham, England. Pp. 229-239.

Banks, T., Davey, J., & Brownlow, D. (2006). Driver education and fleet safety climate in an emergency service fleet. *J Occup Health Saf 22* (4), 341-350.

Banks, T., Freeman., J., & Davey, J. (2014). The influence of fleet safety culture on occupational driver behaviours and traffic incidents. *Proceedings of the second Occupation Safety in Transport Conference,* Gold Coast, Australia.

Brown, I., Groeger, J., & Biehl, B. (1987). Is training contributing enough to road safety? In Rothengatter J.A., & de Bruin R.A (Eds) *Road Users and Traffic Safety.* Assen/Maastricht, Van Gorcum, pp. 135-156.

Bureau of Labor Statistics (2006). *Fatal Workplace Injuries in 2006: A Collection of Data and Analysis.* http://www.bls.gov/iif/cfoibulletin2006.htm.

Celebi, S. (2015). How do motives affect attitudes and behaviors toward internet advertising and Facebook advertising. *Computers in Human Behavior, 51*, 312-324.

Christie, R. (2001). *The Effectiveness of Driver Training as a Road Safety Measure: A Review of the Literature.* Royal Automobile Club of Victoria (RACV): Melbourne.

Darby, P., Murray, W., & Raeside, R. (2009). Applying online fleet driver assessment to help identify, target and reduce occupational road safety risks. *Accident Analysis and Prevention, Safety Science, 47,* 436-442.

Davey, J., Wishart, D., Freeman, J., & Watson, B. (2007). An application of the driver behaviour questionnaire in an Australian organisational fleet setting. *Transportation Research Part F*, *10*, 11−21.

Davey, J., Freeman, J., Wishart, D., & Rowland, B. (2008). Developing and implementing fleet safety interventions to reduce harm: where to from here? *Proceedings of the International Symposium on Safety Science and Technology, 24-27,* China.

De Vaus, D. (2002). *Surveys in Social Research.* Crows Nest: Allen Unwin.

Edwards, J. R. D., Davey, J., & Armstrong, K. (2013). Returning to the roots of culture: A review and re-conceptualisation of safety culture. *Safety Science, 55*, 70-80.

Edwards, J., Freeman, J., Soole, D., & Watson, B. (2014). A framework for conceptualising traffic safety culture. *Transportation Research Part F: Traffic Psychology and Behaviour, 26,* 293-302.

Farmer, C., Kirley, B., & McCartt, A. (2010). Effects of in-vehicle monitoring on the driving behavior of teenagers. *Journal of Safety Research, 41,* 39-45.

Freeman, J., Wishart, D., Davey, J., Rowland, B., & Williams, R. (2009). Utilising the driver behaviour questionnaire in an Australian organisational fleet setting: Can it identify risky drivers? *Journal of the Australasian College of Road Safety*, *20*, 38−45.

Gregersen, N., Brehmer, B., & Moren, B. (1996). Road safety improvement in large companies. *Accident Analysis and Prevention, 29,* 745-757.

Groeger, J., & Brady, S. (2004). *Differential Effects of Formal and Informal Driver Training.* Road Research Report, N0.42, London.

Groeger, J., & Clegg, B. (2000). *Practice and Instruction When Learning to Drive.* Road Research Report, No. 14, London.

Guldenmund, F. W. (2000). The nature of safety culture: A review of theory and research. *Safety Science, 34*, 215-257.

Haworth, N., Greig, K. & Wishart, D. (2008). *Improving fleet safety - Current approaches and best practice guidelines*. Sydney, Australia: Austroads.

Haworth, N., Tingvall, V., & Kowadlo, N. (2000). Review of Best Practice Fleet Safety Initiatives in the Corporate and/or Business Environment. Monash University Accident Research Centre, Melbourne.

Health and Safety Executive (2000). *Driving at Work: Managing occupational road safety*. Sudbury, United Kingdom.

Horrey, W., Lesch, M., Dainoff, M., Robertson, M., & Noy, Y. (2012). Ob-board safety monitoring systems for driving: review, knowledge gaps and framework. *Journal of Safety Research, 43,* 49-58.

Huang, Y.H., Zohar, D., Robertson, M.M., Garabet. A., Lee, J. & Murphy, L.A. (2013). Development and validation of safety climate scales for lone workers using truck drivers as exemplar. *Transportation Research Part F, 17,* 5–19.

Lehmann, G., & Cheale, A. (1998). The contribution of onboard recording systems to road safety and accident analysis. *Proceedings of the 16th International Technical Conference on Enhanced Safety to Vehicles, (ESV),* pp 462-466.

Ludwig, T. D. (2000). Intervening to improve the safety of delivery drivers: A systematic behavioral approach. *Journal of Organizational Behavior Management, 19*(4), 1-124.

Ludwig, T. & Geller, E. (1991). Improving the driving practices of pizza deliverers: Response generalization and moderating effects of driving history. *Journal of Applied Behavior Analysis, 24*, 31-34. Matlow, A., Wray, R., & Richardson, S. (2012). Attitudes and *beliefs, not just knowledge, influence the effectiveness of environmental cleaning by environmental service workers. American Journal of Infection Control, 40*(3), 260-262.

Maybeck, H., Silva, A., Brannan, S., Tekell, J., Mahurin, R., McGinnis, S., & Jerabek, P. (2002). The functional neuroanatomy of the placebo effect. *The American Journal of Psychiatry, 159*(5), 728-737.

Maycock, G., Lester, J., & Lockwood, C. (1996). *The Accident Liability of Car Drivers: The Reliability of Self-report Data, TRL Report 219.* Transport Research Laboratory, Crowthorne.

Mearns, K., Whitaker, S. M., & Flin, R. (2003). Safety climate, safety management practice and safety performance in offshore environments. *Safety Science, 41* (8), 641-680.

Mortimer, R., Goldstein, K., Armstrong, R., & Macrina, D. (1990). Effects of incentives and enforcement on the use of seat belts by drivers. *Journal of Safety Research, 21*(1), 25-37.

Murray, W. (2007). Worldwide Occupational Road Safety (WORS) Review Project.

Murray, W., Newnam, S., Watson, B., Davey, J., & Schonfeld, C. (2003). *Evaluating and improving fleet safety in Australia*. Canberra, ACT, Australia: Australian Transport Safety Bureau (ATSB).

Newnam, S., Griffin, M., & Mason, C. (2008). Safety in work vehicles: a multi-level study linking safety values and individual predictors to work-related driving crashes. *Journal of Applied Psychology, 93*(3), 632-644.

Newman, S., & Watson, B. (2009). A participative education program to reduce speeding in a group of work-related drivers. *Proceedings of Australasian Road Safety Research, Policing and Education Conference,* 10-12 November, New South Wales.

Newman, S., & Watson, B. (2011). Work-related driving safety in light vehicles: a review of past research and the development of an intervention framework. *Safety Science, 49,* 369-381.

Newnam, S., Watson, B., & Murray, W. (2002). A comparison of the factors influencing the safety of work-related drivers in work and personal vehicles. *Proceedings of the Road Safety Research, Policing and Education Conference, Adelaide,* [CD-ROM].

Newnam, S., Watson, B., & Murray, W. (2004). Factors predicting intentions to speed in a work and personal vehicle. *Transportation Research Part F, 7*, 287-300.

Olson, R. & Austin, J. (2001). Behavior-based safety and working alone: The effects of a self-monitoring package on the safe performance of bus operators. *Journal of Organizational Behavior Management, 21*(3), 5-43.

Öz, B., Özkan, T., & Lajunen, T. (2010). An investigation of the relationship between organizational climate and professional drivers' driver behaviours. *Safety Science, 48,* 1484-1489.
Reason, J., Manstead, A., Stradling, S., Baxter, J., & Campbell, K. (1990). Errors and violations: a real distinction? *Ergonomics, 33,* 1315-1332.
Regan, M., Horberry, T., & Stevens, A. (2014). *Driver Acceptance of New Technology: Theory, Measurement and Optimisation*. Farnham: Ashgate Publishing Ltd.
Riebl, S., Estabrooks, P., Dunsmore, J., Savla, J., Frisard, M., Dietrich, A., Peng, Y., Zhang, X., & Davy, B. (2015). A systematic literature review and meta-analysis: the theory of planned behavior's application to understand and predict nutrition-related behaviors in youth. *Eating Behaviors, 18,* 160-178.
Rowland, B. D., Wishart, D. E., & Davey, J. D. (2005) Occupational Fleet Safety Research: A Case Study Approach. In *13th Annual Occupational Health and Safety Conference (Visions 2005)*, 27-30 September 2005, Cairns, Qld.
Safe Work Australia (2014). Work-related Traumatic Injury Fatalities Australia 2013. Safe Work Australia: Canberra.
Stradling, S.G., Meadows, M.L., & Beatty, S. (2000). Driving as part of your work may damage your health. In G.B. Crayson (Ed.), *Behavioural research in road safety IX, Crowthorne:* Transport Research Laboratory.
Sullman, M.J., Meadows, M., & Pajo, K.B. (2002). Aberrant driving behaviours amongst New Zealand truck drivers. *Transportation Research Part F, 5,* 217-232.
Suskind, A., Brymer, R., Kim, W., Lee, H., & Way, S. (2014). Attitudes and perceptions toward affirmative action programs: an application of institutional theory. *International Journal of Hospitality Management, 41,* 38-48.
Toledo, T., Lotan, T. (2006). In-vehicle data recorder for evaluation of driving behaviour and safety. *Transportation Research Record,* 1953, 112-119.
Toledo, T., Musicant, O., & Lotan, T. (2008). In-vehicle data recorders for monitoring and feedback on drivers' behaviour. *Transportation Research Part C, 16,* 320-331.
Watson, B.C. (1997). *When common sense just won't do: Misconceptions about changing the behaviour of road users.* In: The 2nd International Conference on Accident Investigation, Reconstruction, Interpretation and the Law, 20-23 October 1997, Brisbane, Queensland.
Weiner, B., Amick, H., & Lee, S. (2008). Conceptualization and Measurement of Organizational Research and Other Fields Readiness for Change: A Review of the Literature in Health Services. *Medical Care Research Review, 65*, 379-436.
Wills, A.R., Watson, B., & Biggs, H.C. (2009). An exploratory investigation into safety climate and work-related driving. Work 32(1), 81-94.
Wills, A.R., Watson, B., & Biggs, H.C. (2004). The relative influence of fleet safety climate on work-related driver safety. *In: Proceedings of the Road Safety Research, Education and Policing Conference,* Perth, Australia.
Wills, A., Watson, B., & Biggs, H. (2006). Comparing safety climate factors as predictors of work-related driving behaviour. *Journal of Safety Research, 37,* 375-383.
Wishart, D. E. & Davey, J. D. (2004). A research based case study approach to the development of fleet safety interventions in large vehicle fleets. In *Safety In Action Conference*, 30 March - 1 April 2004, Melbourne, Victoria.
Wishart, D., Freeman, J., Davey, J., Rowland, B., & Wilson, A. (2011). When non-significance may be significant: lessons learned from a study into the development, implementation and evaluation of a risk assessment tool for fleet settings. In L. Horn (Eds.) *Driver Behaviour and Training, Vol 4. Human Factors in Road and Rail Safety.* Aldershot: Ashgate.
Wouters, P. I., & Bos, J. M. (2000). Traffic accident reduction by monitoring driver behaviour with in-car data recorders. *Accident Analysis and Prevention, 32*(5), 643-650.
Xie, C., & Parker, D. (2002). A social psychological approach to driving violations in two Chinese cities. *Transportation Research Part F, 5,* 293-308.
Zohar, D. (2010). Thirty years of safety climate research: reflections and future directions. *Accident Analysis and Prevention, 42*(5), 1517-1522.

Achieving safety compliance through safety leadership

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Abstract

Safety leadership is asserted to positively influence safety compliance amongst employees. We examine this assertion by conducting a systematic literature review of the available academic literature on safety leadership practices and observed safety outcomes. We identified 22 empirical studies, the majority of which measured leadership through generic scales (MLQ and LMX). Closer scrutiny of the outcome measures suggested that these were mainly aligned to the implementation and operations phases of the safety management systems framework proposed by the British Standards Institution in response to legislation and incorporating HSE guidance. We conclude that safety compliance has been narrowly defined in academic study, and in practice embraces a much wider range of activities. While safety leadership may contribute to successfully achieving these other actions, there is no empirical evidence for this. Moreover, there is considerable critique of transformational and transactional leadership, so that the specification of desired leadership practices is problematic. We propose that a broader conceptualization of safety compliance requires safety leadership to embrace organizational context, which is currently ignored, and suggest that a relational model of leadership adopting the notion of distributed leadership may ensure safety compliance.

Keywords: Leadership; Compliance; Regulated Environments; Self-Regulation

1. INTRODUCTION

Leadership is always exercised within a particular context, and yet it is frequently ignored despite calls for greater attention to be given to the environment within which leadership is enacted (Osborn et al., 2002; Porter and McLaughlin, 2006). Studies of safety leadership also follow to this pattern. For example a recent meta-analysis of safety leadership styles as antecedents of safety behaviours (Clarke, 2013) took no account of context and how this might influence choice of styles or required behaviours. Conchie et al. (2013) noted this lack of research on the impact of context on leadership, using it to justify their study of supervisors' engagement with safety leadership.

In the UK an organization's safety environment is replete with legal requirements, stemming from the Health and Safety at Work Act (1974), safety standards (e.g. BSI, 2004), guidance on safety practices from the Health and Safety Executive (e.g. HSE, 2013) and specific codes of practice. Such safety regulations are an integral component of the external environment and a key aspect of the safety leader's role is to ensure compliance with them. Members of the top management team have a legal responsibility to ensure their organization's safety management systems (broadly defined) are compliant with these regulations. However, the requirements of these systems are extensive ranging from risk assessment and hazard identification to evaluating compliance against organizational policies and practices, and also including training, operational control and emergency preparedness (e.g. BSI, 2007; HSE, 1997). Achieving compliance with all of these different requirements is a challenging task for the safety leader(s). Compliance encompasses much more than the narrow definition of safety compliance provided by Neal et al. (2000, pg. 101), namely "adhering to safety procedures and carrying out work in a safe manner", and regularly rehearsed in subsequent studies of safety leadership. Safety compliance, broadly understood, would require differential leadership responses depending on a combination of the nature and object of the regulation; the role or position of the leader; and the role and position of the employees required to comply; as well as their perception of risk.

The aim of this paper is therefore to explore from within existing academic literature the extent to which safety leadership has ensured compliance with this wider range of safety requirements demanded of organizations. The paper is structured as follows. A literature review considering particular safety leadership styles, the subjective nature of risk and motivations for compliance is followed by a description of the systematic literature review methodology deployed to elicit empirical studies of safety leadership roles and practices. The findings for safety compliance are represented against good practice guidelines for a comprehensive safety management system. These findings together with leadership styles are discussed and an alternative model of safety leadership to ensure compliance based on distributed leadership is proposed.

2. LITERATURE REVIEW

2.1 Safety Leadership

According to the HSE sponsored literature review of effective leadership behaviours for safety (Lekka and Healey, 2012) existing safety leadership research has focused on either transformational-transactional leadership or leader-member exchange (LMX).

Transformational leadership may be defined as "leader behaviours that transform and inspire followers to perform beyond expectations while transcending self-interest for the good of the organization" (Avolio et al., 2009; pg 423). Transformational leadership comprises four leader behaviours (Bass, 1985) namely; idealized influence, inspirational motivation, intellectual stimulation and individual consideration and is characterized by value-based and individualized interaction, which results in better exchange quality and greater concern for welfare (Clarke, 2013). ***Idealized influence*** is based on trust and occurs when leaders demonstrate high standards of moral conduct in their own behaviour, becoming role models for their subordinates. ***Inspirational motivation*** occurs when leaders provide clarity, communicate a positive value-based vision for the future state of the organization and its employees and challenge employees to go beyond their personal interests and focus their attention on the goals of the collective. Leaders exhibit ***intellectual stimulation*** when they encourage employees to share their perspectives on issues, to challenge organizational norms, question assumptions and to think creatively. Leaders draw on a variety of opinions in order to make decisions. Leaders displaying ***individual consideration*** recognize the unique needs and abilities of the followers and by adapting their approach seek to coach or mentor them in order that they might reach their full potential. Each of these four dimensions of transformational leadership has implications for safety leadership (see Kapp, 2012 or Hoffmeister et al., 2014).

In contrast, transactional leadership is based on non-individualized hierarchical relationships and comprises three dimensions (constructive leadership, corrective leadership and laissez-faire leadership) (Zohar, 2002a). ***Constructive leadership*** offers material rewards (e.g. increased salary, promotion, job security) contingent upon satisfactory performance. This requires clear communication between leader and follower. Some understanding of the individual needs and abilities is needed in order to offer motivationally relevant rewards. ***Corrective leadership*** (or active management by exception) monitors individual performance against standards, detecting errors and correcting them. ***Laissez-faire leadership*** (passive management by exceptions) disowns all leadership responsibility and only engages with subordinates in an emergency.

In adopting a transactional leadership style for safety, leaders typically establish appropriate safety goals, monitor performance towards these goals and reward behaviours that sustain or improve safety practices (Kapp, 2012; Zohar 2002a, 2002b). By contrast, leaders adopting a transformational leadership style for safety demonstrate 10 different actions, as outlined in Kelloway et al. (2006). These include: expressing satisfaction when jobs are performed safely; rewarding achievement of safety targets; continuous encouragement for safe working; maintaining a safe working environment; suggesting new ways of working more safely; encouraging employees to openly discuss safety at work; talking about personal value and beliefs in the importance of safety; behaving in a way that demonstrates commitment to safety; spending time to demonstrate how to work safely; and, listening to safety concerns.

LMX focuses on the dyadic social exchange processes between leader and follower, acknowledging that leaders develop different exchange relationships with their followers thereby differentially impacting important leader and member outcomes (Graen and Uhl-Bien, 1995). In dyadic relationships, the early social exchanges (essentially between strangers or acquaintances) which are more 'transactional' in nature, change to become more 'transformational' as the relationship develops into a partnership (Graen and Uhl-Bien, 1995). Thus low LMX relationships align more closely with descriptions of transactional leadership while high LMX relationships align more closely with the descriptions of transformational leadership (Graen and Uhl-Bien, 1995). Leadership occurs when leaders and followers develop effective relationships based on trust, respect and mutual obligations, resulting in mutual and incremental influence to meet shared interests (Uhl-Bien, 2006). Safety studies adopting this perspective (e.g. Hofmann and Morgeson, 1999; Yagil and Luria, 2010) investigated relationship quality using the 7-point LMX scale (Graen and Uhl-Bien, 1995) relying on practices implicit within the scales that constitute trust, respect and obligation. These are giving feedback, problem solving, providing personal support, decision making, providing direction and clarity, which strongly resemble aspects of both transactional and transformational leadership.

While many of these studies explicitly focused on particular relationships and consideration of the specific compliance context, what was required and from whom was often reported in the methods section, how together these influenced the choice of leadership style to ensure safety compliance was not discussed.

2.2 Variation in understanding risk

Krimsky and Golding (1992) drew attention to ontologically different perspectives on risk. The dominant one, adopted typically by safety engineers, is agent-centred and based on "a model of rationality that is fixed and invariant" (Tansley, 2004; pg 18), this renders safety and safety compliance amenable to traditional scientific methods and standards. An alternative draws on structural-cultural approaches that emphasize the contextual, situated and socially-constructed nature of risk, risk perceptions and therefore safety (Tansley, 2004). Hutter (2011, pg 305) acknowledged the "situated and negotiated character of regulatory compliance", so that compliance with what, by whom and for what purpose is not clear cut. Regulation and safety compliance is therefore fraught with dilemmas and conflicts as different groups have different perspectives on what the particular risks are and what is required to mitigate them. Hutter (2011) draws on her earlier investigation of British Rail to note the differences in perspective on risk between senior managers who had learned about risks through reports and safety data, and employees who had little knowledge of risk but understood very well through experience and anecdote the nature of accidents and their causes in their workplace. As a consequence these two groups would have different capabilities and motivations to comply. While board members or senior managers may have engaged with a regulator, middle managers, supervisors and front-line workers are unlikely to have had that experience. Indeed even board members and senior managers may not have met a regulator because most organizations are never inspected (Gray and Silbey, 2011). Knowledge and understanding of safety compliance requirements will therefore vary across the organizational hierarchy, so that who is trying to comply with what and how this is to be achieved cannot be assumed and needs to be made explicit.

2.3 Achieving compliance

Achieving compliance depends not only on knowledge, understanding and skill (Gray and Silbey, 2011) but also on individual motivation (Tyler, 2011), which may be either extrinsic or intrinsic (Ryan and Deci, 2000). Extrinsic motivation to achieve compliance draws on an individual's instrumental concerns and their utility maximization goals, and is often achieved through either fear of punishment or anticipation of reward (Tyler, 2006), which may be tangible, for example financial, or intangible, for example praise. Leadership practices associated with a transactional style typically adopt this 'command-or-control' form of regulation to ensure compliance in general, and safety compliance, defined narrowly as 'adhering to safety procedures and carrying out work in a safe manner, pg. 101' (Neal et al., 2000), in particular. In contrast, self-regulation depends on the internalization of social norms and values which drives individual behaviours (Tyler, 2006). Intrinsic motivation appeals to these norms and values so that the individual desires to conform, or comply, through a sense of obligation or feelings of morality (Tyler, 2006). These can be encouraged and developed by establishing the legitimacy of the rules or the authority figure, where 'legitimacy refers to the judgement that the actions of an entity are desirable, proper or appropriate within some socially constructed system of norms, values, beliefs and definition' (Suchman, 1995; pg. 574). A transformational leadership style characterized by value-based and individual interaction, seeks to establish the legitimacy of the leader by appealing to the values of the individual.

This brief review of the literature suggest that safety leadership may be either transformational or transactional drawing respectively on intrinsic motivation which encourages voluntary rule following out of obligation to the leader, and the organization they represent, or extrinsic motivations, which establishes control through fear of punishment or anticipation of reward. These are presented as discrete alternatives to achieve safety compliance. Nevertheless it is unclear to which circumstances either applies, even though we know that motivations and ability to comply and understanding and knowledge of compliance requirements vary amongst individuals employed in different roles. Furthermore this assumes that both transformational and transactional leadership are single constructs, when clearly they are multi-dimensional.

Consequently it is unclear whether particular aspects of leadership practice encourage specific sorts of compliance, and if so which. For example how do corrective and constructive leadership differ in the ways they deliver compliance with standard procedures? And, what difference would an employee experience it their leader adopted individual consideration rather than inspirational motivation to ensure more individuals were involved in safety planning? Although Griffin and Hu (2013; pg. 197) argued that "more empirical studies are required to understand how safety leaders can promote safety compliance", we believe that a closer inspection of existing safety leadership studies taking account of their contextual differences, allied with either a "command-or-control" or a self-regulation perspective (Tyler, 2011), will reveal more about how safety leaders achieve compliance with the variety of safety requirements noted above.
Specifically, this paper has three objectives. First, we will review existing empirical studies of safety leadership noting aspects of the context and identifying the different reported leadership practices. Based on the alignment between transformational leadership and intrinsic motivation and between transactional leadership and extrinsic motivation, we can infer the ways the leadership practices support various motivations for the range of observed employee groups to comply with the particular safety regulations evident in any particular study. Second, drawing on a self-regulation framework (Lord et al., 2010) we will suggest how these might explain the achievement of compliance with safety requirements by different safety leadership styles apparent in the existing literature. Third, drawing on selected reviews of the wider leadership literature we will suggest how a newer conceptualization of leadership, namely distributed leadership, may engender a different form of compliance by employees. Rather than relying on the traditional psychological approaches to understanding individual behaviours and motivations and personal characteristics of individual leaders in relation to safety, we draw on more relational perspectives (Emirbayer, 1997) from sociology to present an alternative approach to safety leadership to support safety compliance.

METHOD

A literature review based on the systematic literature review methodology developed for management and business studies (Tranfield et al., 2003) was deployed. A series of key words were developed in relation to the three primary terms of interest, namely, safety, leadership and role (Table 1).

Table 1. Keywords used to create search strings

Main Term	Additional Terms
Safety	safety OR security OR sure* OR safeguard OR protect* OR reliab* OR resilien*
Leadership	leader* OR manage* OR advisor OR director OR supervisor OR facilitator OR officer OR superintendent OR chief OR commander OR expert OR coach OR specialist
Role	activity OR action OR role OR function OR skill OR enact OR do OR conduct OR routine OR practi?e

These keywords were combined to make strings using the Boolean character 'OR' and different strings were combined using the Boolean character 'AND' (Table 2). These were applied to five different electronic databases (ABI-Proquest, EBSCO Host – Business Source Complete, SCOPUS, Science Direct and PsychInfo). Table 2 shows the numbers of items appearing in scholarly peer reviewed academic journals in the different databases in relation to the different search string combinations. An initial screen of titles permitted a substantial reduction in apparently relevant articles (Table 2). Exclusion criteria included book reviews and non-English language articles, as well as those that focused on different forms of security (including cyber, food, financial, energy and national) and various forms of safety (including health and patient, environmental, technical, transport, chemical and product). Papers that dealt with modelling, families, education and business performance were also excluded. After removal of the duplicates occurring in each of the databases the articles from the string for 'safety + leadership + role' was reduced from 112 to 54. The three authors then reviewed the abstracts of these articles together, and by discussion eliminated a further 47 articles that were deemed not relevant to safety leader practices.

Table 2. Number of items discovered by applying a search string to an electronic database.

Number of relevant titles are in parenthesis.

	Database				
Search String	**ABI**	**EBSCO**	**SCOPUS**	**Science Direct**	**PsychInfo**
Safety + Leadership	1192	1169	6486	1949	577
Safety + Role	1263	1533	20425	6124	2250
Safety + Leadership + Role	90 (12)	100 (21)	480 (37)	134 (18)	66 (24)

Scanning the reference list of the remaining seven articles and tracking their citations surfaced 15 additional papers relevant to safety leader practices. These 22 articles were then read and analysed and the following information was extracted from each paper (where appropriate):

- Industry / sector;
- Focal actor(s) (*e.g.* manager, supervisor, front-line worker taking note of the leader);
- Focus of measure (*e.g.* consciousness, communication, compliance and participation) used to describe compliance (defined broadly);
- Scale (where appropriate) used to indicate leadership. Many studies used the MLQ scale to indicate transformational-transactional leadership (Bass and Avolio, 2002), while Leader-Member exchange was indicated by the LMX scale. A few authors created their own leadership measures (e.g. Dahl and Olsen, 2013; Lu and Yang, 2010); and
- Safety practices. It was discovered that these were implicit in the different scales often for the dependent variable used in the study (e.g. safety consciousness (Barling et al., 2002).

The measures used to describe safety compliance were then aligned to the requirements of an occupational health and safety management system as outlined by the British Standards Institution (BSI, 2007) which facilitates compliance with the UK's Health and Safety at Work (1974) and subsequent Regulations (The management of H&S at work regulation, 1992) (Table 3). This allowed us to identify the breadth of safety compliance that was being considered in each of the papers.

FINDINGS

We identified 22 academic articles that explored the role and practices of safety leaders and provided details of their environmental context. Our review confirms the findings of the earlier review of effective leadership behaviours for safety (Lekka and Healey, 2012) that current safety research focuses mainly on either transactional – transformational leadership or leader-member exchange (LMX) (Table 4). 15 of the reviewed papers had this focus. Many of the remainder adopted qualitative approaches to data capture either exploring factors that influenced leadership enactment through focus groups (Conchie et al., 2013) or investigating the effects of supervisory feedback on worker safety compliance through brief interviews (Zohar, 2002b; Zohar and Luria, 2003).

Table 4 reveals a number of key findings. First, leadership defined by the standard measures of MLQ or LMX (Table 4) was deemed to be an antecedent to several different safety behavioural outcomes, most commonly safety compliance and safety participation, although safety citizenship, including voice, and safety consciousness were also measured (Table 4). The measure for safety compliance developed by Neal and colleagues (Neal et al., 2000; Neal and Griffin, 2006) comprised four items. Dahl and Olsen (2013) supplemented these with other measures. Together these provide only a partial coverage of the many activities outlined in the framework for an OSH management systems (BSI, 2007), and against which compliance might be judged (Table 3). Table 3 suggests that the other measures of safety behaviours align with different elements of the British Standards OSH management system and therefore may themselves be considered to support safety compliance more broadly defined. It should also be noted that no scale provided a complete assessment of safety compliance, although safety citizenship (Hofmann et al., 2003) came closest (Table 3). The focus of most measures is on implementation and operation, rather than planning and checking, and with no coverage of reviewing. The focus in the studies on supervisor-front-line worker relationships may be a contributing factor, although this does ignore the responsibilities of more senior managers and their influence on organizational safety compliance.

Second, much of the research on safety leadership has been conducted in manufacturing industries which are commonly organized as hierarchies. Perhaps as a consequence many (n=14) of the studies have investigated explicitly supervisor-front-line worker relationships. Moreover, other studies (e.g. Hoffmeister et al., 2014 looking at journeymen-apprentice relationships, and Yagil and Luria (2010) looking at manager-employee) examined similar relationships between a low ranked worker and a higher ranked worker, leaving different and more senior relationships in the organizational hierarchy under-explored.

In contrast to the majority of studies which used generic scales, the work of Zohar and colleagues in Israel, focused on particular aspects of compliance, namely the use of PPE, specifically ear-plugs by workers, and safety communication, specifically the giving of feedback to workers by their supervisors (e.g. Zohar and Luria, 2003; Luria et al., 2008). In addition Conchie et al. (2013) used investigated the influence of contextual factors, in particular role overload, production demands and formal procedures on supervisor enactment of leadership.

Table 3. Compliance focus of different scales used to measure impact of leadership aligned to components of the British Standards management framework for Occupational Health and Safety (BSI, 2007).

Author	Safety Compliance (Neal and Griffin, 2006[a]; Dahl and Olsen, 2013[b])	Safety Participation (Neal and Griffin, 2006[a]; Clarke and Ward, 2006[b])	Safety Consciousness (Barling et al., 2002)	Safety Citizenship (Hofmann et al., 2003)	Safety Communication (Hofmann and Morgeson, 1999)
1. Develop, Deploy & Monitor OSH Policy					
2. Plan					
2.1Risk assessment/hazard identification	X[b]	X[b]		X	
3. Implement & Operate					
3.1 Resources & role clarity					
3.2 Competence / Training /Awareness	X[a]	X[a]	X	X	
3.3 Communication / Participation		X[a,b]	X	X	X
3.4 Documentation (provision and control)	X[b]				
3.5 Operational Control	X[a,b]		X	X	
3.6 Emergency preparedness and response			X		
4. Checking					
4.1 Monitor OSH objectives					
4.2 Evaluate compliance		X[b]		X	
4.3 Investigate accidents / non-conformity				X	
4.4 Audit		X[b]			
5. Review					

DISCUSSION

Complying with safety regulations requires attention to more than just operational practices which is the primary focus of many of the measures of safety compliance in the academic literature (e.g. Neal and Griffin, 2006) and indicated in Table 3. In the UK, the Health and Safety at Work etc Act (1974) covers: the provision and maintenance of plant and systems of work; the safe deployment of processes and practices; the provision of information, instruction and training; maintenance of a safe work place which implies attentiveness; the provision of necessary safety equipment to ensure the work environment is safe. These imply a range of activities as developed in various standards documents (e.g. BSI, 2007), including but not limited to planning and design, controlling, monitoring and evaluating, developing policy, process and procedure, and training. Although this larger compliance framework is UK-centric and directly applicable only to the studies by Conchie and her colleagues and by Clarke and her colleagues, nevertheless it is probable that safety legislation in other countries will have a similarly wide remit, so that safety compliance should be understood broadly. As a consequence, and in marked contrast to existing research studies, not only is the scope of safety compliance enlarged, but also a greater diversity of factors may contribute to its successful enactment.

One factor in particular, leadership, is often perceived to influence safety compliance. Hitherto most studies of safety leadership (Table 4) have adopted a transactional-transformational perspective, either explicitly or implicitly, because the LMX perspective adopted by some “is both transactional and transformational: it begins as transactional social exchange and evolved into transformational social exchange” (Graen and Uhl-Bien, 1995, pg 238). This perspective draws on both the extrinsic and intrinsic motivation of individuals to achieve its effects, so that safety compliance in a ‘command and control’ form is achieved by transactional leadership which appeals to an individual’s extrinsic motivation. Intrinsic motivations encourage self-regulation, and are supported by transformational leadership. One might conclude simplistically that different forms of safety leadership motivate individuals in different ways and these differentially impact safety compliance, or that individuals naturally differ in their inherent motivations and the role of the safety leader is to modify his/her style to match these requirements of the individual to ensure safety compliance. What is much less clear, and yet altogether more practical, is how safety compliance may be achieved in specific circumstances and how this varies as context changes. The use of generic scales in safety questionnaires may contribute partially to this absence of clarity and lack of utility. In contrast the studies by Zohar and Luria (2003) and Luria et al. (2008) which measured particular leader practices (supervisory feedback on safety) in relation to the use of PPE by workers have greater conceptual clarity and more obvious practical application.

Table 4. Data extracted from empirical studies of safety leadership identified by a systematic literature review.

Author	Country / Industry	Focal Actor(s) (Leader indicated first)	Focus of study	Measure of Leadership type used
Barling et al. (2002)	Canada. Food & beverage industry	Supervisor + Front-line worker	Safety Consciousness	MLQ
Clarke and Ward (2006)	UK. Manufacturing	Supervisor + Front-line worker	Safety Participation	Bespoke measure of leader influence
Conchie and Donald (2009)	UK. Construction	Supervisor + Front-line worker	Safety Citizenship	MLQ
Conchie et al. (2012)	UK. Oil Company	Supervisor + Front-line worker	Safety Citizenship	MLQ
Conchie et al. (2013)	UK. Construction	Supervisor + Operatives	Safety Leadership Behaviours	Job Demands-Resources Framework
Credo et al. (2010)	USA. Drilling Company	Managers + Supervisors/Front-line worker	Safety Consciousness	LMX
Dahl and Olsen (2013)	Norway. Oil Company	Leaders + workers	Safety Compliance	Bespoke scale
Hoffmeister et al. (2014)	USA. Construction	Journeymen + apprentices	Safety Compliance and	MLQ

	Company		Participation	
Hofmann and Morgeson (1999)	USA. Manufacturing	Group leader + supervisor / front-line worker	Safety Communication	LMX
Hofmann et al. (2003)	USA. Army transport team	Leaders + team members	Safety Citizenship	LMX
Innes et al. (2010)	USA. Range of industries	Supervisor + Front-line worker	Safety Compliance and Participation	MLQ
Kapp (2012)	USA. Construction and Manufacturing	Supervisor + Front-line worker	Safety Compliance and Participation	MLQ
Kath et al. (2010)	USA. Railway maintenance	Supervisor + Front-line worker	Safety Communication	LMX
Kelloway et al. (2006)	Canada. Service sector	Supervisor + Front-line worker	Safety Consciousness	MLQ
Lu and Yang (2010)	China. Container terminal	Senior Manager + worker	Safety Compliance and Safety Participation	Bespoke scale
Luria et al. (2008)	Israel. Manufacturing	Supervisor + front-line worker	Supervisory feedback + Worker use of PPE	Supervisory feedback on safety
Michael et al. (2006)	USA. Wood product manufacturing	Supervisor + Front-line worker	Safety Communication	LMX
Mullen and Kelloway (2009)	Canada. Hospitals	Manager + employees	Safety Compliance and Participation	MLQ
Yagil and Luria (2010)	Israel. Manufacturing	Manager + employees	Safety Compliance and Participation	LMX
Zohar (2002a)	Israel. Metal processing	Supervisor + employees	Safety Climate	MLQ
Zohar (2002b)	Israel. Maintenance of heavy equipment	Supervisor + Front-line worker	Worker use of PPE	Supervisory feedback on safety
Zohar and Luria (2003)	Israel. Oil Refinery + Processing industries	Supervisor + Front-line worker	Supervisory feedback + worker use of PPE	Supervisory feedback on safety

Many of the studies of transformational-transactional safety leadership have used the MLQ scale (Bass and Avolio, 2002), often selecting particular items, most notably the four items relating to transformational leadership plus contingent reward, a component of transactional leadership (e.g. Barling et al., 2002; Kapp, 2012). However the general concept of transformational leadership, and because it is a continuum transactional leadership also, has been the focus of severe critique both conceptually and methodologically (van Knippenberg and Sitkin, 2013). According to Yukl (1999) these critiques "include ambiguous constructs, insufficient description of explanatory processes, a narrow focus on dyadic processes, omissions of some relevant behaviours, insufficient specification of limiting conditions (situational variables) and a bias towards heroic conceptions of leadership, pg. 286". These flaws are inevitably present in safety leadership studies because they use the same scales. Future studies of safety leadership should seek to ensure greater conceptual clarity in the dimensions of the leadership construct under investigation and in their relationship to each other. Moreover, it is important that the explanatory processes linking leadership characteristics to follower outcomes are made explicit and are unambiguous. For example in the studies of safety leadership that use LMX (e.g. Credo et al., 2010; Kath et al., 2010) perceived organizational support (POS) (Eisenberger, et al., 1986) is additionally used to explain the safety outcomes, yet it is unclear how the leader does or does not also contribute to providing organizational support and whether the two constructs (leadership and POS) are conflated and to what extent. As a consequence it is unclear what specifically individual safety leaders do when they are leading for safety. Moreover the mechanisms are poorly understood by which their actions stimulate safety compliance either with the narrow range of activities embraced in academic studies of safety compliance or with the broader range of activities specified in regulations, standards and guidelines which also demand compliance. Some of the latter may be covered in other academic studies of safety participation, safety consciousness and safety citizenship (Table 3).

We contend that safety compliance has been narrowly focused in the academic literature and that this needs to be broadened to reflect practice. In addition existing studies of safety compliance (including safety participation, safety citizenship and safety consciousness) suggest implicitly that compliance is a binary state: either it has been achieved or it has not. The role of the safety leader is to ensure compliance. In practice of course safety is not static but rather a dynamic on-going process, needing continual intervention. Gray and Silbey (2011) note that "compliance as a process evolves among countless transactions across a heterogeneous set of compliance agents, with varying degrees of agency, knowledge, hierarchy, autonomy and experience, pg 134". Their observation also indicates that compliance is not the sole responsibility of one individual – the safety leader, but rather a collaborative endeavour which, because of variation in context and diversity in actor abilities and engagement with risk and so safety, requires collective leadership. Safety compliance is therefore a dynamic process that requires collective rather than individual responsibility.

All of the studies in this review of safety leadership and leadership practices to achieve safety compliance adopted a unitary view of the leader as an individual. More recent reviews of the general leadership literature (e.g. Thorpe et al., 2011) consider that leadership skills and responsibilities can be dispersed throughout an organization. Such perspectives are described as 'plural leadership' (Denis et al., 2012). One particular form of 'plural leadership' embraces the work on distributed leadership (Fitzsimmons et al., 2011), where leadership roles are dispersed across organizational levels over time, so that multiple actors take on leadership roles at appropriate moments exerting influence jointly. Adopting such a distributed perspective on safety leadership would accommodate the need for collective responsibility and accountability for safety compliance by drawing on the diverse skills, knowledge, expertise and experience within an organization to develop policies, practices and procedures that ensure safety compliance while remaining relevant and viable. This enhances the possibility of greater employee buy-in and increases the chance of success in achieving safety compliance. This moves away from the traditional psychological approach to safety leadership and points towards a more relational approach to safety leadership that also gives consideration to context, which has been absent in studies hitherto.

A particular formulation of this possibility is the concept of 'relational regulation' (Huising and Silbey, 2011).They observe that because of circumstances in the organizational environment there is frequently a gap between the expectations of regulatory systems and the actual practices enacted in organizations and designed to meet those expectations. In other words there is a failure to achieve safety compliance. They suggest that relational regulation allows managers to keep "organizational activities within an acceptable range of variation close to regulatory specifications" (Huising and Silbey, 2011; pg .14). Managers do this: by building a support network through which they exchange information and learn from others; by pursuing expertise wherever it may be found (i.e. both formally and informally) within the organization and beyond; by developing a comprehensive multi-faceted view of the relations, practices and resources available across the organization, and how these may enable safety; and finally by being pragmatic about what is possible and what is required in any presenting circumstance. While 'relational regulation' focuses on a particular individual acting as a safety leader (rather than on a collective) it is nevertheless a collaborative endeavour that suggests how these individuals may more effectively engage with many others to develop practices, procedures and policies that are locally relevant, pragmatic and more effective because others have been involved in their development. Safety leadership that involves others encourages more widespread adoption and deployment of safe practices in the organization. This enhances safety compliance. 'Relational regulation' provides such a contextually-sensitive alternative model of safety leadership for safety compliance.

Where previous studies of safety leadership have focused on an individual, future research could explore the connectivity between individuals perhaps using social network analysis techniques, aligning their connections to their individual beliefs about safety and their particular safety skills and knowledge. This would permit the investigation of distributed safety leadership and the occurrence of 'relational regulation'

CONCLUSIONS

This paper demonstrates that academic studies have not investigated the full range of practices that are deployed in practice by organizations to ensure safety compliance. The selection of sample population, typically of supervisors and front-line workers, ensures that safety compliance focused mainly on implementation and operations. Moreover, the adoption of existing leadership scales narrows the focus of safety leadership to individuals, and it must be inferred that they use either intrinsic or extrinsic motivations congruent with their leadership style. From these observations we suggest first that safety compliance should be conceptualized more broadly to conform closely to the requirements of OSH management systems, and second that a 'relational regulation' perspective on safety compliance drawing on distributed leadership could be more fully developed to ensure safety compliance is more effectively achieved in organizations and that studies of safety leadership embrace organizational context more fully.

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REFERENCES

Avolio, B.J., Walumbwa, F.O., & Weber, T.J. (2009). Leadership: Current theories, research, and future directions. *Annual Review of Psychology*, 60, 421-449.

Bass, B.M. (1985). *Leadership and Performance Beyond Expectations.* Free Press: New York.

Bass, B.M., & Avolio, B.J. (2002). *MLQ: Multifactor Leadership Questionnaire,* 2nd Edition. Redwood City: CA.

Barling J., Loughlin C., & Kelloway, E. K. (2002). Development and test of a model linking safety-specific transformational leadership and occupational safety. *Journal of Applied Psychology*, 87 (3), 488-496.

BSI (2007). *Occupational health and safety management systems – Requirements*. BS OHSAS 18001:2007. BSI: London.

BSI (2004). *Guide to Occupational health and safety management systems*. BS8800:2004. BSI: London.

Clarke, S. (2013). Safety leadership: a meta-analytic review of transformational and transactional leadership styles as antecedents of safety behaviours. *Journal of Occupational and Organizational Psychology*, 86, 22-49.

Clarke S., & Ward K. (2006). The Role of Leader Influence Tactics and Safety Climate in Engaging Employees' Safety Participation. *Risk Analysis*, 26 (5), 1175-1185.

Conchie S., & Donald I. (2009). The moderating role of safety-specific trust on the relation between safety-specific leadership and safety citizenship behaviors. *Journal of Occupational Health Psychology*, 14 (2), 137-147.

Conchie, S., Taylor P., & Donald I. (2012). Promoting safety voice with safety-specific transformational leadership: The mediating role of two dimensions of trust. *Journal of Occupational Health Psychology*, 17 (1), 105-115.

Conchie, S.M., Moon, S., & Duncan, M. (2013). Supervisors' engagement in safety leadership: factors that help and hinder. *Safety Science*, 51, 109-117.

Credo K., Armenakis A., Feild H., & Young, R. (2010). Organizational Ethics, Leader-Member Exchange, and Organizational Support: Relationships with Workplace Safety. *Journal of Leadership and Organizational Studies*,17 (4), 325-334.

Dahl, O., & Olsen, E. (2013). Safety compliance on offshore platforms: A multi-sample survey on the role of perceived leadership involvement and work climate. *Safety Science*, 54, 17- 26.

Denis, J-L., Langley, A., & Sergi, V. (2012). Leadership in the plural. *The Academy of Management Annals,* 6(1), 211-283.

Eisenberger, R., Huntington R., Hutchison S., & Sowa, D. (1986). Perceived organizational support. *Journal of Applied Psychology,* 71(3), 500-507.

Emirbayer, M. (1997). Manifesto for a relational sociology. *American Journal of Sociology*, 103(2), 281-317.

Fitzsimmons, D., Turnbull James, K., & Denyer, D. (2011). Alternative approaches for studying shared and distributed leadership. *International Journal of Management Reviews*, 13, 313-328.

Graen, G.B., & Uhl-Bien, M. (1995). Relationship-based approach to leadership: development of leader-member exchange (LMX) theory of leadership over 25 years: applying a multi-level multi-domain perspective. *Leadership Quarterly,* 6(2), 219-247.

Gray, G.C., & Silbey, S.S. (2011). The other side of the compliance relationship. In: *Explaining Compliance: Business Responses to Regulation.* Eds C. Parker and V.L. Nielsen. Edward Elgar: Cheltenham, UK. pg 341-369*.*

Griffin, M.A., & Hu, X. (2013). How leaders differentially motivate safety compliance and safety participation: the role of monitoring, inspiring and learning. *Safety Science*, 60, 196-202.

Health and Safety at Work etc. Act (1974). http://www.legislation.gov.uk/ukpga/1974/37/pdfs/ukpga_19740037_en.pdf downloaded 26 June 2015.

Hoffmeister, K., Gibbons, A., Johnson, S., Cigularov, K., Chen P., & Rosecrance, J. (2014). The differential effects of transformational leadership facets on employee safety. *Safety Science* 62, 68-78.

Hofmann, D. A., & Morgeson, F. P. (1999). Safety-related behaviour as a social exchange: the role of perceived organizational support and Leader-Member Exchange. *Journal of Applied Psychology*, 84 (2), 286-296.

Hofmann, D. A., Morgeson, F. P., & Gerras, S. J. (2003). Climate as a moderator of the relationship between leader-member exchange and content specific citizenship: safety climate as an exemplar. *Journal of Applied Psychology*, 88 (1), 170-178.

HSE (1997). *Successful Health and Safety Management (HSG65).* Second Edition. Health and Safety Executive.

HSE (2013). *Managing for Health and Safety (HSG65).* Third Edition. Health and Safety Executive.

Huising, R., & Silbey, S.S. (2011). Governing the gap: forging safe science through relational regulation. *Regulation and Governance*, 5, 14-42.

Hutter, B.M. (2011). Negotiating social, economic and political environments: compliance with regulation within and beyond the state. In: *Explaining Compliance: Business Responses to Regulation*. Eds C. Parker and V.L. Nielsen. Edward Elgar: Cheltenham, UK. pg 305-321.

Inness, M., Turner, N., Barling, J., & Stride, C. B. (2010). Transformational leadership and employee safety performance: a within-person, between-person job design. *Journal of Occupational Health Psychology* 15 (3), 279-290.

Kapp, E. (2012). The influence of supervisor leadership practices and perceived group safety climate on employee safety performance. *Safety Science* 50, 1119-1124.

Kath, L. M., Marks, K. M., & Ranney, J. (2010). Safety climate dimensions, leader-member exchange, and organizational support as predictors of upward safety communication in a sample of rail industry workers. *Safety Science*, 48, 643-650.

Kelloway, E., K., Mullen, J., & Francis, L. (2006). Divergent effects of transformational and passive leadership on employee safety. *Journal of Occupational Health Psychology*, 11 (1), 76-86.

Krimsky, S. & Golding, D. (1992). *Social Theories of Risk*. Praeger: Westport, CT.

Lekka, C., & Healey, N. (2012). *A review of the literature on effective leadership behaviours for safety*. Health and Safety Executive: London.

Lord, R.G., Diefendorff, J.M., Schmidt, A.M., & Hall, R.J. (2010). Self-regulation at work. *Annual Review of Psychology*, 61, 543-568.

Lu, C. S. & Yang, C. S. (2010). Safety leadership and safety behaviour in container terminal operations. *Safety Science,* 48 (2), 123-134.

Luria, G., Zohar, D., & Erev, I. (2008). The effect of workers' visibility on effectiveness of intervention programs: Supervisory-based safety interventions. *Journal of Safety Research*, 39 (3), 273-280.

Michael, J. H., Guo, Z. G., Wiedenbeck, J. K., & Ray, C. D. (2006). Production supervisor impacts on subordinates' safety outcomes: an investigation of leader-member exchange and safety communication. *Journal of Safety Research*, 37 (5), 469-477.

Mullen, J. E., & Kelloway, E. K. (2009). Safety leadership: a longitudinal study of the effects of transformational leadership on safety outcomes. *Journal of Occupational and Organizational Psychology*, 82 (2), 253-272.

Neal, A., Griffin, M.A., & Hart, P.M. (2000). The impact of organizational climate on safety climate and individual behaviour. *Safety Science*, 34, 99-109.

Neal, A., & Griffin, M.A. (2006). A study of the lagged relationship among safety climate, safety motivation, safety behaviour, and accidents at the individual and group levels. *Journal of Applied Psychology*, 91 (4), 946-953.

Osborn, R.N., Hunt, J.G., & Jauch, L.R. (2002). Toward a contextual theory of leadership. *The Leadership Quarterly*, 13(6), 797-837.

Porter, L.W., & McLaughlin, G.B. (2006). Leadership and the organizational context: Like the weather? *The Leadership Quarterly*, 17, 559-576.

Ryan, R.M., & Deci, E.L. (2000). Intrinsic and extrinsic motivation: classic definitions and new directions. *Contemporary Educational Psychology*, 25, 54-67.

Suchman, M.C. (1995). Managing legitimacy: strategic and institutional approaches. *Academy of Management Review*, 20, 571-610.

Tansey, J. (2004). Risk as politics, culture as power. *Journal of Risk Research*, 7(1), 17-32.

The Management of Health and Safety at Work Regulation (1992). http://www.legislation.gov.uk/uksi/1992/2051/contents/made Downloaded 26 June 2015.

Thorpe, R., Gold, J., & Lawler, J. (2011). Locating distributed leadership. *International Journal of Management Reviews*, 13, 239-250.

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management,* 14(3), 207-222.

Tyler, T.R. (2006). Psychological perspectives on legitimacy and legitimation. *Annual Review of Psychology*, 57, 375-400.

Tyler, T.R. (2011). The psychology of self-regulation: normative motivations for compliance. In: *Explaining Compliance: Business Responses to Regulation*. Eds C. Parker and V.L. Nielsen. Edward Elgar: Cheltenham, UK. pg 78-99.

Uhl-Bien, M. (2006). Relational leadership theory: exploring the social processes of leadership and organizing. *The Leadership Quarterly*, 17(6), 654-676.

Van Knippenberg, D., & Sitkin, S.B. (2013). A critical assessment of charismatic-transformational leadership research: back to the drawing board? *The Academy of Management Annals*, 7(1), 1-60.

Yagil, D., & Luria, G. (2010). Friends in need: the protective effect of social relationships under low-safety climate. *Group and Organization Management*, 35 (6), 727-750.

Yukl, G. (1999). An evaluation of conceptual weaknesses in transformational and charismatic leadership theories. *Leaderahip Quarterly*, 10(2), 285-305.

Zohar, D. (2002a). The effects of leadership dimensions, safety climate, and assigned priorities on minor injuries in work groups. *Journal of Organizational Behavior*, 23 (1), 75-92.

Zohar, D. (2002b). Modifying supervisory practices to improve subunit safety: a leadership-based intervention model. *Journal of Applied Psychology*, 87 (1), 156-163.

Zohar, D., & Luria, G. (2003). The use of supervisory practices as leverage to improve safety behaviour: a cross-level intervention model. *Journal of Safety Research*, 34 (5), 567-577.

Effective risk assessment of major accident: case study of LPG storage risk analysis

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Abstract
The goal of this contribution is presentation of the risk assessment and management of risk sources in industrial enterprises. The main part of the paper will deal with so called unclassified risk sources, i.e. LPG storages, especially in small and medium-sized enterprises (SME). The evaluated SME are characterized as risk sources with an amount of dangerous materials under the limits of the SEVESO III Directive that could represent, as a result of the area location or specific process activities, significant major-accident risks. The major-accident prevention of these risk sources is not specified in any law at present, and that is why any adequate pressure is put neither on the assessment, nor the reduction of risks. Therefore, one of the goals of the article is to increase awareness on these unclassified risk sources, because risk perception is one of the main influencing factors within accident prevention.

Keywords: Major Accident Prevention, Risk Assessment Methods, ARAMIS, Hazardous Materials, LPG.

1. INTRODUCTION
In view of the growing prices of petrol and oil, the interest of drivers in liquefied propane-butane (LPG) as a fuel for cars rises. The number of storage tanks for car filling, both stand-alone tanks and tanks as part of petrol filling stations, increases. Prevention of accidents associated with LPG storage facilities is a priority in the protection of people in the vicinity of the facilities and equipment and forms an integral part of the management of system safety. The aim is to contribute to the prevention of accidents and incidents of process equipment with LPG based on the analysis of possible scenarios of accidents of LPG storage tanks and on the assessment of risks. Equipment with propane-butane (pressure vessels, tanks for heating) together with its transport by road and rail represents a significant number of risk sources. New LPG filling stations are built, but the issue of distances between them and petrol filling stations has not been sufficiently solved yet. During normal operation, fuel filling stations are not regarded as significant sources of risk in spite of the fact that from statistical data a certain level of major accident risk follows. In case of accident, a so-called domino effect, when an accident of one piece of equipment may cause a major accident of another piece of equipment, has to be considered.
From the point of view of present amounts of stored LPG, the following facts can be stated. The amount of LPG in filling stations moves in a range from 2.1 t to 4.2 t in storage tanks of various sizes (e.g. a 5 m^3 storage tank contains 2.1 t of LPG). Similar tanks are used for house heating (1.1 or 2.1 t of LPG for family houses) and for establishments in isolated places (e.g. hotel – 8.4 t of LPG). These tanks can be of underground or aboveground type (see example in Figure 1). Further, propane-butane is sold in pressure vessels of various sizes (2, 5, 10 and 33 kg of LPG). The sources of risk can be above all rather large storage facilities for vessels, when the total amount of propane-butane can be to 4 t.


Figure 1 – LPG filling station in a plant.

When storing the LPG in tanks, the following types of accidents may occur - Jet Fire, Flash Fire and VCE-type and BLEVE-type explosions. In the case of handling of LPG pressure vessels, the start of fire and explosion can be expected as well. Table 1 presents the possible types of phenomena of accidents in the case of damaged equipment containing selected fuels and their subsequent leaks.

Table 1 – Overview of phenomena of accidents involving specific fuels.

	Pool fire	Jet fire	Flash fire	VCE	BLEVE
Petrol	+			+	
Oil	+				
LPG		+	+	+	+
CNG			+	+	
LNG			+	+	

2. METHODS OF RISK ASSESSMENT

Risk assessment can be carried out by quite a number of methods developed by modifying several most widely used methods. The publication "Review of 62 risk analysis methodologies of industrial plants" (Tixier, et al, 2002) summarises the best known methods of risk assessment. To the most significant publications in the area of quantitative risk assessment belong Lees' Loss Prevention in the Process Industries, Hazard identification, assessment and control, 2005 (Mannam, 2005), Guidelines for Chemical Process Quantitative Risk Analysis - CPQRA, 1989 (CCPS, 1989) and Guidelines for Quantitative Risk Assessment –"Purple Book", 1999 (Guidelines for Quantitative Risk Assessment, 1999). It is just the Dutch methodology CPR 18E Guidelines for Quantitative Risk Assessment known as "Purple Book" that represents a recognized approach to the overall risk assessment.

For making the risk analysis, various methods exist that are used for individual steps of the analysis, namely risk source identification and determination of consequences and probabilities of scenarios. The first group of the methods can be characterized by taking pre-defined data from well-known literature based on experience from the past (they use so-called reference scenarios). The second group of methods uses a demanding procedure of the very generation of development of a scenario that is necessary, e.g. in the case of assessment of new technologies and new risks, when the first procedure of reference scenarios cannot be used owing to the lack of information and experience. The ARAMIS methodology, belonging to the second group, uses logical graphs - fault trees and event trees – for the preparation of accident scenarios.

3. ARAMIS METHODOLOGY

The methodology ARAMIS ("Accidental Risk Assessment Methodology for Industries in the framework of the SEVESO II directive") was developed in the framework of an EU 5FP project. A harmonized methodology for risk assessment, aimed especially at reducing uncertainties and variability in results and at including the evaluation of risk management efficiency into the analysis, was proposed. It is necessary to regard ARAMIS as a comprehensive tool for efficient implementation of risk identification and analysis with many pre-prepared and recommended steps (ARAMIS, 2004).

The procedure of the ARAMIS methodology can be divided into three basic steps, the outputs of which are relevant indexes, see Figure 2:

1. assessment of consequence severity (S - severity index),
2. evaluation of risk management efficiency (M - management index),
3. assessment of surrounding environment vulnerability (V- vulnerability index).

All the indexes can be evaluated separately, but above all the indexes S and M are considerably interconnected in the selection of reference accident scenarios and consequence severity determination, when efficient measures to reduce the risks can affect the frequency of accidents or to limit the consequences of them.

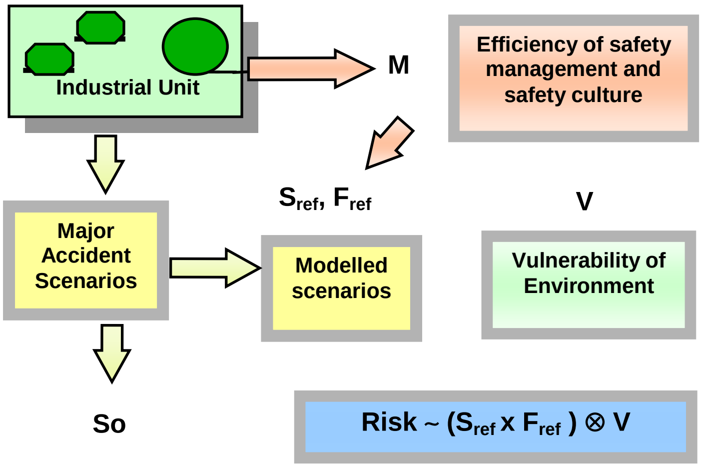

Figure 2 – Summary diagram of the ARAMIS methodology (Hourtolou, 2004).

To determine the S index, or reference scenarios of accidents it is necessary to do two partial assessments according to the methods for the identification of risk sources designed by the ARAMIS project – MIMAH and MIRAS methods.
The goal of MIMAH is to identify potential scenarios of accidents that may occur in the industrial process. MIMAH defines the maximum dangerous potential in the piece of equipment. The bow-tie diagram is built by the association of the critical event with the corresponding fault tree on the left and the corresponding event tree on the right (see Figure 3). These bow-tie diagrams must be understood as scenarios for major accident without considering any installed safety measures. The evaluation of safety systems forms a basis of MIRAS methodology application.

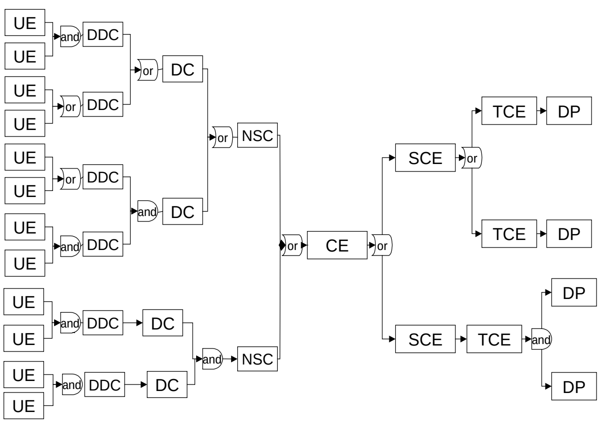

Figure 3 – A common 'bow-tie' diagram for one critical event (Nevrly, 2004).
Notes: UE – Undesirable Event, DDC – Detailed Direct Cause, DC – Direct Cause, NSC – Necessary and Sufficient Condition, CE – Critical Event, SCE – Secondary Critical Event, TCE – Tertiary Critical Event, DP – Dangerous Phenomena

The objective of MIRAS is to select reference scenarios from the scenarios identified in the MIMAH part. The method rests on studying the influence of elements of safety and risk management on the scenarios selected in MIMAH. The reference accident scenarios (RASs) represent a real hazardous potential of the piece of equipment after considering safety systems, including management (see Figure 4). In the MIRAS methodology, safety systems installed on the piece of equipment, the safety management system, the frequency of accident occurrence and the possible consequences of the accident are considered.

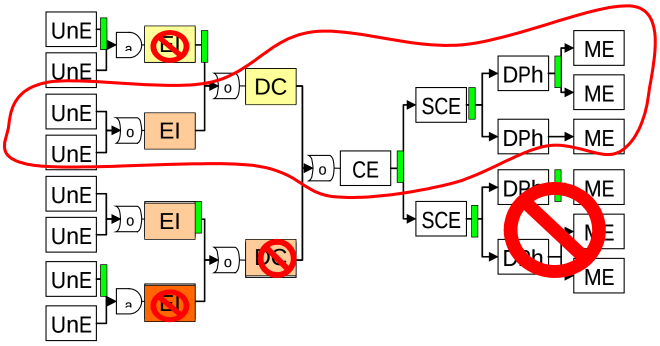

Figure 4 – Identification of reference accident scenarios -MIRAS (Nevrly, 2004).
Notes: UnE – Undesirable Event, EI – Initiating Event, DC – Direct Cause, CE – Critical Event, SCE – Secondary Critical Event, DP – Dangerous Phenomena, ME – Major Event

The goal of the next part of the ARAMIS methodology (S- index) is the determination of severity of reference accident scenarios by means of proposed parameters. Map of the risk severity index (see example in Figure 5) is based on these data can be made to:

- individual dangerous phenomena (DPi),
- individual critical events (CEj),
- for the whole installation,
- for each type of hazardous effects (toxic, overpressure, thermal radiation, pollution).

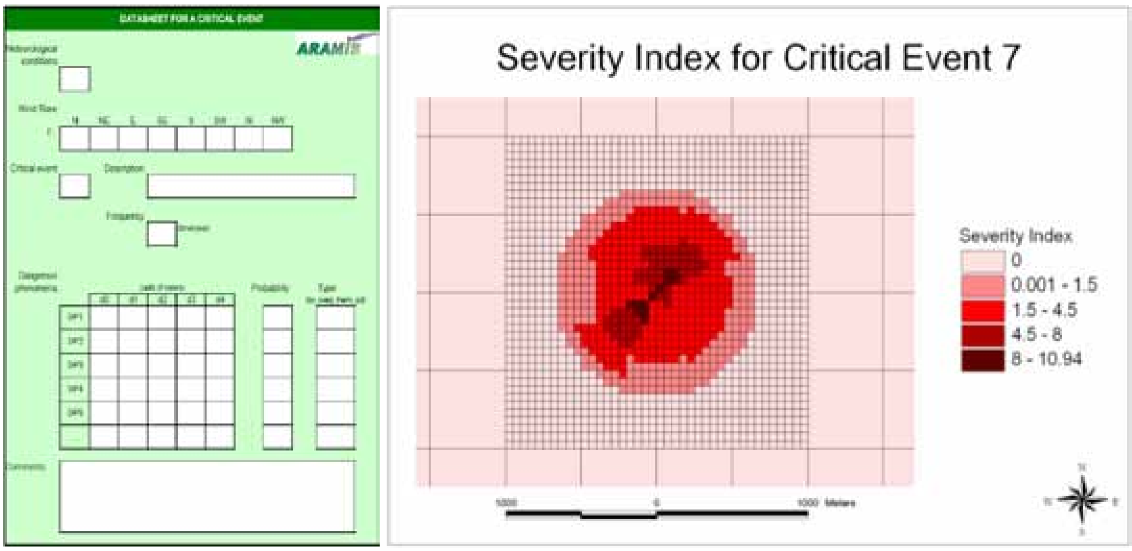

Figure 5 – Datasheet for a critical event and an example of Severity Index Map for a particular critical event (Nevrly, 2004).

The ARAMIS methodology was justly selected for the analysis and assessment of risks associated with the LPG filling station.

3. CASE STUDY

Risk analysis and assessment by the ARAMIS methodology were carried out in an industrial plant using the LPG for powering forklifts and having a built-up LPG filling station on its premises. The filling station consists of two cylindrical horizontal tanks; the total maximum amount of LPG is 4.9 t (see Figure 1 and 8). In the vicinity of the filling station, which is located on the boundary of the industrial plant, there are a housing estate and a public road. In case of major accident, a threat to both the employees of the plant and the population can be expected. For the purpose of simplification, other risk sources in the plant are not assessed.
Furthermore, the procedure for determining the index S-assessment of consequence severity will be presented. In the first phase, a list of sources of risks of major chemical handling accidents is made up.

- - LPG filling station, 4 900 kg of propane-butane, extremely flammable liquefied gas.

For the purpose of risk source identification, 16 types of equipment (selected EQ equipment) are defined in the methodology. In our case, it is EQ4–Pressure storage type of equipment.
To each selected risk source, a critical event has to be assigned (CE - Critical Event). The critical event is defined as a release of liquid content (LOC - Loss of Containment) from equipment. The method assumes 12 critical events. For our purposes, a critical event CE10 – Catastrophic ruptures was selected.
Further, fault trees and event trees that are connected to a so-called bow-tie (diagram) are built. Bow-ties are to be understood as major accident scenarios without considering installed safety systems. The result of this part is the construction of a bow-tie.
The aim of the next phase of ARAMIS methodology is to select a reference scenario of accidents from scenarios identified in the first part. It is based on the study of influence of safety elements and risk management on selected scenarios. The reference accident scenarios (RAS) represent a real hazardous potential of equipment after considering safety systems (including management). In the methodology, the following items are taken into account:

- safety systems installed on equipment,
- safety management system,
- frequency of accidents,
- possible consequences of accidents.

For the determination of frequencies of initiating events, the methodology offers selected data in appendices; above all the summary of frequencies of initiating events from specialist literature, list of possible safety barriers, method of evaluation of effects of individual barriers are stated. For the needs of placement of barriers into the fault tress, the safety barriers are divided by actions to be achieved, namely to avoid, to prevent, to control, to detect and to limit. For the needs of evaluation of effects of the barriers, 4 main categories of safety barriers are defined: passive, activated, human actions and symbolic barriers. The very evaluation of barrier effects is carried out by means of three parameters, especially according to the level of confidence (Level of Confidence -LC), effectiveness and response time. The output is a fault tree with determined frequencies of critical events (will be discussed during paper presentation as well).
The result of this part of the methodology is the frequencies of critical event after considering safety barriers in the fault trees.

- For CE10 –catastrophic rupture of LPG storage tank – 2.1×10^{-6} /year.

In the case of frequency of critical event of less than 10^{-7} /year, there is no need to apply subsequent steps.
The aim of this step is to determine the frequencies of all dangerous phenomena of selected critical events. The procedure is based on considerations concerning the safety barriers in the event trees that can decrease the frequency or consequences of the dangerous phenomena.
Results for the selected critical event are illustrated in Figure 6. The methodology again offers rough values of probability of immediate ignition, probability of delayed ignition and probability of VCE from specialist literature.

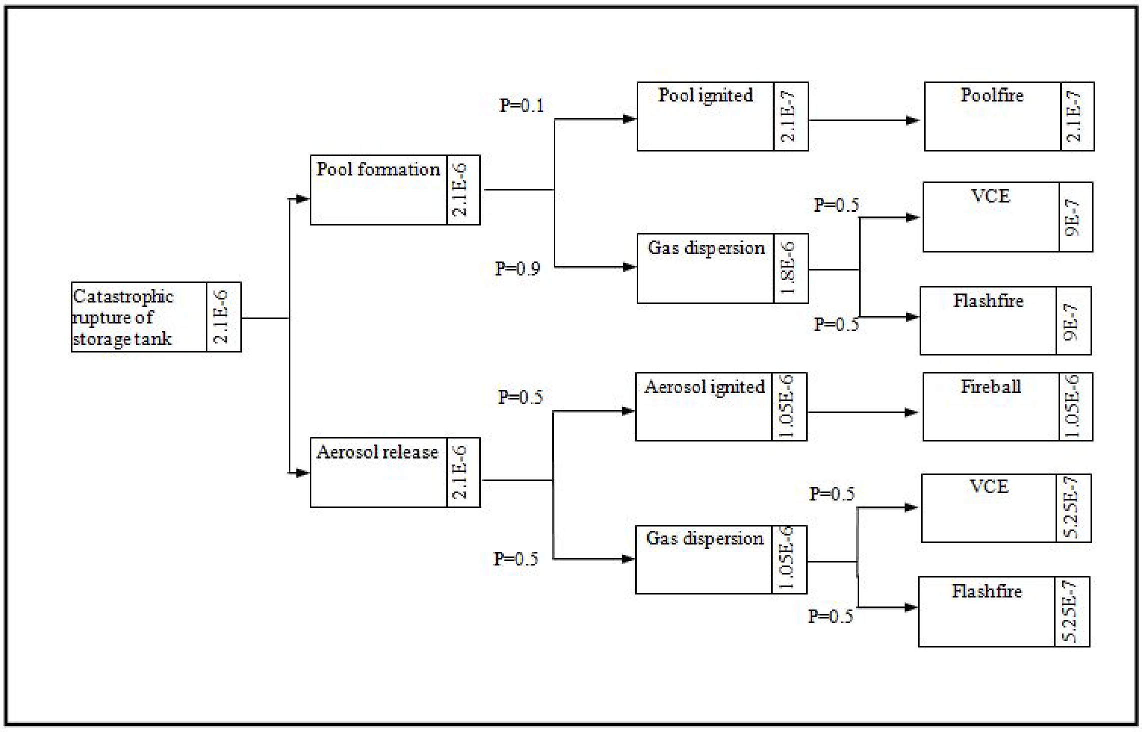

Figure 6 – Event tree with the frequencies of dangerous phenomena – rupture of LPG storage tank.

In the next step, it is necessary to carry out the rough evaluation of consequences of dangerous phenomena. This qualitative evaluation of consequences is based on classifying the dangerous phenomena into 4 classes of consequences (C1- 4), when the class C4 means the most serious consequences on human health and/or the environment. For individual dangerous phenomena the methodology offers pre-defined classes of consequences that can be modified according to the efficiency of barriers limiting the released amount of the substance or the impact of the dangerous phenomenon. The final classes of consequences are given in Table 2.

Table 2 – Frequencies and classes of consequences of dangerous phenomena.

No.	**Dangerous phenomenon**	**Frequency**	**Class of consequences**
1.	1a) Poolfire	2.1×10^{-7} / year	C2
	1b) VCE	1.4×10^{-6} / year	C3
	1c) Flashfire	1.4×10^{-6} / year	C3
	1d) Fireball	1×10^{-6} / year	C4

Definition of classes of consequences:

C1 - no injury or slight injury with no stoppage of work
- only observable effects on the environment, no action

C2 - injury leading to a hospitalization more than 24 hours
- serious effects on the environment, requiring local means of intervention

C3 - irreversible injuries or death inside the site, reversible injuries outside the site
- effects on the environment outside the site, requiring national means

C4 - irreversible injuries or death outside the site
- irreversible effects on the environment outside the site, requiring national means.

Reference scenarios are selected by means of a tool – risk matrix (see Figure 7). In the matrix, the following 3 zones are defined:

- “Negligible effects” zone corresponds to dangerous phenomena with sufficiently low frequencies and consequences that probably will not be significant. There is no need to evaluate these scenarios any more.
- “Medium effects” zone corresponds to the reference accident scenarios that will probably have significant impacts. These scenarios are selected for further detailed assessment of severity.

- “High effects” zone corresponds to reference accident scenarios that will certainly have significant impacts. These scenarios are selected for further detailed assessment of severity and additional safety barriers should be proposed.

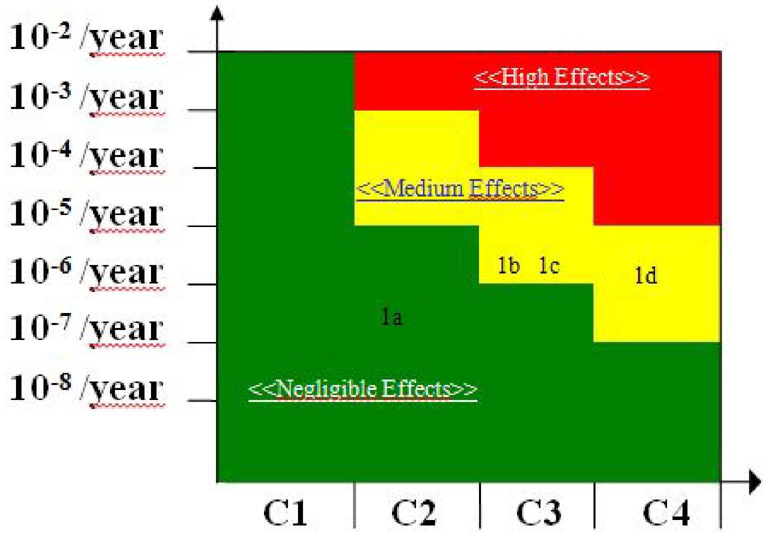

Figure 7 – Risk matrix with results.

It is necessary to state that the risk matrix in this phase of the methodology does not decide about the acceptability of risks but that it merely selects the reference accident scenarios that are further modeled for the purposes of severity determination.

For the determination of individual distances, any mathematical model can be used. With regard to the fact that the use of computing module is entirely independent of the methodology for the determination of index S, the user can employ any mathematical model for the evaluation of accident effects. Distances for particular levels of effects were calculated using the recognized Dutch model EFFECTS. One of advantages of this model is a possibility of calculation of consequences of fires, explosions and dispersion of toxic substances. Table 3 states the results in the form of distances (in meters) for particular levels of consequences d1 – d4 (d1 – small effects, d2 – reversible effects, d3 - irreversible effects, d4 – lethal effects) and for each dangerous phenomenon that was selected as a reference accident scenario. The type of consequences expresses one of four possible serious effects of accidents (thermal radiation, overpressure, missiles, toxic effects).

Table 3 –Results of range distances of dangerous phenomena for CE10

Dangerous phenomena	**d1**	**d2**	**d3**	**d4**	**Frequency (/year)**	**Type**
1b) VCE	260	165	75	45	1.4E-06	overpressure
1c) Flashfire	72	72	68	35	1.4E-06	thermal
1d) Fireball	430	330	255	195	1.0E-06	thermal

Another case study of methodology ARAMIS applications can be found in e.g. (Nevrly, 2004), (Delvosalle, 2004) or (Bernatik, 2005).

4. CONCLUSIONS

The application of the ARAMIS methodology in an industrial plant using the LPG as a fuel for powering forklifts is described. The aim was to test the applicability of the methodology to such types of risk sources. The following conclusions can be stated:

- ⇒ ARAMIS enables the assessment of risk sources containing the LPG.
- ⇒ In a number of steps, pre-defined data facilitate the procedure of detailed risk assessment.
- ⇒ However, making the analysis is difficult from the specialist as well as time point of view.

In spite of rather high professional and time demands, the ARAMIS methodology can be recommended as a suitable approach to the carrying out of quantitative risk analysis.
From the results it follows that it is the explosion of LPG storage tank (deadly consequences within a distance of about 195 m) that represents the greatest threat to the population and employees of the industrial plant. It is necessary to state that in the plant, high-level safety is ensured; many technical and organizational measures are implemented. For example, spraying equipment above storage tanks as a safety measure to protect against BLEVE type explosions was additionally installed (see Figure 8). In the plant, the equipment was installed as a result of an accident of a similar filling station abroad and recommendations of the multinational owner.

Figure 8 – LPG filling station after installed spraying equipment.

5. ACKNOWLEDGMENTS

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6. REFERENCES

ARAMIS. (2004). *Accidental Risk Assessment Methodology for IndustrieS in the framework of the SEVESO II directive,* User Guide, contract number: EVG1–CT–2001–00036, December 2004, from: http://aramis.jrc.it

Bernatik A., Horehledova S., Nevrla P. (2005). Harmonised approach to the assessment of major accident risks in the framework of Seveso II Directive: Case study on ARAMIS methodology application. *Komunikacie*, 7(3), 38-44.

CCPS. (1989). *Guidelines for Chemical Process Quantitative Risk Analysis – CPQRA.* Center for Chemical Process Safety of the American Institute of Chemical Engineers, New York, ISBN 0-8169-0402-2

Delvosalle C., Fiévez C., Pipart A. (2004). ARAMIS Project, Deliverable D.1.C.

Guidelines for Quantitative Risk Assessment, (1999). *Guidelines for Quantitative Risk Assessment, "Purple Book", CPR 18E.* TNO, The Hague, ISBN 90-12-087961

Hourtolou D., Salvi O. 2004. ARAMIS project: Achievement of the Integrated Methodology and Discussion about Its Usability from the Case Studies Carried Out on Real Test Seveso II Sites, *Loss Prevention and Safety Promotion; Proc. intern. symp., Prague, 1-3 June 2004*.

Mannan, S. (Ed.). (2005). *Lees´ Loss Prevention in the Process Industries: Hazard identification, assessment and control*, Third Edition, Elsevier, ISBN: 0-7506-7555-1.

Nevrly V. (2004). Srovnání metod pro hodnocení rizik závažných havárií, diplomová práce, (Comparison of Methods of Major Accident Risk Assessment, Diploma thesis), VSB-Technical University of Ostrava.

Tixier J., Dusserre G., Salvi O., Gaston D. (2002). Review of 62 risk analysis methodologies of industrial plants. *Journal of Loss Prevention in the Process Industries 15, Elsevier, pp. 291-303.*

Using business process modelling notation to improve learning process in a high-risk industrial facility

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Abstract
Health and safety issues are very important aspects of the operation in high-risk plants, like the refineries. One of the relevant elements of safety management is learning from incidents. Research on learning in organizations is often focused on the ability of the new knowledge to lead to *changes* in the relevant settings. We assume that learning also covers *confirmation* of existing knowledge and gaining deeper *comprehension* of existing practices at the refinery. Learning processes implemented in refineries could be complex due to the multiplicity of actors involved (interacting employees) and the performance of learning activities could be highly individualized. The motivation for our research has been to understand learning processes implemented in a European refinery and to provide measures and recommendations to improve learning from incidents.
The visualization of the organizational processes is an established method facilitating the understanding by explicitly presenting the interdependencies between the actors (units) as well as the nature of those links, e.g. the flow of information or communication patterns. Links represent the flow of information, its type and form. However, visualization of studies of organizational learning is not common. The novelty of the presented approach consists in the use of the graphic representation for improving the learning process in the refinery.
In order to present the learning processes in the refinery we apply the approach called Business Processes Modeling Notation (BPMN). BPMN visualizes interdependencies of the processes and records all accident and near miss information in an easy and transparent way. We used BPMN to understand, optimize and re-engineer the learning processes in the refinery.
In this paper we sketch the graphic representation of the learning processes in the refinery. It helps understand how the process is accomplished, who the stakeholders are and their related roles, how they communicate and what type of information they pass. Graphic representation of the processes enables fast identification of the loops, for example in incidents management.
Negative impact of the loops on the performance of the processes is related to the fact that any loop requires a repetition of one or more of the activities. Repetition slows down the whole process and increases the use of the human and material resources. The identification of loops and their elimination or modification is a method that improves the efficiency of processes. It is worth to note that the loops identified in visualization are a different concept than "the learning loops". Organizational loop corresponds to the repetition of identical activities and involvement of the same actors while "learning loops" assume the change of information contents by the application of sets of additional rules or reflection on the learning process itself. BPMN enables the identification of organizational loops in the process of learning, which provides the basis for improvement and simplification of the whole process. Rationalization of information flow inside an organization should contribute to facilitation of the process of learning from incidents.
In this paper we propose a set of performance measures adapted to the BPMN. The assessment of the performance of learning in an organization could, for example, be done by analysing the ability of various loops to accumulate knowledge, the time needed for this accumulation, the number of employees having access to knowledge and so on. The aspect of access to knowledge is particularly addressed in this paper in order to provide a deeper comprehension of one of the performance measures based on empirical data from the refinery.

Keywords: learning process in organization, modeling of organizational processes, business processes modeling notation,

1. INTRODUCTION
Learning is a crucial topic to organizations that want to be powerful competitors in the modern economic world. Research on learning in organizations is often centred on the ability of new

knowledge to lead to changes in the relevant settings. We assume that learning also covers confirmation of existing knowledge and gaining deeper comprehension of existing practices in the organization.

Organizational learning (OL) is a multilevel process and can be considered in a wider perspective. Wang and Pervaiz (2002) in their work present the five focuses of the concept to clarify the understanding of organizational learning. According to them, OL may depend on the following assumptions: process or system, collective aspects of individual learning, culture or metaphor, knowledge management and continuous improvement. In our work it is important to focus on the OL as process and knowledge management, and this we can observe in Crossan's work about 4I process and in Nonaka's dynamic theory of organizational knowledge creation (Barker Scott, 2011; Crossan, Lane, and White, 1999; Nonaka, 1994; Wang and Pervaiz, 2002).The health and safety issues are very important operational aspects in high-risk plants such as refineries. The intensification of research in the field of safety was caused by the series of disasters in the 1980s, i.e. Bhopal (1984), Chernobyl (1986), Challenger (1986) and Piper Alpha (1988) (Le Coze, 2013). At present, to prevent the incidents many organizations put a lot of effort in safety management, and learning from incidents (LFI) is one of its relevant elements. LFI can be defined as: learning from incidents by individuals and groups in organizations with the aim of improving safety (Russell Vastveit, 2015). Learning from incidents is a complex process, that is defined by the Swedish Centre for Lessons Learned from Incidents and Accidents (NCO) as: "learning from accidents is to extract, put together and analyse and also to communicate and bring back knowledge on accidents and near-misses, from discovery to course of event, damage and cause to all who need this information. The purpose is to prevent the occurrence of similar events, to limit damage, and thereby improve safety work" (Lindberg, Hansson and Rollenhagen, 2010). Incidents can refer to unwanted and unexpected events in the form of accidents and near misses (which include potentially harmful conditions that are discovered) (Russell Vastveit, 2015). We assume that incidents include occupational accidents, process safety incidents and near misses that lead or can lead to losses in human lives, property or the environment.

Organizations expect, that through learning from incidents they will increase the level of safety and they will prevent the occurrence the same or the similar events. However, organizations have a lot of problems with the reduction of the number of incidents. According to Drupsteen and Guldenmund (2014), it can be associated with inappropriate management of LFI. In the literature we observe interest in activities aimed at the identification of factors that hinder and facilitate the LFI process, and proposals to improve the process (Drupsteen and Guldenmund, 2014; Lindberg et al., 2010; Lukic, Littlejohn and Margaryan, 2012). In order to improve the process it is very important to understand complex processes such as learning from incidents. For this purpose Lukic et al., (2012) highlight four main factors: type of knowledge, type of incidents, learning process and participants, who influence the process.

Due to the constantly increasing interest and demand for improving the process of learning from incidents, in this article we propose an innovative method to improve the LFI process at the organizational level using the BPMN. BPMN is a specific language, which consist of a set of graphic elements and rules for their application that enables graphic representation of business processes, such as learning from incidents, accomplished in an organization.

For this purpose we explain how organisations learn to use knowledge obtained from investigation of incidents, then we describe learning from incidents and the role of the process in organizations. Next, we refer to the role of graphic representation of procedures used in organizations and we clarify what BPMN is and why we used this type of notation.

2. ORGANIZATIONAL LEARNING

To remain competitive in the modern economic world organizations must fulfil new requirements imposed by consumers and other organizations; the key factor to fulfil these requirements is learning in the organization (Gilaninia, Abdolhasan Askari Rankouh, and Abbas Poor Gildeh, 2013). In the literature relating to learning in an organization, depending on the discipline and the trends of research scholars, there are many definitions and concepts of learning in organizations. Moreover, concepts of organizational learning discussed in the literature can be classified according to five focal points such as: focus on collective nature of individual learning, focus on the process or system, focus on culture or metaphor, focus on knowledge management and focus on continuous improvement (Wang and Pervaiz, 2002).

Learning in organizations can be defined as multilevel processes, through which members individually and collectively acquire knowledge by acting together and reflecting together.

Knowledge is acquired, created and applied by individuals. Then individual knowledge is shared, combined, expanded, tested, and applied amongst individuals to become group or community knowledge. As that knowledge is captured, disseminated and embedded in organizational strategies and protocols, it becomes part of an organizational context. Knowledge internalized in procedures influences individual and group learning (Barker Scott, 2011). We assume that learning also covers confirmation of existing knowledge and gaining deeper comprehension of existing practices within the organization (Braut and Njå, 2012).

In our work we present OL in the context of learning from incidents, therefore we consider OL in terms of learning of the stakeholders of LFI, dissemination and utilization of knowledge obtained from LFI process, and we take into account the tension between the acquisition of new knowledge and utilization of existing learning stock.

It is therefore important in terms of the above conditions proposed by the Crossan model *4I*., in which it is assumed that the OL is multilevel and takes place at 3 levels: individual, group and organizational level (Crossan et al., 1999). In this model, learning starts from individual level, and all three levels are related with each other by social and psychological processes of: *intuiting, interpreting, integrating* and *institutionalizing*. An important issue addressed in this model is the tension between assimilating new learning (*exploration*) and using what has been learned (*exploitation*). Exploration refers to the feed forward process and occurs in individual learning further continued by the group and organizational learning and exploitation called also the feedback process starts from the organization and moves to the group and individual levels (Crossan et al., 1999).

Another assumption, which takes into account the fact that organizational learning has got the starting point at the individual level is the concept of March (1991). He developed a cycle of mutual learning, through which organization learns from its members at the individual level and over time acquired knowledge is embedded in the strategy, procedures, standards, practices, protocols and forms. That influences the beliefs, behaviours and openness to new science of individual members of the organization. March (1991) in his work also showed the tension between consideration of new learning by the members and the use of existing learning, which he described as *Functional Constructs of Exploration and Exploitation* (March, 1991).

Management of knowledge derived from the process is important from the point of view of learning from incidents in organizations. Nonaka developed *the Dynamic Theory of Organizational Knowledge Creation* (Fig. 1), which describes the acquisition of knowledge and its transformation at the level of individuals as a process of internalizing and externalizing knowledge. Central theme of this theory assumes that organizational knowledge is created through continuous dialogue between tacit and explicit knowledge, that is knowledge which is difficult to articulate using plain language and knowledge which can easily be expressed with words. The Dynamic Theory of Organizational Knowledge Creation, similarly to previously presented OL models, also takes into account learning between individual, group, organizational and inter-organizational levels. Transformation of tacit and explicit knowledge takes place through the following steps: *socialization, externalization, combination* and *internalization*. The Figure below depicts the transformation of two types of knowledge: tacit and explicit at every stage of the process and shows how stakeholders influence each other at every stage.

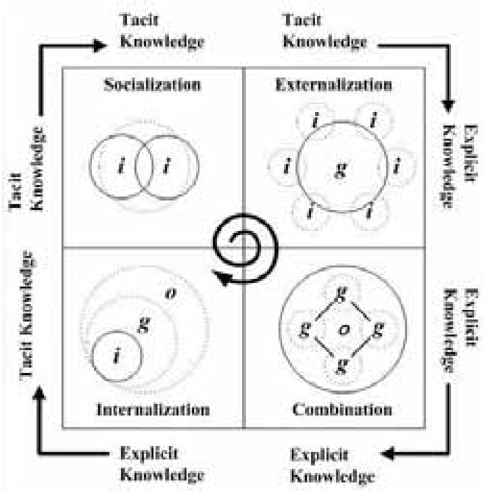

Figure 1 - The Dynamic Theory of Organizational Knowledge Creation

Another interesting assumption in organizational learning is presented in the work of Gilaninia et al. (2013) where organizational learning is presented as a set of organizational activities such as knowledge acquisition, information distribution, information interpretation, and memory that consciously or unconsciously affects positive development of organizations (Gilaninia et al., 2013). These stages are very important aspects when considering learning from incidents.

3. LEARNING FROM INCIDENTS

Learning from incidents leads to improved safety and prevents unwanted events in organizations, if the LFI process is appropriately understood and managed. Therefore, literature shows great interest in the topic expressed by practitioners and scientists. LFI is often described as a process consisting of consecutive steps. Depending on the model, processes differ from each other in the number of stages and activities included in stages, but the crucial purpose of the all LFI models is the same and it is to obtain knowledge from incidents and then improve the safety at work through preventing the re-occurrence of the same or similar events (Drupsteen and Guldenmund, 2014; Lindberg et al., 2010; Lukic et al. 2012)

One interesting LFI model described in literature is the Chain model proposed by Lukic et al. (2012). This model consists of five steps: reporting of accidents (possible incidents), selection, investigation, and dissemination of the obtained results and actual prevention of such accidents (Lukic et al. 2012). A more complex LFI model is the one developed by Drupsteen and Guldenmund (2014) that consists of eleven steps divided into four stages: investigating and analysing incidents, planning interventions, intervening and evaluating. Each of the stages leads to results considered to be vital inputs into the next stage of the learning process (Drupsteen and Guldenmund, 2014). According to both presented models, learning process is as strong as its the weakest link and if some of the stages are lesseffective, the whole process does not bring the potential learning lessons and changes. In the chain model attention is paid to the dissemination of knowledge and information obtained from analysis and investigation of incidents. Such dissemination of lessons can be considered another learning process. Similar assumption is presented in Ramanujam and Goodman's (2011) work, where during the learning from event analysis there is a sub-process called *Learning Process* that includes cyclic steps such as: storage, retrieval and sharing. According to their assumption, the model implies that learning is also a set of processes at the group level and the results are newly established repertoires (Ramanujam and Goodman, 2011). This assumption can be linked to some aspects of organizational learning.

Literature seems to focus on studying the learning process and identifying factors that hinder and facilitate the process at every stage. There are also actions proposed to increase the effectiveness of the whole LFI process, however, researchers highlight the investigation and analysis of the incident stage and they put less efforts in studying the rest of the stages or simply overlook them (Drupsteen and Guldenmund, 2014; Lindberg et al., 2010). To achieve the best results that will lead to the prevention of occurrence of incidents and to improve the safety in an organization we need to understand the entire process of learning from incidents. Therefore, according to Lukic et al. (2012) in order to clarify the nature and to understand the LFI process it is necessary to explore four main aspects that influence it, namely: participants, type of knowledge, type of incidents and learning process.

Learning processes implemented in refineries could be complex due to many actors involved (interacting employees) and the performance of learning activities could be highly individualized. However, learning that takes place can be done at individual, group or organizational level, and such assumption is associated with organizational learning (Ramanujam and Goodman, 2011).

In order to obtain appropriate learning from incidents, it is important to consider the type of aspects of knowledge. Lukic et al. (2012) presented three forms of knowledge: conceptual ("knowing why" and "knowing what"), procedural ("know-how") and dispositional.

For organizations the learning from severe incidents it is very important issues that could help in their prevention. However, the near misses are the crucial source of learning from incidents as they are much more frequent than the severe accidents.

In LFI the key issue is to receive appropriate results. To this end, investigation committees should perform investigation deep enough to find out the immediate but also the underlying causes of incidents (Lukic et al., 2012). With reference to the aspect of learning process presented by Lukic et al., (2012), the causes of incidents are related with the single and double-loop learning. While single-loop learning is based on the solutions to errors that can correct superficial elements of the problem, i.e., address the immediate causes, double-loop learning includes an open inquiry into deep-root causes, system failures and values.

4. GRAPHIC REPRESENTATION OF ORGANISATIONAL PROCEDURES

In order to increase the effectiveness in achieving goals set out in in-house policies, organizations implement the Integrated Management System (IMS), which consists of processes, procedures and practice. IMS is designed to support quality management, environmental management and management of health and safety. The procedures included in the IMS describe how incidents should be dealt with. In those procedures we can find, inter alia, the following information: how incidents are defined; what are the ways to manage incidents depending on their type; who participates in the process and what roles particular stakeholders play in the LFI process; how information about incidents, knowledge and results obtained from LFI process is disseminated; how the systems are used to manage incidents. However, although the procedures describe activities and provide information on how to manage incidents, organizations have problems with achieving the best effectiveness and efficiency of the process. This is due to many factors and, e.g., when we consider reporting it is very important how incidents are defined and what reporting procedure is followed. Because employees working in different departments and at various positions are engaged, it is vital to provide a procedure understandable to everyone. Reporting should be easy and as fast as possible and contain meaningful information about the incident. Besides, we need to select incidents for follow-up activities, such as an investigation or analysis conducted by an appropriate person, who receives information about incidents. The selection should be based on a method that enables choosing incidents offering the maximum learning potential. When it comes to investigation, the important aspect is to quickly initiate the work of the committee. To obtain good results from the investigation of an incident, the committee should consist of people having appropriate knowledge on the specific type of incident in order to identify various causes that have led to a particular incident.

To prevent incidents it is crucial to implement preventive measures developed as a result of the investigation. In order to achieve this objective, it is important is disseminate the results among persons who implement preventive measures. For this purpose, results should be transmitted to appropriate persons to follow-up the implementation.

The above mentioned requirements regarding the content and understandable description of procedures raise problems concerning the management of incidents. To facilitate the understanding of implemented processes in organizations, those processes could be presented in graphic ways. Visualization of organizational processes is an established method that facilitates the understanding by explicitly presenting interdependencies between the actors (units) as well as the nature of those links, e.g. flow of information or communication patterns (Piotrowski, 2007). The links represent the flow of information, its type and form. However, the application of visualization into the studies of organizational learning is not common. The novelty aspect of the presented approach is the use of graphic representation for improving the learning from incidents in the refinery, through graphic presentation of procedures related with the learning process and finding the places to improve.

Graphic representation of the procedures that influence the management of incidents and learning from them facilitates the understanding of how the process is accomplished, who the stakeholders are and their related roles, how they communicate and what type of information they pass (Piotrowski, 2007). Graphic representation of the processes enables fast identification of the places for improvement, for example in incident management processes.

Every process can be shaped depending on the assumptions and the choice of the best solution is dictated by our requirements. Piotrowski (2013) in his work presents main optimization issues in view of the minimization of the process time and the workload.

To ensure good management of processes, it is important to implement efficient procedures , therefore they should not include any loops. The negative impact of the loops is related to the fact that any loop requires the repetition of one or more of the activities. Repetition slows down the whole process and increases the use of the human and material resources. The identification of loops and their elimination or modification is a method for the improvement of the efficiency of processes. It is worth to note that the loops identified in the process of visualization are a different concept than “the learning loops”. The organizational loop corresponds to the process of repetition of identical activities and the involvement of the same actors while “learning loops” assume the change of the information contents by application of the sets of additional rules or reflection on the learning process itself (Lukic et al., 2012).

Graphic representation of organizational procedures enables to identify organizational loops in the process of learning, which is the basis for improvement and simplification of the whole process. The rationalization of information flow inside an organization will improve the process of learning from incidents.

5. BUSINESS PROCESS MODELING NOTATION (BPMN)

In organizations a lot of complex business processes occur, which involve stakeholders who work in various organizations or departments and perform different tasks, which are supported by distinct systems. In order to facilitate the work of the participants to the process a system of notation was developed by the organization called *Business Process Modeling Initiative*, which enables graphic representation of business process (Piotrowski, 2007).
In the literature we can see interesting methods of business process modeling, such as, inter alia, ebXM (Electronic Business Extensible Markup Language), BPMN (Business Process Modeling Notation), XPDL (XML Process Definition Language), UML (Unified Modeling Language), EPC (Event-Driven Process Chain). In this paper we have applied the BPMN because of its relevance to standardization, simplicity, power of expression and a large selection of software. BPMN is a specific language, which consist of a set of graphic elements and rules for application in domain tasks that enable the users to graphically represent business processes accomplished in the organization.
As mentioned above, BPMN is standardized and easy to use, which allows the notation to be used by all users withinthe process independently of the level of involvement in BPMN issues. In addition, the simplicity of recording enables quick start of work with the notation. According to the survey prepared by Recker (2008), 70% users of BPMN learned notation by self-education or using it at work and only 13.6% users received formal training in process modeling with BPMN. An advantage of BPMN is the possibility to adjust the level of detail of the processes depending on the requirements of users, which makes it possible for the graphic representation of processes to be used by business and IT communities.
Because of the level of detail of the presented processes using BPMN, we can use visualization to document the processes in order to understand them, to design and analyse them and to improve them. A more complex presentation of processes can be used in automation, re-engineering and optimization.

6. APPLICATION OF BPMN

Below we present a procedure utilizing BPMN followed when investigating incidents. The procedure is a part of the Integrated Management System and is assumed to influence the learning from incidents within a refinery. The procedure which is the subject of our considerations is called “Post-breakdowns investigations”. It consist of three the following parts:

- appointment of the committee for breakdowns,
- documentation of the work of the committee,
- monitoring the delivery of tasks specified in the breakdown report.

The purpose of graphic representation of the organizational procedure is to optimize the process in order to improve learning from incidents. To this end, we visualized the above mentioned organizational procedure, and then we identified places where it needs improvement. We consider changes in the procedure regarding two objectives: improving the flow of process and improving internal communications.
In our work we delimit the optimization and improvement to the first part of the procedure: appointment of the committee for breakdowns. Breakdowns should be understood as unexpected, deviating from the normal state, sudden events, involving, or not, a hazardous substance that may result in risks to the health or life of people or / and the threat of environmental pollution and / or the threat to property.

Figure 2 below shows elements of the procedure which have been optimized.
A part of the process takes place in the Environmental Protection Office (EPO), but the process has got its stakeholders: the Person Who Appoints the Committee (a director) and the Chairman of the Committee. The employees of EPO deal with different tasks related with environmental protection. They, inter alia, participate in investigating breakdowns that lead or can lead to environmental consequences.

The event that initiates the process at this level is the receiving of information about the appointment of the committee from the Person Who Appoints the Committee. After preliminary assessment of the breakdown, the process is divided in two parallel paths. One of them is designed to tell us whether the breakdown should be registered in the "Register of Environmental Accidents". While the other path checks whether an employee from the office has been appointed to the committee; if not and if he/she should have been appointed, an application is sent to the Chairman of the Committee. In order to improve the process, we propose to change its flow. Changes to the procedure are presented in Figure 3. The requirement that has to be met under the task "Breakdown registration in - Register of Environmental Accidents" is related with the requirements connected with "Applying for an extension of the committee with an EPO worker". Therefore the two inquiries (gates) can be replaced with one. This change allows to simplify the process maintaining its objectives. Before the improvement, the process could lead to a situation where a breakdown relevant from the point of view of the Environmental Protection Office is entered only into the "Register of Environmental Accidents", while nothing is happening with respect to the membership of the committee, even if an EPO employee, who should have been involved in the investigation is not a part of it or vice versa: a breakdown has been studied by an appropriate employee but has not been entered into the register. The improvement allows participants to better manage their work and visualization can lead to better understanding of the process, which following the improvement is easier to grasp. In the context of learning from incidents, the process improvement means relevant breakdowns will be accordingly dealt with, i.e., they will be investigated by EPO staff and will be entered into the Register, meaning the persons who have access to the register can look up the information about breakdowns included in it, the lessons have partially been learned.

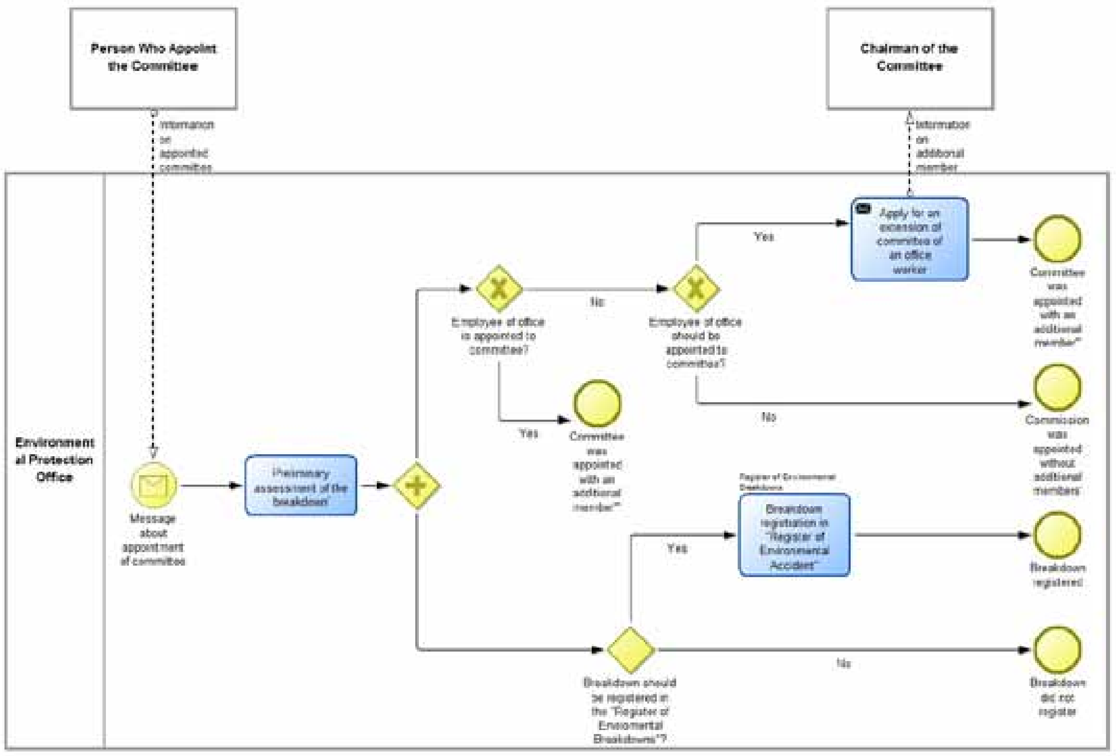

Figure 2 - Visualization of the fragment of the first part of the procedure before improvement.

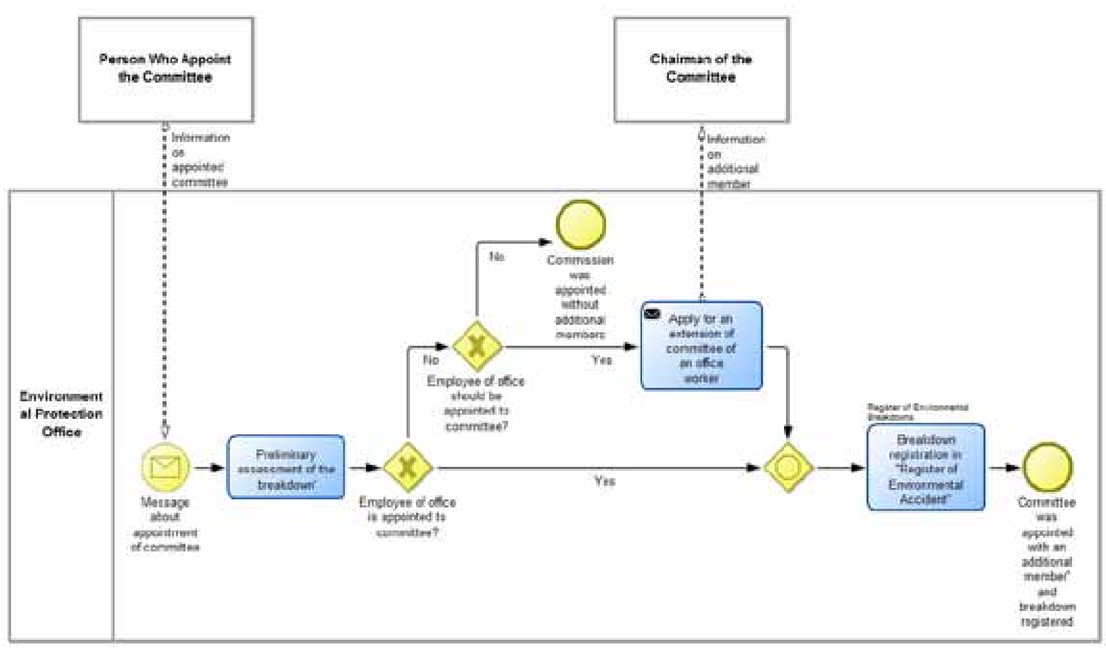

Figure 3 - Visualization of the fragment of the first part of the procedure after improvement – changes in the flow process.

The second assumption aimed to improve internal communications is presented in the next element of the procedure in question; Figure 4 describes the process according to implementing procedures in the organization. Improvement of the process is presented in Figure 5.

This element of the procedure involves three main stakeholders: the Person Who Appoints the Committee (a director), the Chairman of the Committee and of the Team for Reliability and one minor stakeholder from the Environmental Protection Office.

One of responsibilities of the Team for Reliability is to manage the reports of breakdowns and "the register of the breakdown committee". The whole process begins with receiving information about a breakdown by the Person Who Appoints the Committee and next transfers this information to the others above mentioned stakeholders.

In Fig. 4 and 5, the fragment of the process realized by Environmental Protection Office is represented as pool "collapsed" as it was already given in Fig 2. At the level of the Chairman of Committee, the process is initiated by the message. Its first task is a preliminary assessment of event as well as composition of the committee. Next, if needed, the chairman can change the composition by appointment of the additional members. The pool of the Chairman of the Committee contains the process activated by the information sent from EPO office. It is proposal related to the incorporation of the member of EPO into the commission. This sub-process does not interrupt the flow of the main process, but it shows that the additional flows should be considered. The process taking place in the pool, realized by Team for Reliability, is also initialized by information on the appointment of the commission. This information is stored in "the Register of the Breakdown Committee". Next the Team for Reliability sends information on duties of the Chairman of Committee, template of the report and its number. The monitoring of the process of the event analysis is the last step realized in this pool.

In Fig 4 we can see that the information flow is directed from the person who appoints the committee to the rest of stakeholders and next from the team for reliability to the Committee chairman. In our opinion, the fragment of the procedure does not allow to take sufficient care of the dissemination of information, namely there is lack of information flow from the chairman of the committee to the rest of stakeholders. It which can lead to the mistakes when disseminating the results obtained from the investigation of incidents.

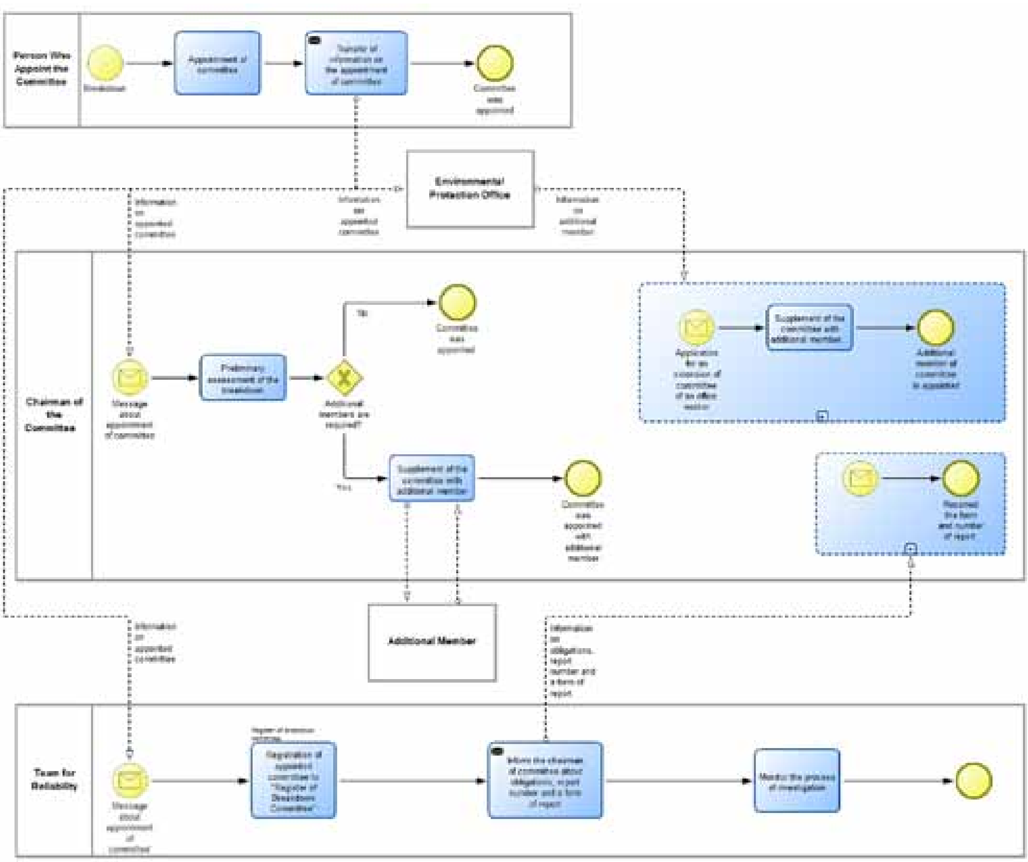

Figure 4 - Visualization of an element of the first part of the procedure before improvement.

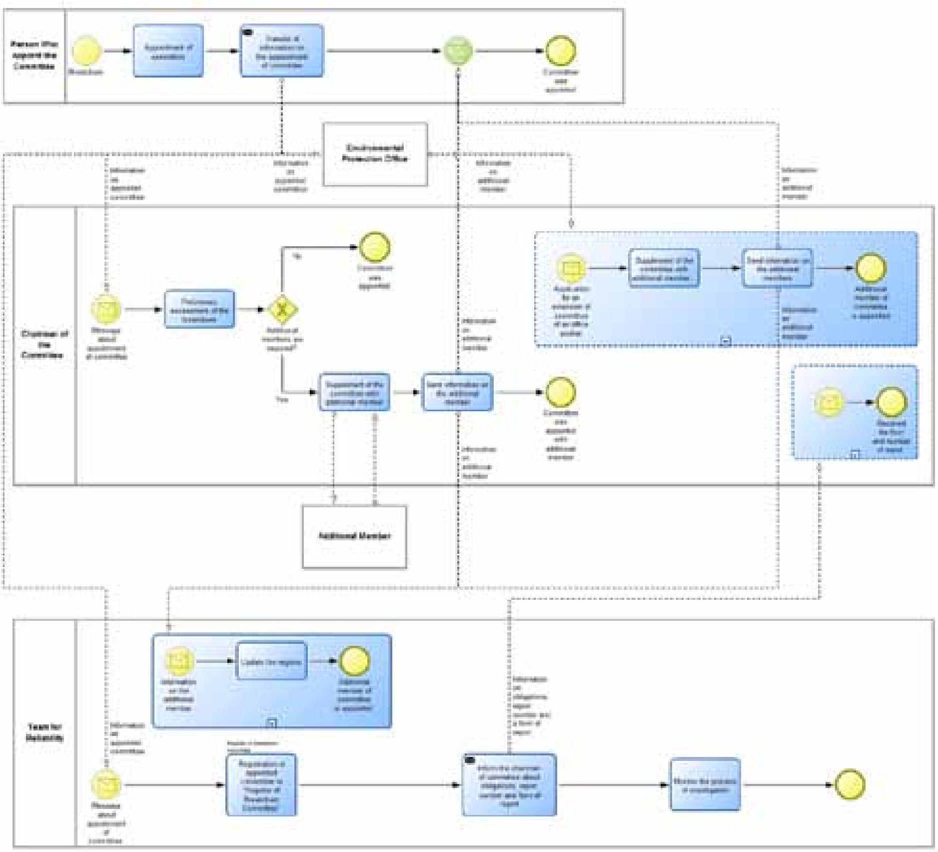

Figure 5 - Visualization of an element of the first part of the procedure after the improvement of internal communications.

7. DISCUSSION

In high-risk facilities such as a refinery, learning from incidents is one of the key elements that allow maintaining competitiveness in the economic world. Therefore, such organizations aim to improve processes and procedures related to learning from incidents. Visualization of organizational processes is an established method facilitating the understanding by explicitly presenting interdependencies between the actors (units) as well as the nature of those links, e.g. flow of information or communication patterns. The motivation behind our research has been to reveal the innovatory aspect of presented approach and to use graphic representation for improving the learning process in organization. Visualization of organizational processes is an established method of their improvement, however it is not a common approach to reflect on improving the learning process.

For our considerations we take the procedure called "Post-breakdowns investigations" that consists of three parts: appointment of the committee for breakdowns, documentation of the work of the committee, monitoring the delivery of tasks specified in the breakdown report. We propose changes in one of the parts of the procedure and those changes are related to two objectives: improving the flow of the process as well as internal communication.

The implementation of changes in some part of the procedure should lead to the improved learning from incidents. It should be expected as information about incidents is disseminated among a bigger group of persons, which is crucial in the learning process. The next issue resulting from the changes at the EPO level that should lead to an improved learning process is the simplification of the flow process. Visualization can lead to better understanding of the process and participants should better manage their work. In the context of improving the learning process the simplification of the process should lead to better management of incidents, which is also important aspects of safety management.

The above proposals to improve are merely preliminary considerations on the subject as is the improving of the learning process and that is why we do not take into account issues such as improvement by minimizing the duration of the process, minimizing the correspondence or workload.

Despite that, obtained results show that the topic of BPMN application to improve learning from accidents should be further considered and focus on the above mentioned aspects of optimizing the processes sets new paths for researchers who are dealing with improving the process of learning from accidents.

8. REFERENCES

Barker Scott, B. (2011) "Organizational Learning: A Literature Review", Queens University IRC.

Braut, G. S. and Njå, O. (2012) "Components of a tool to address learning from accident investigation", *International Journal of Disaster Risk Reduction*, Volume 6, pp. 40-49.

Crossan, M. M., Lane, H. W. and White, R.E. (1999) "An Organizational Learning Framework: From Intuition to Institution", *Academy of Management Review*, Volume 24, Number 3, pp. 522-537.

Drupsteen, L. and Guldenmund, F. W. (2014) "What Is Learning? A Review of the Safety Literature to Define Learning from Incidents, Accidents and Disasters", *Journal of Contingencies and Crisis Management*, Volume 22, Number 2, pp.81-96.

Gilaninia, S., Abdolhasan Askari Rankouh, M. and Abbas Poor Gildeh, M. (2013) "Overview on the Importance of Organizational Learning and Learning Organization", *Journal of Research and Development*, Volume 1, Number 2, pp.44-49.

Le Coze, J. C. (2013) "What have we learned about learning from accidents? Post-disaster reflections", *Safety Science*, Volume 51, Number 1, pp. 441-453.

Lindberg, A. K., Hansson, S.O. and Rollenhagen, C. (2010) "Learning from Accidents - What More Do We Need to Know?", *Safety Science*, Volume 48, Number 6, pp. 714-721.

Lukic, D., Littlejohn, A. and Margaryan, A. (2012) "A framework for Learning from Incidents in the Workplace", *Safety Science*, Volume 50, Number 1, pp. 950-957.

March, J. G. (1991) "Exploration and Exploitation in Organizational Learning", *Organizational Science*, Volume 2, Number 1, pp.71-86.

Nonaka, I. (1994) "A Dynamic Theory of Organizational Knowledge Creation", *Organizational Science*, Volume 5, Number 1, pp. 13-37.

Piotrowski, M (2007) *Business Process Modeling Notation Notacja Modelowania Procesów Biznesowych Podstawy*, BTC, Warszawa.

Piotrowski, M. (2014) *Procesy Biznesowe w Praktyce, Projektowanie, Testowanie i Optymalizacja*, Helion, Gliwice. Ramanujam, R. and Goodman, P. S. (2011) "The Challenge of Collective Learning from Event Analysis", *Safety Science*, Volume 49, Number 1, pp. 83-89.Recker, J. (2008) "BPMN Modeling- Who, Where, How and Why", *BPTrends*, Volume 5, Number 3, pp. 1-8.

Russell Vastveit, K. (2015) *Learning from incidents at a Scandinavian refinery*, PhD thesis, University of Stavanger, Norway.

Wang, K. L. and Pervaiz, K. A. (2002) "A Review of the Concept of Organizational Learning", University of Wolverhampton, Number WP004/02.

Work related traffic safety – the potential of expanding enterprises' HES management to encompass traffic safety issues

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Abstract

A major part of the traffic and accidents on Norwegian roads are related to transport connected to work. The ISO 39001:2012 "Road traffic safety (RTS) management systems. Requirements with guidance and use", has been issued for increasing safety. The study presented in this paper was organized in three major phases. First, we analyzed the ISO 39001 with the aim to address what matters and how enterprises that adopt the standard would be able to influence traffic safety on the public roads. The standard's assumption of possible users, objectives, underlying accident models and recommendations of risk reducing measures were also part of the analysis. Next, we made four case-studies in relevant enterprises from various sectors, with the aim to discuss how their representatives responded to the idea of implementing a standard like ISO 39001 as part of the HES management. The interviews from the case-studies and the background information were further developed into a Delphi-survey in which 36 traffic safety and HES experts responded. The issues were; 1) Prerequisites for a successful implementation of ISO 39001; 2) tools at hand to implement the standard, 3) possible effects of an implemented standard, and 4) Norwegian Public Roads Administration's (NPRA's) role and options related to implementation of the standard in enterprises using the Norwegian public roads.

We conclude that ISO 39001 represents an interesting opportunity in the Norwegian context of traffic safety work. Internal control principles have been in place in Norwegian enterprises for more than 20 years, and road traffic safety is getting societal foothold as an important value. However, the driving forces for implementing a traffic safety standard in enterprises must become much more visible for enterprises being the dominating stakeholders in the road traffic system. In real competitive life, it is difficult for managers and employees to internalize the philosophy "traffic safety is part of everything we do". Thus, the premises for easy implementation and related benefits needs careful consideration. Here, the NPRA plays an important role being the traffic safety coordinator. Through a well-communicated implementation of the traffic safety standard in NPRA's own organization, the experts anticipated amplifications in other enterprises. This will lead to increased knowledge in the road-user population about traffic accident causes and traffic safety, possibly implying increased acceptance of traffic regulations (speed limits, signs and traffic marking).

Keywords: ISO 39001; risk management, traffic accidents, road authorities, implementation of codes.

1. INTRODUCTION

A major part of the traffic and accidents on Norwegian roads are related to transport connected to work. The ISO 39001:2012 "Road traffic safety (RTS) management systems. Requirements with guidance and use", has been issued for increasing safety. The Norwegian Government has adopted the Zero Vision strategy since 1999, which is operationalized by the Norwegian Public Roads Administration (NPRA). This strategy fits very well with the ideas in the ISO 39001, thus the NPRA as a major stakeholder for transport safety has taken an initiative to assess the traffic safety potential in ISO 39001 as a traffic safety measure in Norway. The general Norwegian regulation on health, environment and safety (HES) could become an attractive option for also implementing traffic safety.

In order to understand the contents of ISO 39001 and who the standard approaches as end-users we did a content analysis of the standard. The standard sees traffic safety in a systems perspective, where it is assumed that traffic safety is a system property created by road users, vehicles, road design, surroundings and the regulation regime. The major goal with the standard is to better control road traffic safety and reduce the number of serious injuries and deaths from road accidents. By developing requirements to the components of the road system, ISO 39001 expect to develop a more resilient system, of which the interaction between the components also imply significant safety effects.

Accident preventive effects can be achieved through reduced road traffic loads due to enterprises collaborating to optimise logistics, the ISO 39001 might promote improved condition for public transport, pedestrians and cyclists becomes prioritised in planning processes, and the ISO 39001 promotes traffic safety behaviour in general. The use of the standard enhance the following goals:

- Use of the standard influences traffic accidents in which organisational factors are significant contributors.
- Use of the standard enables enterprises to focus on own goals as well as societal goals through social corporate responsibilities.
- Use of the standard enables enterprises to adopt a mind-set of continuous improvement, through leadership’s involvement in traffic safety management activities.
- Use of the standard enables enterprises to tailor-make its traffic safety work to its own activities and risk levels.
- Use of the standard enables enterprises to acknowledge that the responsibility for traffic safety is a shared responsibility, not an issue for the public roads authorities alone.

The users of the standard seem to be:

- *Traffic generators*. Organizations that have activities that generate traffic such as; department stores, schools, sport arenas, etc.
- *General enterprises*. All enterprises with employees that use the road system back and forth to jobs or official journeys, either by car, by (motor)cycle or walking.
- *Professional transport enterprises*. Enterprises that provide commercial goods or person transport services, or enterprises that administer contracts on transport services. Examples on this is bus transport, taxi, commercial goods transport (heavy goods vehicles or other vehicles), etc.
- *Road designers*. Organisations that perform services directly at the road system, for example engineering, construction, maintenance on roads and vehicles, emergency services etc.
- *Certifying organisations*, employed to carry out revisions in enterprises to control conformity.
- *Individual employees* influenced by their organisations.

ISO 39001 is a product of the mind-set of high reliability organisation (HRO) theory, which is seen in its weight upon organisational measures to influence traffic safety (La Porte & Consolini, 1991; Roberts, 1990; Weick, 1987). This mind-set of the possibilities to design reliable systems from unreliable components is adopted by societal systems. James Reason’s book on safety management (Reason, 1997) has been very influential in the Nordic countries’ development of traffic safety approaches based on the Zero Vision philosophy. The ISO 39001 promotes collective mindfulness (Weick, Sutcliffe, & Obstfeld, 1999), traffic safety barriers (Vinnem, 2009) and safety culture/climate (Guldenmund, 2000). The standard addresses processes within the enterprises to include traffic safety concerns. By doing such activities the standard infer that implementing more technical vehicle measures, driver behaviour measures and emergency preparedness measures will naturally be part of the safety management processes.

ISO 39001 provides some ideas for user incentives, which could enhance the end-users’ views of the standard being useful and meaningful to them. These are:

- Accreditation in accordance with the standard (status).
- Obtain better traffic safety records (societal responsibility).
- Increase the available time for production by reducing unavailability due to accidents, injuries and damages (economic factors).
- Increase the enterprises’ trust and affirmative effect in their clients and stakeholders (credibility).

However, in order to succeed, implementation of a standard on traffic safety, as part of enterprises HES systems, need to overcome obstacles as well. Organisations’ use of time connected to strategies, planning, analyses, documentation, communication etc., could be regarded counterproductive, especially if road transport is not part of the core activities. There might be competence barriers, because ISO 39001 assume high competency related to analysis and design of traffic safety measures. Normal enterprises do not possess that kind of competency and must either hire or purchase the services. The incentives related to corporate social responsibilities could be challenging, and it is difficult to predict effects such as reduced number of accidents, reduced costs related to operation and management of the vehicle fleet, reduced number of sick leave, improved reputation etc. A major challenge is to identify the potential of the benefits from implementing a traffic safety standard. These concerns led us to the major issue of the work presented in this paper:

What potential does the ISO 39001 has as a traffic safety measure in the Norwegian society?

This paper reports on a study carried out for the NPRA in 2014/2015 (Njå, Bjelland & Braut, 2015). We have a futuristic perspective (looking into the future), and the idea was to reveal important assumptions and conditions that the NPRA and other enterprises responsible for traffic safety standards can supervise, and thereby influence the implementation process of the ISO 39001 in the Norwegian enterprises.

This paper is organised with first a presentation of a Delphi study involving professional transport enterprises, road designers, traffic generators and certification organisations. Then we present findings from four example cases; municipal home care services, public transport, grocery trade and the taxi sector. The findings are assembled and discussed to the end of the paper.

2. SOME RESULTS FROM THE DELPHI-STUDY

The aims of the study were to identify different views on what potential, in terms of increased traffic safety, a standard on traffic safety adopted by Norwegian enterprises could have. The investigation was inspired by the Delphi-technique developed in the early 1950-ies (Linstone & Turoff, 1975). The methodology assumes that if we lack data on a subject or a phenomenon, eliciting expert opinions is the only feasible approach to data collection. Based on our knowledge of the transport sector and participation on two relevant conferences, we defined our “experts” from important enterprises. No one is really experts on the implementation of standards and at the same time an expert within the traffic safety domain. We chose persons based on their knowledge and experiences from management of relevant enterprises, knowledge of their own enterprise, interest in traffic safety, investigation of and experience from hazardous and accident events in road traffic, and education of drivers. We asked 51 persons, of which 36 agreed to participate (just after Christmas and with short notice, a 70 % response rate was considered very good). The study had one iteration. The first survey was sent to the respondents, they answered and the results were then sent to the experts once more in order for them to change their views after reconsideration. 50 % of the respondents replied the second time, which we reported separately.

The questionnaire was constructed with 23 statements, to which we asked the respondents to assess with a Likert scale from 1 (totally disagree) to 7 (totally agree). We asked the experts to comment upon his or her assessment with free text related to each statement. This gave us valuable perspectives on the subject matters. The statements were sectioned into four groups: 1) statements related to prerequisites for Norwegian organizations ability to adopt and benefit from international traffic safety standards; 2) statements related to how the standard could be effectively implemented in Norwegian organizations; 3) statements related to what effects an implemented standard could have, and; 4) statements related to the NPRA’s role and possibilities to implement and increase the likelihood of gaining the potential benefits of managing traffic safety according to the ISO standard.

The most prominent prerequisites for implementing the ISO 39001 are first of all that the enterprises must recognize their own need for managing traffic safety within their HES-work. The experts think that many enterprises have not realized this and even the professional commercial transport enterprises acknowledge the fact that traffic safety is not part of their enterprise management. Another important issue is the need to realise other positive effects than safety, such as improved economy, well-being, reputation, being a preferred collaboration partner, reduced fuel consumption etc. This factor was enhanced after the second iteration. The third prominent factor is leadership involvement. An expert described it like this: “To introduce a standard requires nothing, implementation require a deeply involved management”.

Many experts were convinced that specific and measurable requirements to traffic safety as part of the tenderers’ HES systems would positively influence the implementation of the standard. However, there was objections related to the structure in the transport sector. A lot of the transport is carried out by very small companies (one or two persons), which will not be capable to adopt the standard.

The largest part of the survey was the experts’ anticipation of effects from an implemented standard. We mixed organisational effects with more direct effects on the road in order to see how the experts responded. We did not ask the experts whether they meant that an implemented standard showed direct effects on number of accidents, because it is very difficult to address any link between occurrences of accidents and organisational factors. However, the experts do believe that an implementation of ISO 39001 would be very positive, cf figure 1.

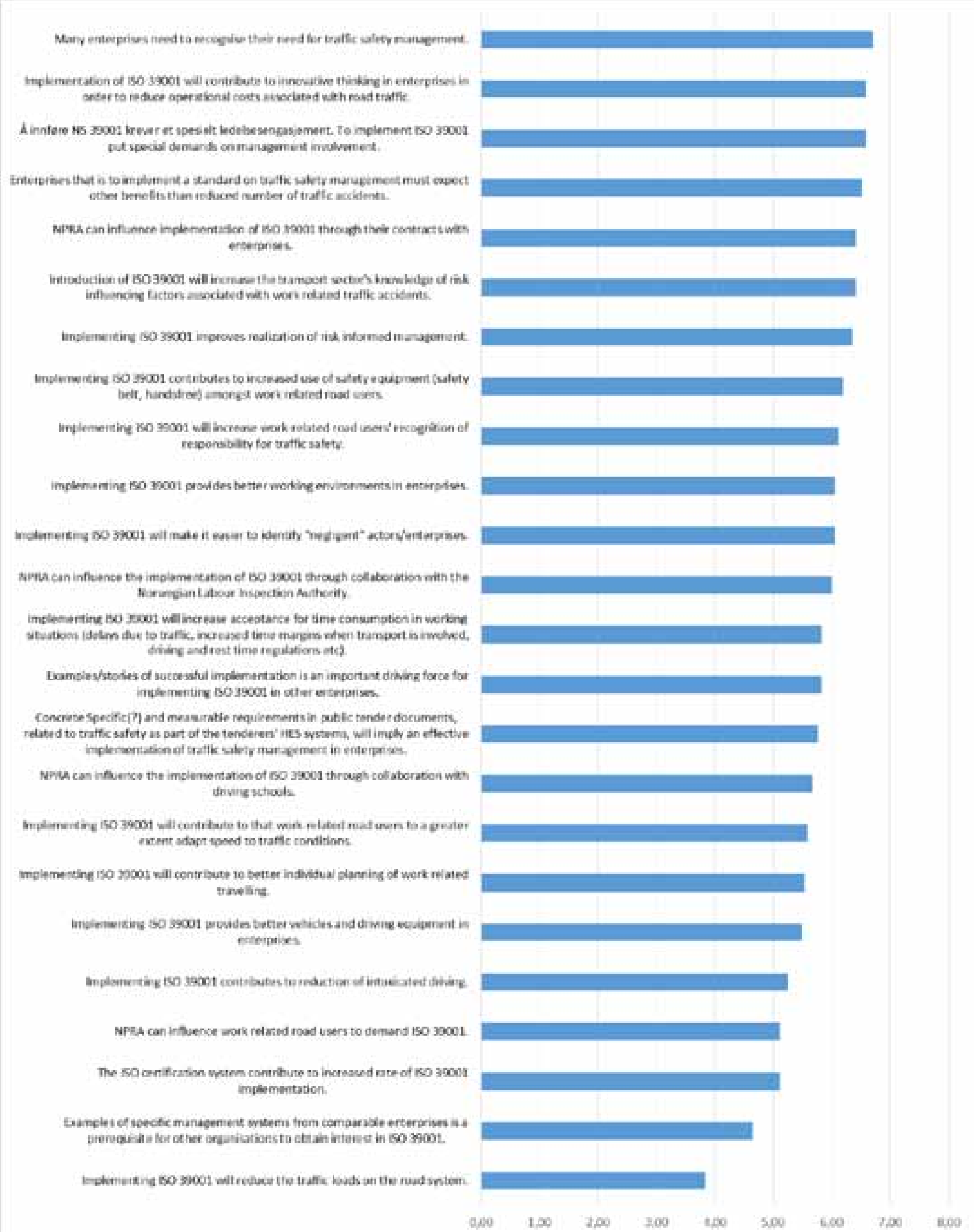

Figure 1, average scores of the experts’ assessments of potentials of implemented standard

The experts are generally positive to the potential of the standard, especially with regard to organizational effects. This includes the organizations' ability to think out of the box (innovation), the conduction and outcomes of risk management processes, a better working environment and the organizations' willingness to accept traffic safety responsibility. The experts were more reluctant to agree with our statements related to intermediate effects on the roads, such as drug or alcohol abuse and speeding. However, the experts were positive to our statement that the standard would enhance usage of personal safety equipment, such as seat belts.

These results coincides very well with other similar studies (Coglianese, 2012). For example, studies of health supervision often present statements on correlation between supervision activities and health effects, but they lack scientific evidence (Packard, 2013; Riksrevisjonen, 2014). In the health sector the focus is shifted to intermediate factors which might influence the effects from the supervision activities (Coglianese, 2012). An important finding is that the enterprises that are exposed to supervision activities must possess intention, ability and capability to carry out change processes (Kotter, 1996). Thus, engaged leadership is very important to prepare the organization for changes, within the frames of the enterprises' responsibilities, sizes and frame conditions. The number of experts that responded to each statement in our study varied (35-30). This could be interpreted as a measure of self-assessed competencies and their uncertainties. Instead of speculating into the most uncertain factors we conclude that these should be further studied.

The experts also considered the NPRA's role in the implementation processes of the standard. The most prominent factors here was that the NPRA could use its power in contract negotiations and their collaboration with the Norwegian Labour Inspection Authority and thus be very effective. However, the experts were not so harmonized about the sole positive effects, and objections such as the Norwegian Labour Administration do not have a constructive attitude to working activities, foreign companies will make good intentions problematic because they do not conform to the standard, the NPRA is not assessed as a consistent contract administrator – price is the only criteria.

3. FOUR CASES OF SECTORS WHERE ISO 39001 IS RELEVANT

From rather context free assessments from experts, we also looked at four cases, in which we interviewed key informants. We wanted to challenge the key informants on the essence of the standard and see how they responded. Only some of the respondents were familiar with ISO 39001, but the relevance of the standard was high for all the enterprises interviewed. They were:

- Municipal home care services in a medium sized Norwegian municipality (approximately 20 000 inhabitants),
- Public transport based on a large area in the Norwegian context (approximately 400 000 inhabitants).
- Grocery trade company, one of the largest companies in the sector.
- The taxi sector in Norway, two major enterprises.

Below we list the major findings from the cases.

3.1 Municipal home care service

Geographically it is a rather small municipality, approximately 115 km^2. The interview data reveals that the employees in the home care service might travel as much as 100 km on their duty. Even though there exist driving plans, these are often departed due to emerging events. The employees on duty are often contacted via cell phones during transport, which demand some sort of flexibility. All the cars have Bluetooth and hands-free. The respondents emphasized that the small cars were minimum equipped and the cars were perceived as ordinary. The organisational working pressure is high, but there have not been many serious accidents. Minor events causing scratches and other damages occur often, and many employees have been fined for speeding. Traffic safety is not on the agenda and neither not a part of the HES-system. When the respondents were asked for things that they wanted different they replied; 1) Heat traced steering wheel (to avoid cold hands when they meet and treat the clients) and stronger motors (for better ability to navigate to distant places).

3.2 Public transport

This case involves interviews with representatives from a transport administrator and a transport contractor.

The transport administrator is an enterprise owned by the regional government, and it is responsible for administering three major contracts on public person transport in the county, which comprised regular public transport, transporting pupils and ferry transports. The transport administrator promotes employees to use the public transport and financially support long-term tickets. Within their sector the respondents claimed that a standard like ISO 39001 (they were not familiar with the standard) would only be effective if it was implemented in the key enterprises, and that these enterprises collaborated on achieving results in the traffic safety area. They suggested a “traffic safety council”, which could regularly meet, but they were clear on that it must not become a bureaucracy provider. The respondents was particularly concerned with the public roads authority’s role and involvement. The respondents had manager roles and they claimed that the management in collaboration with the board could be very influential in the implementation process of such a standard. Traffic safety was regarded important and they listed school transport, mixed transport activities in the terminals, road widths, design of stops and tunnels partly closed as critical areas. Their major concern was the information flow, which in their opinion could be significantly improved.

The transport contractor is a large national contractor working on two of the contracts within the county. The company provides services at sea, rail and road. The contractor is certified in accordance with ISO 9001 and ISO 14001. Traffic safety is managed in two ways; they have a traffic safety committee, which investigates events; and they carry out their own traffic safety education program with their drivers. The company put weight on latent conditions and underlying causes of accidents in their traffic safety work. They use their traffic safety information system actively. They had been involved in a fatal accident some years ago, and in the summer 2013 the company was involved in a collision with person injury in this particular region. The respondent claimed that key enterprises and their leaders, such as the director of the public roads administration might be very influential regarding implementation of ISO 39001 in the sector. Barriers against successful implementation of the traffic safety standard was not a bigger challenge than implementing changes in general, there is always resistance in organisations he said. The respondent meant that road transport could learn much from the sea transport with respect to traffic safety.

3.3 Grocery trade

The company studied is a large national grocery transport business. We studied the Oslo section. Their transport services are characterised by: Short travel distances in heavy traffic, and thus relatively low speed; generally acceptable road infrastructure, but often quite complex routes and narrow access points at delivery stations; a high technical standard on vehicles, and; nearly a monopoly situation with regards to contracts (the organization deliver goods to its own grocery chain). The organization is already working systematically with traffic safety issues. This includes performing risk analyses of new processes and transport routes, accident investigation, safety courses for the employees, registration of the drivers’ safety behaviour in traffic, acknowledgment of good safety behaviour. Their incentives were: The standard need to be demanded by clients, the management in the organizations need to believe in the standard and the processes it entails, the management need to be good role models for the employees, the employees need to feel heard, and the employees could receive bonuses for good road traffic behaviour. The respondents complained about the commercial goods transport sector, which has a deserved bad reputation, and the respondent emphasized foreign companies providing services in Norway completely unfamiliar with Norwegian conditions.

3.4 Taxi-sector

In this case we interviewed respondents from the taxi trade organisations and two representatives from two of the largest taxi centres in Norway. There are two different organisational structures of taxi centres. One type of centres is owned by the taxi owners (minor companies of few drivers). In this case the taxi owners are both employers and subordinate of the managing director of the centre, which might provide challenges for the directors’ ability to manage for example traffic safety. The other structure is a regular limited company working as a taxi centre. Taxi owners are related to the centre through distinct contracts, but in this case they are free to leave for other centres if the taxi owners are dissatisfied in one way or another. The respondents meant that organisational structures was a big challenge for managing traffic safety in the taxi sector. However, the sector experiences few accidents, and when they occur the consequences are usually minor. An accident is very critical for the single taxi owner because his or her economic margins does not put up with many damages. Incentives for implementing ISO 39001 were perceived to be: reduced fuel cost, service cost and operational costs, and potential demands from the government, clients and the insurance sector.

Challenges was raised: It is difficult to influence the taxi owners. The respondents had difficult to see the connection between traffic accidents and the law on working environment. Recording working hours is difficult. Tender assessment is entirely about price, nothing else. There are many foreign taxi drivers, which struggle with cultural conditions and language. The tacit knowledge and oral communication complicates traffic safety information.

In one of the taxi centres they had employed a supervisor working in the field looking up taxi drivers to influence them in the real and active working situations. Various foreign cultures have been influenced by addressing informal leaders. Government campaign directed towards the taxi sector, for example through audits have been successful. The taxi centres have developed their own training programs that drivers must follow.

4. IMPLEMENTATION OF STANDARDS – IMPORTANT FACTORS

Phillips & Meyer (2012) claim that road transport is the largest accident risk in many enterprises. Traffic safety as a HES-measure in organisations is becoming an important issue at the European agenda, inter alia through the *European Transport Safety Council* and *European Safety and Health Agency.* The Norwegian national transport plan (2010-2019) suggests that traffic safety should be implemented in the HES-work in the governing of the working life.

The transport sector is diverse, and so is the end users deploying the road infrastructure in their businesses. Two important dimension to characterize the involvement in work related road transport is the level of functions and the enterprises' connections with road elements, see figure 2. The elements are to be understood in a systems perspective, that is the road, the road users, the vehicles and the emergency response systems, and they are parts of an overall system property (Leveson, 2011), also encompassing surroundings (weather, climate, road conditions) and frame conditions (regulation regimes, economics, culture etc.). Functions in road transport is shown to the left side of figure 2, and the more and comprehensive involvement in the functions connected with elements it decides what level of involvement exists from minor focus up to key enterprise, cf. figure 3.

Our study is based on interviews and expert opinions. What are the qualities of this material and can we say that the reliability and validity is satisfying? Critics would say that the data is persons expressing strong opinions in an area one knows little about. Such critics are often seen in studies with a futuristic perspective, such as risk analyses, prognoses, scenario-descriptions and Delphi studies. Our underlying assumption is not positivism rather socially constructed assessments of what the future might look like if the ISO 39001 was implemented in a huge number of enterprises. It is not estimates of true values, but the experts beliefs. This is the best knowledge we can obtain and it is not arbitrary statements from random people. We have included a variety of backgrounds and experiences in our study, and we have found good correlations between the cases and the survey data, in which we think strengthen our findings. However, there are uncertainties, which should be followed up. The precisions in the responses varies, and we have therefor been very concerned with experts and interviewees to reveal their reasons for the assessments. But what are the heuristics and biases? The respondents do have a common interest in the field of traffic safety, which could provide too optimistic responses (Kahneman, Tversky, & Slovic, 1982 - representativeness heuristics). Since we do not use the absolute numbers of the scale, we think we have reduced the effect of representativeness heuristics.

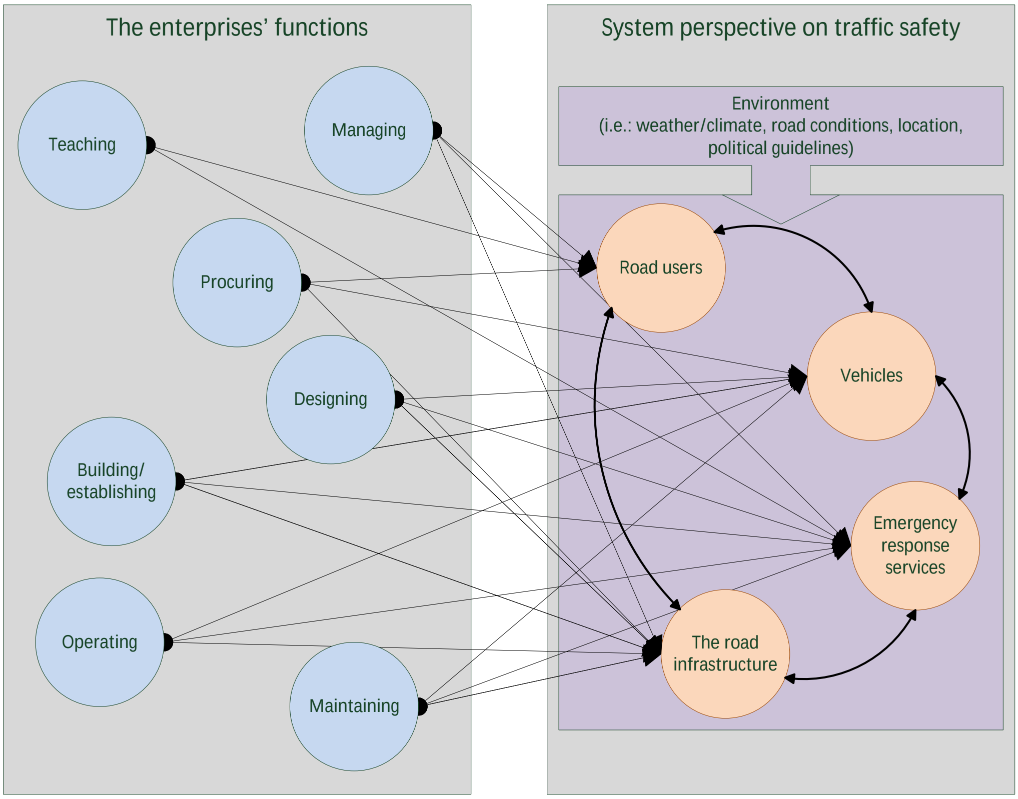

Figure 2 – Functions and links to elements in a road traffic system perspective

The major findings in our study are as follows:

- There is a traffic safety potential in the enterprises' self-realization and knowledge of their need to manage traffic safety.
- Traffic safety management must be perceived as meaningful, thus measures that increase the knowledge, measures that increase leadership engagements, success stories and customer requirements and incentives, are needed.
- Customers are important stakeholders. If the customers demand traffic safety through ISO 39001, this will be a powerful prerequisite.
- Important stakeholders, such as the NPRA, the Police and the Norwegian Labour Inspection Authority, must be good role models.
- The effect of implementing ISO 39001 could be measured through intermediate factors, such as increased work satisfaction, reduced fuel consumption, reduced maintenance and operational costs, improved quality of vehicles and equipment, better speed adaption amongst road users, increased use of safety equipment in vehicles, and generally improved traffic safety knowledge amongst road users.
- The NPRA has many options to influence the implementation of ISO 39001, e.g. through their development of regulations, contracts with entrepreneurs, consultancies, and vendors, internal HES work, collaborations and networking activities in sectors, and aiding tailor-made traffic safety management packages for various businesses.

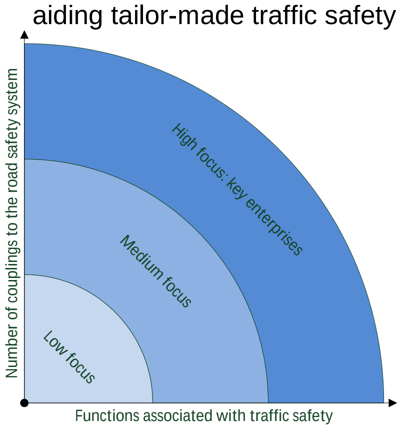

Figure 3, layers of enterprise categories in the traffic safety area

Wallington et al. (2014) have studied British Telecom's (BT) implementation of a risk-based management system for work-related transport. BT has 95 000 employees and a high transport workload. It is interesting to note that the number of traffic accidents in BT fell by 50 % in the ten-year period from 2002 to 2012. There is a strong correlation between the number of insurance claims per 1000 vehicles and the number of conducted risk assessments. The study has also identified many weaknesses in the coupling between scientifically based knowledge and practical working skills and experience. This is a bi-effect the assessors had not beien able to identify without the implementation of a risk-based regime, such as the ISO 39001.

We are of the opinion that it would be very difficult (impossible) to measure the effect of ISO 39001 in terms of accidents (severely injured and killed) directly. Still, it is natural to believe that, over time, we would see a reduction in the number of accidents if we measure improvements on intermediate effects. Enterprises, such as BT, claim that a commitment to traffic safety management has given a severe positive effect (Wallington et al., 2014), but they have not collated their results with the general improvement in traffic safety in Great Britain during the same period. To isolate effects from organizational initiatives, such as implementing a system for traffic safety management, is very difficult. Our own studies of the commercial goods transport identifies positive attitudes towards the effect of HSE-related work in enterprises. Of the enterprises that responded to our investigation, 26.5 % had experienced severe accidents (killed or severely injured) the past ten years (Njå & Fjelltun, 2010). HSE-related work in the enterprises was not only associated with positive attitudes. A factor we identified was that HSE-related work reduces work motivation. In our opinion, a successful implementation of ISO 39001 in Norway entails a great deal of efforts from key enterprises.

5. CONCLUDING REMARKS

A reinforced risk-informed system for traffic safety management, in the form of ISO 39001, is considered an effective initiative towards better traffic safety by most of our respondents. Our results show that the key enterprises with regard to traffic safety; the NPRA, the Police, the Norwegian Labour Inspection Authority, the county councils and municipalities need to strive to be good role models. This means showing that they can manage traffic safety in accordance with the main principles in the standard. If the NPRA are to succeed with a requirement, which requires that cooperating enterprises and vendors certify in accordance with ISO 39001, they will need trust from the surroundings. A first step towards building trust is that the NPRA begins with itself, and implement the principles of the standard. A subject that occupied our respondents was contracts. If clients demand the standard, implementation is likely to succeed.

Another important aspect is to clarify the contents of the concept "work-related driving", identify the extent of such driving and collate this against accident production. We recommend the NPRA to conduct a study of a sample of randomly selected reports from accidents involving severely injured and killed persons (zero-vision accidents), to identify how work-related driving is treated: Are accidents seen as the driver's own responsibility? Or is there consistency in the accident insurance provided by the employer and the mode of treatment conducted? What roles do employers and employees take?

Our respondents clearly express that there is a potential for enterprises to acknowledge their own needs for traffic safety management. The NPRA could for instance use the ongoing work associated with developing a *HSE-charter in the building and construction industry* as a gateway to introducing traffic safety as a natural part of the enterprises' management systems. The NPRA is already one of the parties that have signed the HSE-charter. Other parties who have signed the charter is, e.g.: the Norwegian National Rail Administration, the Norwegian government's key advisor in construction and property affairs (Statsbygg), the Norwegian Association for Consulting Engineers (RIF), the Federation of Norwegian Construction Industries (BKL) and the Norwegian Association of Heavy Equipment Contractors (MEF).

When an enterprise fails to acknowledge its needs for systematic traffic safety management, it may originate from lack of knowledge of its challenges with and possibilities to influence traffic safety. The above-mentioned initiatives, associated with clarifying the contents of work-related driving, is important to increase this knowledge in the enterprises. Our major conclusion is that the Norwegian Public Roads Administration should be active in the implementation processes of traffic safety management standards for businesses that use the Norwegian public road systems.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Coglianese, C. (2012). Measuring Regulatory Performance. Evaluating the Impact of Regulation and Regulatory Policy. In Organisation for Economic Co-operation and Development (Ed.), *Expert Paper No. 1, August 2012*: OECD.

Guldenmund, F. W. (2000). The nature of safety culture: a review of theory and research. *Safety Science, 34*(1–3), 215-257. doi: http://dx.doi.org/10.1016/S0925-7535(00)00014-X

Kahneman, D., Tversky, A., & Slovic, P. (1982). *Judgment under uncertainty: heuristics and biases*. Cambridge: Cambridge University Press.

Kotter, J. P. (1996). *Leading change*. Boston, Mass: Harvard Business School Press.

La Porte, T., & Consolini, P. M. (1991). Working in Practice but Not in Theory: Theoretical Challenges of High Reliability Organizations. *Journal of Public Administration Research and Theory, 1*(1), 19-47.

Leveson, N. (2011). *Engineering a safer world: systems thinking applied to safety*. Cambridge, Mass.: The MIT Press.

Linstone, H. A., & Turoff, M. (1975). *The Delphi method: techniques and applications*. London: Addison-Wesley.

Njå, O., Bjelland, H. & Braut, G. S. (2015). Trafikksikkerhetspotensialet i Norsk Standard NS-ISO 39001 [The traffic safety potential in ISO 39001]. Stavanger: International Research Institute of Stavanger.

Njå, O., & Fjelltun, S. H. (2010). Managers' attitudes towards safety measures in the commercial road transport sector. *Safety Science, 48*(8), 1073-1080.

Packard, T. (2013). Organizational Change: A Conceptual Framework to Advance the Evidence Base. *Journal of Human Behavior in the Social Environment, 23*(1), 75-90. doi: 10.1080/10911359.2013.739534

Phillips, R. O., & Meyer, S. F. (2012). *Fatal road accidents involving people at work An analysis of the situation in Norway from 2005 to 2010*. Oslo: Transportøkonomisk institutt.

Reason, J. (1997). *Managing the risks of organizational accidents*. Aldershot: Ashgate.

Riksrevisjonen. (2014). *Riksrevisjonens undersøkelse av statlig tilsynsvirksomhet* (Vol. nr. 2 2014). Oslo: Riksrevisjonen.

Roberts, K. H. (1990). Some Characteristics of One Type of High Reliability Organization. *Organization Science, 1*(2), 160-176.

Vinnem, J. E. (2009). On causes and dependencies of errors in human and organizational barriers against major accidents. In S. Martorell, C. Guedes Soares, & J. Barnett (Eds.), *Safety, reliability and risk analysis : theory, methods and applications* (Vol. 2, pp. 1181-1189). Boca Raton, Fla.: CRC Press.

Wallington, D., Murray, W., Darby, P., Raeside, R., & Ison, S. (2014). Work-related road safety: Case study of British Telecommunications (BT). *Transport Policy, 32*, 194-202. doi: 10.1016/j.tranpol.2014.01.002

Weick, K. E. (1987). Organizational Culture as a Source of High Reliability. *California Management Review, XXIX*(2), 112-127.

Weick, K. E., Sutcliffe, K. M., & Obstfeld, D. (1999). Organizing for high reliability: Processes of collective mindfulness. In R. I. Sutton & B. M. Staw (Eds.), *Research in Organizational Behavior* (Vol. 21, pp. 81-123).

Validation of the Health and Work Survey (INSAT) under Rasch Model Measurement Analysis

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Abstract
Occupational health and wellbeing may be understood as a multi-dimensional phenomenon. It comprises the interaction of physical, psychological and social dimensions, which manifests in the workers cognitions, motivations, behaviors, and self-reported physical and psychological health. The Health and Work Survey (INSAT - Inquérito Saúde e Trabalho) was conceived with the contribution of different European questionnaires, and aims to analyze the relations of work conditions and their consequences in worker health and wellbeing. INSAT is a self-applied survey instrument which focuses on several questions related with work situations and their impact on health and wellbeing. The main goals of this work are to analyze statistically 706 questionnaires applied between 2010 and 2014 and to validate the discomfort scale of the instrument. In the validation process was used the Rasch Partial Credit Model, an extension of Rasch's simple logistic model that is suitable for use when items are scored polytomously. As result from the application of Rasch Partial Credit Model, Person Separation Reliability was obtained (0.8761) and the value can be considered very good (>0.8). From the statistical analysis we can see that Overall Model fit information, given by Outfit Mean square /Infit Mean square, are between 0.5 and 1.5, that means "Productive for measurement" and "acceptable fit overall". As result, these items can generate predictable response patterns. Some of the items do not fulfill these criteria and must be analyzed more carefully to ensure the instrument improvement.

Keywords: health and work relations, survey validation, Rasch Partial Credit Model

1. INTRODUCTION

Occupational health and wellbeing may be understood as a multi-dimensional phenomenon. It comprises the interaction of physical, psychological and social dimensions, which manifests in the workers cognitions, motivations, behaviors, and self-reported physical and psychological health (Ilmarien, 2009; Moliné & Leroyer; Taris, Van Horn, Schaufeli, & Schreurs, 2004).
The Health and Work Survey (INSAT - Inquérito Saúde e Trabalho) (Barros-Duarte & Cunha, 2014) was conceived with the contribution of different European questionnaires, and aims to analyze the relations of work conditions and their consequences in worker health and wellbeing (Barros-Duarte & Cunha, 2010). INSAT is a self-applied survey instrument which focuses on several questions related with work situations and their impact on health and wellbeing.
The INSAT is a good evaluation tool as it focuses on the diverse and variable questions related to the different work situations. In fact, the inclusion of a diverse number of questions related to the work context, even those that focus on a more subjective dimension of work, is one of the main concerns of this questionnaire and a constant point of reference in the suggested methodology (Barros, Carnide, Cunha, Santos, & & Silva, 2015).
To validate the survey instrument it was used the Rasch Partial Credit Model, an extension of Rasch's simple logistic model that is suitable for use when items are scored polytomously. Although the classical statistical methods more used to examine construct validity are exploratory factor analysis (EFA) and Cronbach's alpha, these methods have been criticized by several authors as being insufficient for determining construct validity in psychological survey instruments (Cortina, 1993; S. Green, Lissitz, & Mulaik, 1977; Kline, 2000; Schmitt, 1996; Sijtsma, 2009; Tabachnick & Fidell, 2007; Waugh & Chapman, 2005).

2. MATERIALS AND METHOD

2.1. INSAT

The Health and Work Questionnaire (INSAT: Inquérito Saúde e Trabalho) (Barros-Duarte & Cunha, 2010) was developed in 2007 and suffered some changes in 2010 and 2013. It originated from the contribution of European questionnaires (Barros-Duarte, Cunha, & Lacomblez, 2007) and it aims to understand the notion that workers have of their own working conditions and the impact on their health.

The actual survey, the INSAT 2013 version, is composed by 154 items (questions). Responses to these items are generally dichotomous (e.g., \yes" or \no", \agree" or\disagree") and/or ordinal (e.g., from 1 to 5, where 1 represents the maximum discomfort and 5 represents the absence of discomfort). The survey is self-reported because, as mentioned above, the main goal is to ascertain what the workers' perception is of the effects of their work conditions on their health and wellbeing.

INSAT begins with a set of questions designed to collect general and personal information (gender, age, sector of activity, profession) and followed by queries grouped into seven categories: i) work: a set of questions focused on the job description in terms of the nature of work, type of contract, working hours and shifts; ii) conditions and characteristics of work: another group of questions concentrates on work constraints and their effects on workers, namely, environmental and physical constraints, organizational (pace and autonomy) constraints, relationship (colleagues and customers) constraints, and work characteristics; iii) conditions of life outside work; iv) training and work; v) work and health; vi) my health and my work: another set of questions broaches the effects of work on health, it includes health problems such as: back pain, headache, respiratory, heart and vision problems, and musculoskeletal disorders, among others vii) my health and my well-being: corresponds to the Portuguese version of the Nottingham Health Profile (NHP) (Ferreira & E., 1999).

The INSAT survey was validated by the ethical commission of the University of Porto and University Fernando Pessoa.

2.2. Sample

For the validation process of the INSAT survey instrument it was used a sample with 706 Portuguese workers. The sample included six economic sectors: (a) Health and Social Support (hospital front offices and pharmacists); (b) Education (high school and university teachers); (c) Wholesale and Retail (salespeople, store managers and market cashiers; (d) Manufacturing Industry (highly-qualified and technical staff, middle managers, back office workers, warehouse and logistics workers, and assembly line workers); (e) Public administration and defense (directors, middle managers, case-workers, human resources technicians, front and back office workers), and (f) Other service activities (hairdressers, psychologists). The exclusion criterion of the sample was not having answered a third or more of the questions.

The survey follows the researchers' guidance, and was conducted between 2010 and 2014. We ensured the confidentiality on the data collected by maintaining the anonymity of the participants. All the participants provided signed informed consent to participate.

2.3. Statistical procedures

The statistical analysis applied to this survey was divided into two parts. The first part is based on a descriptive analysis for the groups I – general and personal information items and some work information, III – Conditions of life outside work, IV - training and work; V – Work and health, VI – My health and my work, and VII – My health and wellbeing). The second part is associated with the validation process using the Rasch Parcial Credit model (PCM) applied only to the group II – Conditions and characteristics of work with de sub-dimensions: 1 – Environmental and physical constraints; 2 – Organizational constraints; 3 – Work characteristics. The main goal of this Rasch model application was to validate the group of items with a polytomuos discomfort scale. For that it was used the Rasch Partial Credit Model, an extension to Rasch's simple logistic model, suitable for use when items are scored polytomously and when response categories in each item are ordered but not necessarily equidistant from each other in terms of the latent trait being described. This model specifies that each item has its own rating scale structure. It derives from multiple-choice tests where responses that are incorrect, but indicate some knowledge, are given partial credit towards a correct response. The amount of partial correctness varies across items. This is considered for

some authors as one of the most simplest and useful Item Response Theory (IRT) model (C. Green & Frantom, 2002; Mair, Hatzinger, & Maier, 2009).
The PCM was applied to 76 items from the group Conditions and characteristics of work (with sub-dimensions: 1 – Environmental and physical constraints; 2 – Organizational constraints; 3 – Work characteristics). The scale applied to these items was "reorganized" to be possible to apply the PCM. Because each item of this group has two types of responses, the first part with a dichotomous scale (yes / no) followed by an ordinal discomfort scale (e.g., from 1 to 5, where 1 represents the absence of discomfort and 5 represents the maximum discomfort) the two types of response were transformed and codified in the following scale: 0 – Not exposed and not discomfort; 1 – Exposed and not discomfort; 2 – Exposed and minor discomfort; 3 – Exposed and discomfort; 4 – Exposed and quite discomfort; 5 – Exposed and too much discomfort.
The software used were the R version 3.2.0, with package eRm, and IBM SPSS statistics, version 22.

3. RESULTS AND DISCUSSION

3.1 Sample characterization and descriptive analysis
The descriptive analysis related to gender, age and education applied to the sample of 706 questionnaires is in Table 1.

Table 1 - Sample characterization and descriptive analysis.

	Gender							
	Male	**Female**						
%	37	63						
		Age						
Min.	**Mean**	**Std**	**Max.**					
18	37.65	9.05	63					
				Education				
	Basic Education (1st cycle)	**Basic Education (2nd cycle)**	**Basic Education (3rd cycle)**	**High Education**	**Bachelor**	**Grad.**	**post-grad.**	**Undefined**
%	1	3	22	43	2	23	5	1

Min. – Minimum; Max. – Maximum; NA – Not applicable; Qu. – quartile; Std – Standard deviation; Grad. – Graduate; Post-grad. – Post-graduation.
Other relevant INSAT results are expressed in terms of frequency of exposure to different risk factors – environmental risk factors, physical constraints, work intensification factors of risk – as it is illustrated in Tables 2, 3, and 4 (for higher frequencies: > 50% in our sample)

Table 2 - Frequency of workers self-declarations to environmental risk factors

Exposure to:	Number of workers (%)
Harmful noise	58.1
Temperature variations (heat/cold)	67.3

Table 3 - Frequency of workers self-declarations to physical constraints

Exposure to:	Number of workers (%)
Repetitive gestures	62.0
Standing up at same position for a long period of time	56.0
Standing up with displacements	58.1

Table 4 - Frequency of workers self-declarations to work intensification constraints

Exposure to:	Number of workers (%)
Intense rhythm	52.3
Production norms or strict deadlines	67.7
Having constantly to adapt to method changes or work tools	63.5
Working for long periods at the	57.8

computer	
Frequent interruptions	64.4
Hyper-request	69.0
Having to continue working beyond my assigned timetable	65.5

As we can see, the descriptive analysis revealed the large exposition either to physical and organisational risks in a sample that contemplates six economic sectors and different professions.

3.2 Rasch Partial Credit Model (PCM)
As mentioned before the PCM was applied to 76 items from the group “Conditions and characteristics of work” and for that only 621 questionnaires were valid (all questionnaires with 75 or more missing items responses were eliminated). The Person Separation Reliability was obtained (0.8761) and the value can be considered very good (>0.8). This measure is used to indicate the proportion of person variance that is not due to error. The concept is similar to Cronbach’s α in definition and value (Wright & Stone, 1999).
From the statistical analysis we can see that Overall Model fit information, given by Outfit Mean square /Infit Mean square, are between 0.5 and 1.5, that means “Productive for measurement” and “acceptable fit overall” based on the criteria defined by Linacre (Linacre, 2002). As result, these items can generate predictable response patterns (table 5).

Table 5 - Overall model fit information

	Items	
	Outfit MSQ	**Infit MSQ**
N	**76**	
Mean	1.07	1.08
Std	0.43	0.37

MSQ: Mean square

The statistical results of the item fit are in table 6. The item fit is an index of whether items function logically and provide a continuum useful for all responses.

Table 6 - Item fit statisticals

Sub-dimension	**Item**	**Location**	**Outfit MSQ**	**Infit MSQ**	**Categories Frequencies (%)**					
					0	**1**	**2**	**3**	**4**	**5**
1. Environmenta and physical constraints	i1	-0.76483	1.081	0.994	0.43	0.00	0.08	0.28	0.11	0.09
	i2	-0.15328	0.809	0.93	0.91	0.01	0.00	0.05	0.02	0.02
	i3	0.13325	0.66	0.745	0.97	0.01	0.01	0.02	0.00	0.00
	i4	-0.84329	0.992	0.995	0.35	0.00	0.07	0.30	0.17	0.11
	i5	-0.40886	0.939	0.972	0.75	0.00	0.05	0.09	0.08	0.04
	i6	-0.11035	0.801	0.905	0.91	0.00	0.02	0.03	0.03	0.01
	i7	-0.38451	0.96	1.002	0.70	0.02	0.08	0.08	0.08	0.04
	i8	-0.47059	1.006	1.029	0.67	0.01	0.05	0.15	0.08	0.04
	i9	-0.1367	0.854	0.973	0.90	0.00	0.01	0.04	0.03	0.01
	i10	-0.62869	1.109	1.09	0.41	0.02	0.15	0.25	0.10	0.05
	i11	-0.37545	1.043	1.05	0.61	0.04	0.15	0.14	0.0	0.02

Sub-dimension	Item	Location	Outfit MSQ	Infit MSQ	Categories Frequencies (%)					
					0	1	2	3	4	5
				7					5	
	i12	-0.5767	0.897	0.962	0.57	0.00	0.05	0.18	0.14	0.06
	i13	-0.6196	0.907	0.97	0.59	0.01	0.06	0.15	0.11	0.08
	i14	-0.74473	1.091	1.088	0.45	0.02	0.06	0.22	0.16	0.10
	i15	-0.70093	1.008	1.033	0.41	0.04	0.12	0.23	0.12	0.07
	i16	-0.3832	1.221	1.222	0.59	0.03	0.13	0.18	0.09	0.02
	i17	-0.03817	0.851	0.897	0.81	0.03	0.07	0.09	0.06	0.01
	i18	-0.325	0.929	0.955	0.73	0.03	0.05	0.08	0.06	0.03
	i19	-0.50502	1.084	0.981	0.53	0.04	0.17	0.21	0.10	0.03
	i20	-0.44544	1.204	1.077	0.54	0.06	0.16	0.20	0.10	0.03
	i21	-0.32409	1.022	1.048	0.49	0.12	0.22	0.11	0.05	0.01
	i22	-0.50827	0.97	0.975	0.33	0.12	0.29	0.17	0.06	0.02
	i23	-0.52126	0.835	0.85	0.38	0.15	0.23	0.15	0.06	0.03
	i24	-0.04838	1.396	0.85	0.95	0.00	0.00	0.01	0.02	0.01
	i25	-0.40967	1.067	1.06	0.44	0.08	0.21	0.17	0.0	0.02
	i26	-0.70868	0.975	0.99	0.37	0.03	0.14	0.24	0.1	0.06
	i27	-0.11461	**1.804**	0.97	0.95	0.00	0.01	0.01	0.0	0.02
	i28	-0.633	0.914	0.92	0.31	0.09	0.23	0.25	0.0	0.04
	i29	-0.15064	0.929	0.96	0.74	0.04	0.08	0.09	0.0	0.01
	i30	-0.69585	1.038	1.03	0.37	0.10	0.21	0.18	0.0	0.06
2. Organizational constraints	i31	-0.56133	0.886	0.92	0.70	0.02	0.05	0.09	0.0	0.07
	i32	-0.64166	0.82	0.87	0.52	0.06	0.13	0.13	0.0	0.07
	i33	-0.53785	0.94	0.93	0.63	0.07	0.09	0.10	0.0	0.06
	i34	-0.06135	0.856	0.93	0.88	0.01	0.03	0.03	0.0	0.01
	i35	0.06733	0.599	0.80	0.97	0.00	0.01	0.01	0.0	0.01
	i36	-0.20227	0.93	0.95	0.83	0.04	0.05	0.05	0.0	0.02
	i37	-0.15521	0.823	0.87	0.75	0.03	0.07	0.09	0.0	0.01
	i38	-0.44175	1.008	0.99	0.52	0.13	0.15	0.12	0.0	0.03
	i39	-0.56487	0.914	0.96	0.58	0.02	0.09	0.18	0.0	0.07
	i40	-0.01413	0.671	0.85	0.97	0.00	0.00	0.00	0.0	0.01
	i41	-0.5262	0.913	0.93	0.30	0.24	0.19	0.20	0.0	0.02
	i42	0.22644	**0.428**	0.64	0.99	0.00	0.00	0.01	0.0	0.00
	i43	0.22946	**0.222**	0.56	0.99	0.00	0.00	0.00	0.0	0.00
	i44	-0.41632	0.771	0.88	0.76	0.03	0.04	0.07	0.0	0.04
	i45	-0.63979	0.8	0.84	0.65	0.01	0.04	0.09	0.1	0.10
	i46	-0.43462	0.801	0.90	0.76	0.01	0.05	0.08	0.0	0.05
	i47	-0.52513	0.747	0.91	0.81	0.00	0.02	0.04	0.0	0.08
	i48	-0.73167	1.058	1.01	0.66	0.02	0.02	0.07	0.0	0.15
	i49	-0.47223	1.25	1.12	0.85	0.01	0.01	0.03	0.0	0.07
	i50	-0.22249	**1.849**	0.97	0.95	0.00	0.00	0.01	0.0	0.03
	i51	-0.70659	0.884	0.98	0.68	0.01	0.01	0.07	0.0	0.14

Sub-dimension	Item	Location	Outfit MSQ	Infit MSQ	Categories Frequencies (%) 0	1	2	3	4	5
	i52	-0.05354	1.049	0.9	0.97	0.00	0.00	0.00	0.0	0.01
	i53	-0.08229	0.855	0.83	0.97	0.00	0.00	0.00	0.0	0.01
	i54	-0.01923	0.909	0.85	0.95	0.00	0.01	0.02	0.0	0.01
	i55	1.84018	**0.429**	0.52	1.00	0.00	0.00	0.00	0.0	0.00
	i56	0.41941	0.606	1.2	0.98	0.00	0.00	0.00	0.0	0.00
	i58	0.40285	**2.137**	**2.19**	0.45	0.36	0.12	0.04	0.0	0.01
	i59	-0.02694	1.346	1.40	0.53	0.06	0.17	0.15	0.0	0.03
	i60	-0.21181	1.298	1.35	0.56	0.03	0.11	0.17	0.0	0.03
	i61	-0.48175	1.406	1.37	0.63	0.03	0.04	0.11	0.1	0.09
	i62	-0.41238	**1.714**	1.42	0.78	0.02	0.02	0.05	0.0	0.08
	i63	-0.23806	1.164	1.24	0.64	0.07	0.09	0.10	0.0	0.03
3. Work characteristics	i64	0.09899	1.003	1.12	0.86	0.04	0.04	0.03	0.0	0.01
	i65	-0.17694	**1.578**	1.41	0.74	0.03	0.06	0.10	0.0	0.03
	i66	0.43851	0.98	0.98	0.91	0.05	0.02	0.01	0.0	0.00
	i67	0.29088	0.972	1.47	0.94	0.01	0.01	0.02	0.0	0.01
	i68	0.22266	**3.095**	**3.28**	0.54	0.20	0.17	0.07	0.0	0.01
	i69	0.09924	1.269	**1.80**	0.96	0.00	0.00	0.01	0.0	0.02
	i70	0.05046	**2.486**	**1.90**	0.95	0.01	0.00	0.01	0.0	0.03
	i71	0.01828	1.349	**1.57**	0.94	0.00	0.00	0.01	0.0	0.03
	i72	0.24739	**1.618**	1.30	0.96	0.00	0.00	0.01	0.0	0.01
	i73	-0.22707	0.831	1.10	0.91	0.00	0.01	0.01	0.0	0.04
	i74	-0.4736	1.036	1.06	0.75	0.01	0.02	0.07	0.0	0.09
	i75	-0.73442	1.165	1.12	0.50	0.05	0.05	0.12	0.1	0.16
	i76	-0.60369	1.276	1.15	0.64	0.04	0.02	0.12	0.0	0.11

Based on outfit measure (since the Infit measure – information weighted fit statistics – is less sensitive than Outfit measure – outlier sensitive statistics) we can see that in sub-dimension 2 some items (i27 – Take work home; i50 - sexual harassment; i58 – Direct contact with the public; and i62 - Physical aggression from the public), as well as some items from sub-dimension 3 (i65 – monotonous work; i68 – Complex work; i70 – lack of career evolution; and i72 – lack of resources to do my work), under fit the data, meaning that contain unusual and /or inappropriate response patterns (C. Green & Frantom, 2002; Joan Stelmack et al., 2004). In the sub-dimension 2 some items (i42 – no help from colleagues; i43 - rare exchange experiences; and i55 – nationality discrimination) over fit the data, meaning that there are too little variation in the response pattern suggesting redundant items.
From descriptive data (categories frequencies) we can see that, in all items, the 0 (not exposed and not discomfort) is the most observed category from the polytomous scale.

The person-item maps for sub-dimension are presented in Figure 1, Figure 2, and Figure 3 show the location of item (and threshold) parameters as well as the distribution of person parameters along the latent dimension. Person-item maps are useful to compare the range and position of the item measure distribution (lower panel) to the range and position of the person measure distribution (upper panel).

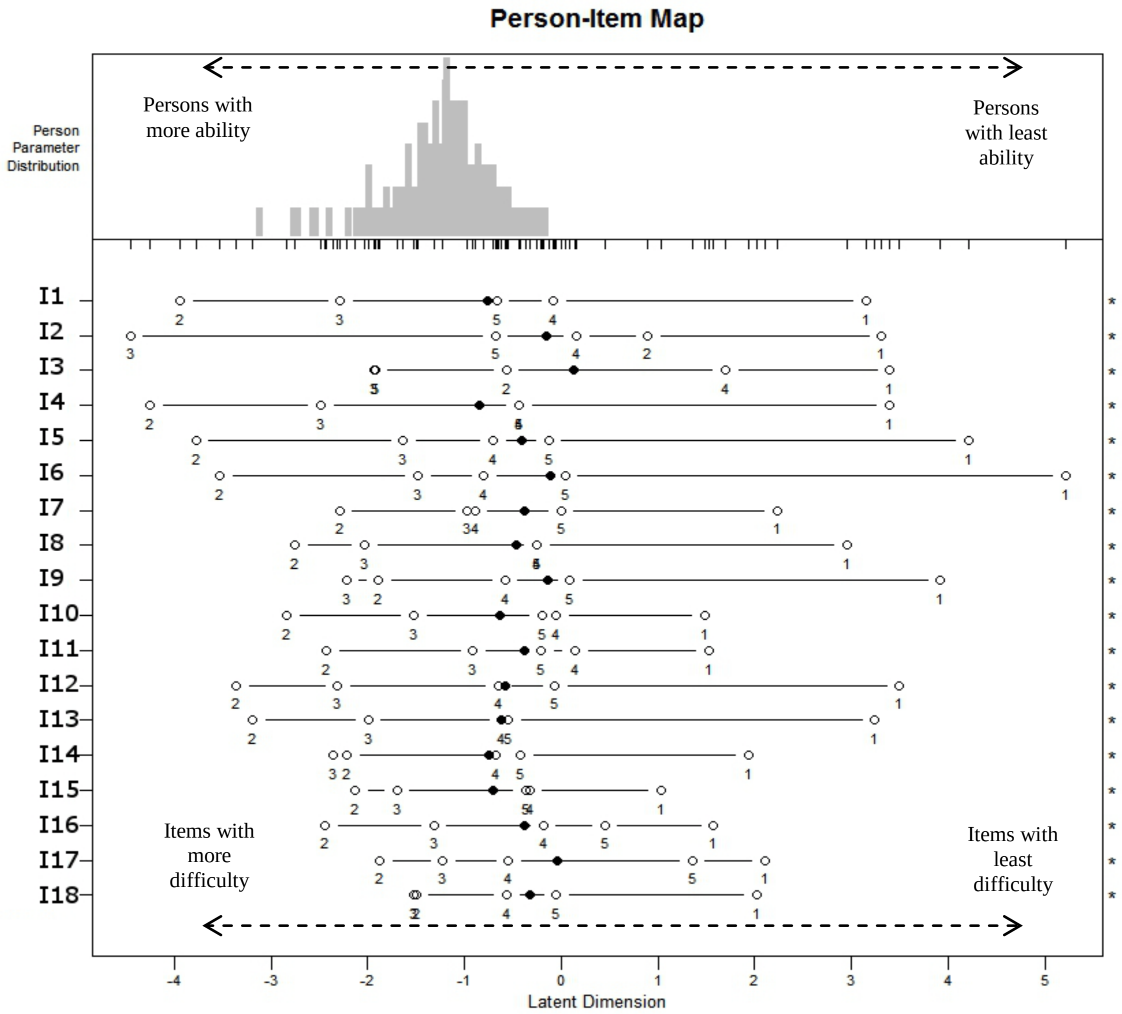

Figure 1 - Person-item map for sub-dimension Environmental and physical constraints

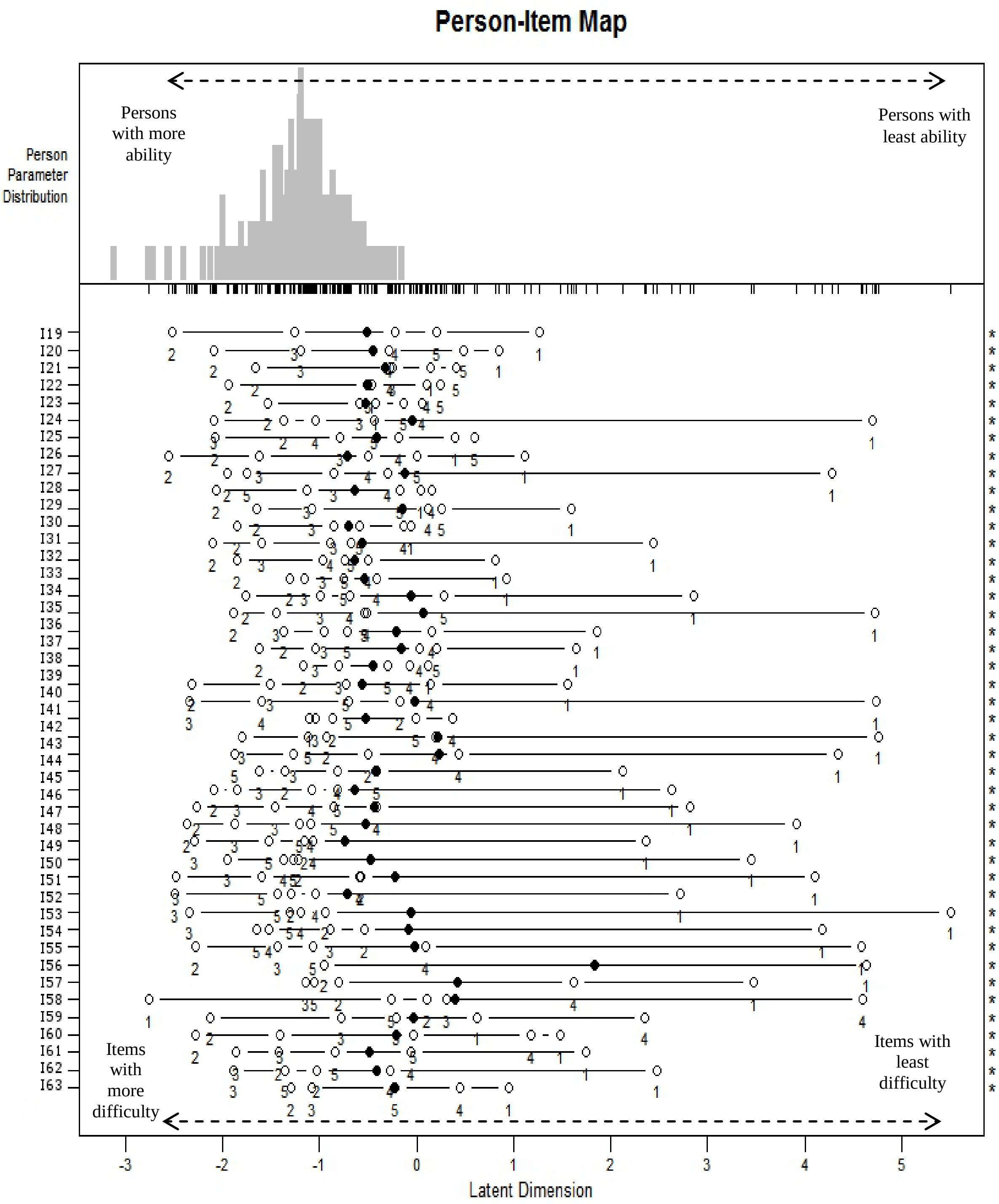

Figure 2 - Person-item map for sub-dimension Organizational constraints

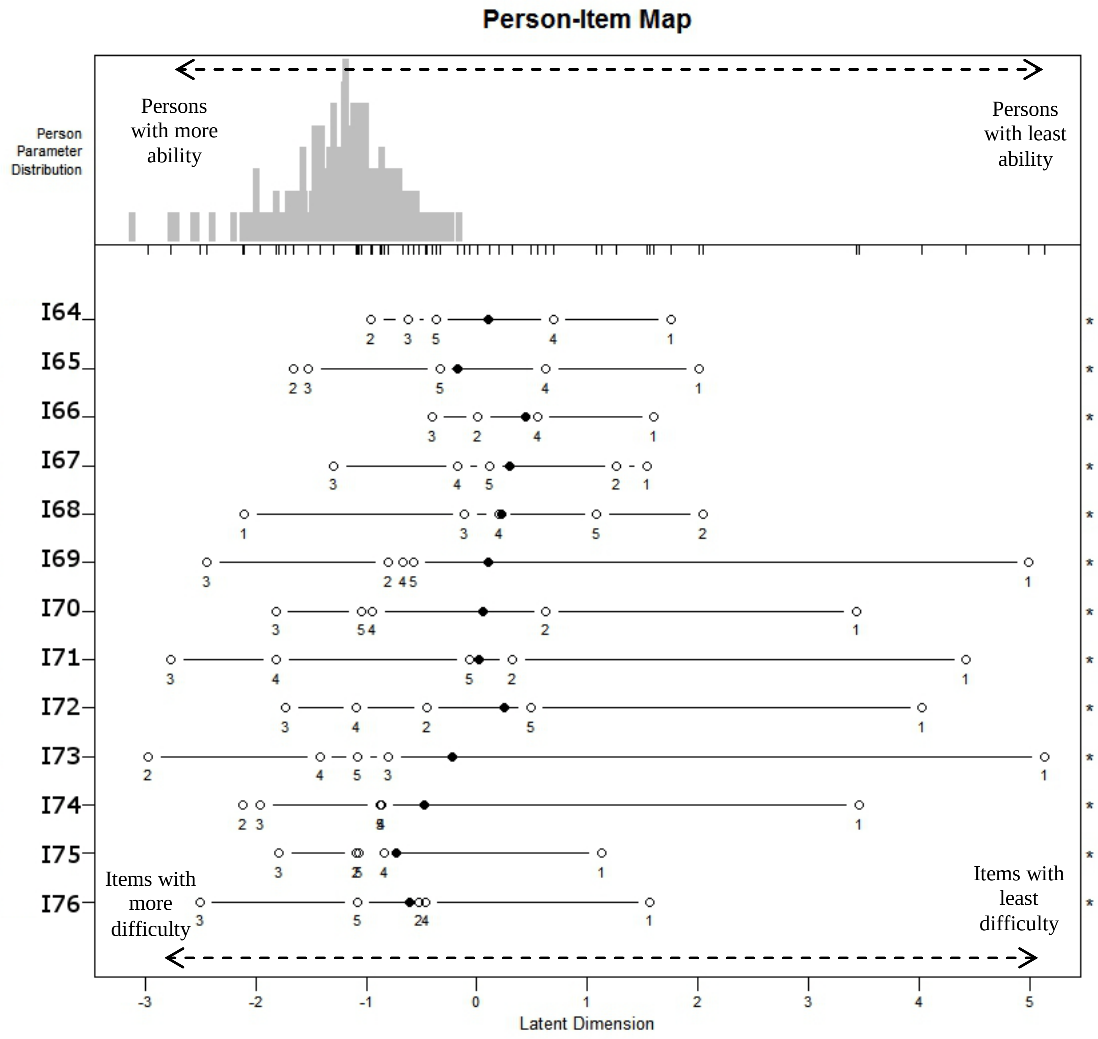

Figure 3 - Person-item map for sub-dimension Work characteristics

As we can see the distribution of person's ability is well shaped and with mode located on the "more ability" range to deal with discomfort. For item map we can see that all of them are in the middle of "discomfort" range, meaning they are not too high disturb / too little disturb impact factor.

4. CONCLUSIONS

The validation of INSAT using Rasch model revealed a very good value - as result from the application of Rasch Partial Credit Model, Person Separation Reliability was 0.8761. From the statistical analysis we can see that Overall Model fit information, given by Outfit Mean square /Infit Mean square, are between 0.5 and 1.5, - that means "Productive for measurement" and "acceptable fit overall". As result, these items can generate predictable response patterns. Some of the items do not fulfill these criteria and must be analyzed more carefully to ensure the instrument improvement.

Beyond this validation process, it was also presented the results obtained using INSAT in a sample of 706 workers. It revealed the exposition either to physical and organizational risks, which enhances the importance of an integrated approach of the work situation, and centered at a local level of analysis – knowing the enterprises involved and its concrete work activities – in order to conceive a contextualized, and not prescriptive, intervention. The results obtained from this work will be considered in the next INSAT revision.

6. REFERENCES

Barros, C., Carnide, F., Cunha, L., Santos, M., & & Silva, C. (2015). Will I be able to do my work at 60? An analysis of working conditions that hinder active ageing. *WORK: A Journal of Prevention, Assessment & Rehabilitation, 51*, 579-590. doi: DOI: 10.3233/WOR-152011

Barros-Duarte, C., & Cunha, L. (2010). INSAT2010 – Inquérito Saúde e Trabalho: outras questões, novas relações. *LABOREAL 6*(2), 19-26. http://laboreal.up.pt/revista/artigo.php?id=48u56oTV6582234;5252:5:52

Barros-Duarte, C., & Cunha, L. (2014). Avaliação dos fatores psicossociais de risco: contributos do Inquérito INSAT (333-346). In H.V.Neto, J.Areosa & P. A. (Org) (Eds.), *Manual sobre Riscos Psicossociais no Trabalho*: Vila do Conde: Civeri Publishing

Barros-Duarte, C., Cunha, L., & Lacomblez, M. (2007). INSAT: uma proposta metodológica para análise dos efeitos das condições de trabalho sobre a saúde. *Laboreal, 3*(2), 54-62.

Cortina, J. (1993). What is coefficient alpha? An examination of theory and applications. *The Journal of Applied Psychology, 78*(1), 98-104. doi: 10.1037/0021-9010.78.1.98

Ferreira, P. L., & E., M. (1999). Percepção de saúde e qualidade de vida: validação intercultural do perfil e saúde de Nottingham. *Nursing, 135*, 23-29.

Green, C., & Frantom, C. (2002, November, 14-17). [Survey development and validation with Rasch Model].

Green, S., Lissitz, R., & Mulaik, S. (1977). Limitations of coefficient alpha as an index of test unidimensionality. . *Educational and Psychological Measurement, 37*, 827-838. doi: 10.1177/001316447703700403

Ilmarien, J. (2009). Work ability – a comprehensive concept for occupational health research and prevention. . *Scand J Work Environ Health, 35*(1), 1-5. doi: 10.5271/sjweh.1304

Joan Stelmack, O., Szlyk, J. P., Thomas Stelmack, O., Babcock-Parziale, J., Demers-Turco, P., Williams, R. T., & Massof, R. W. (2004). Use of Rasch person-item map in exploratory data analysis: a clinical perspective. *Journal of Rehabilitation Research & Development*.

Kline, P. (2000). *Handbook of Psychological Testing* Routledge; 2 edition.

Linacre, J. M. (2002). What do Infit and Outfit, Mean-square and Standardized mean? *Rasch Measurement Transactions, 16*(2), 878.

Mair, P., Hatzinger, R., & Maier, M. J. (2009). Extended Rasch Modeling: The R Package eRm. *PDF-Dateianhang zum Programmpaket eRm*.

Molinié, A.-F., & Leroyer, A. Suivre les évolutions du travail et de la santé: EVREST, un dispositif commun pour des usages diversifiés. . *PISTES 13*(2). doi:http://www. pistes.uqam.ca/v13n2/articles/v13n2a2.htm.

Schmitt, N. (1996). Uses and abuses of coefficient alpha. *Psychological Assessment, 8*(4), 350-353. doi: 10.1037/1040-3590.8.4.350

Sijtsma, K. (2009). On the use, the misuse and the very limited usefulness of Cronabch's alpha. *Psychometrika 74*(1), 107-120. doi: 10.1007/s11336-008-9101-0

Tabachnick, B., & Fidell, L. (2007). *Using multivariate statistics.* : Pearson/Allyn & Bacon. Boston.

Taris, T., Van Horn, J., Schaufeli, W., & Schreurs, P. (2004). Inequity, burnout and psychological withdrawal among teachers: A dynamic exchange model. . *Anxiety, Stress and Coping, 11*(1), 103-122.

Waugh, R., & Chapman, E. (2005). Attitude to Mathematics for Primary-Aged Students: A Comparison of True Score and Rasch Measurement in Frontiers in Educational Psychology (pp. 89-105): Nova Science Publishers , New York, USA.

Wright, B. D., & Stone, M. H. (1999). Measurement essentials. *Wilmington. Wide Range Inc*, 221.

Aspects on safety indicators, management and culture in three big companies in Finland

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Abstract

We describe and analyse three big companies and their supplying partner networks as cases. We investigate demanding jobs such as industrial maintenance and land transport. We choose, define and utilise aspects and indicators in order to clarify the differences in enablers and results as far as health, safety, environment and quality (HSEQ) factors are concerned. The literature review aims to find concrete and activating daily issues related to safety culture. We think we found some important aspects of daily activities and ways to manage and behave versus HSEQ issues. These aspects help to describe and analyse the model and level of safety management and culture in an organisation in question. The most promising link we analysed in details was the one around near misses and hazard observations. Though, the obvious links between activities and ways as well as aspects of safety management and culture should be further studied.

Keywords: accident; near miss; safety attitude; integrated management; supplier**.**

1. INTRODUCTION

Safety management and safety culture are related but distinct. Hale et al. (2004) used many approaches to study the complex interactions of systematic safety management and the underlying safety culture at a steel mill. They found that it is important to interact with the "shop floor" in order to develop effective safety management improvements in the wide and rich context of the safety culture. The European Union's report (Eeckelaert, Starren, van Scheppingen, Fox, & Brück, 2011) explained that: "the concept of safety culture has been used more and more in safety research, particularly in high-risk industries such as the nuclear and petrochemical industry, and (public) mass transportation (railway, aviation), recognising the importance of the human element and soft organisational aspects in accident and risk prevention." Similarly, Smith and Wadsworth (2009) have widely reviewed safety culture as well. The nuclear power industry, naturally, is one of most interested actors in the field of safety culture. The nuclear power industry's description is (Advisory Committee, 1993) "the safety culture of an organisation is the product of individual and group values, attitudes, competencies and patterns of behaviour that determine the commitment to, and the style and proficiency of, an organisation's health and safety programmes." Advisory Committee (1993) has as well explained: "organisations with a positive safety culture are characterised by communications founded on mutual trust, by shared perceptions of the importance of safety, and by confidence in the efficacy of preventive measures." Building upon this belief, Hugnes and Ferrett (2003) recommend the same kind description for all workplaces. Based on the work of researchers Guldenmund, Smith, Wadsworth, Cox, and Flin, Eeckelaert et al. (2011) stated: "Safety culture addresses the deeper, implicit convictions (at the core) which are shared amongst the members of a group, and which are expressed, amongst others, through the safety climate, i.e. the shared perceptions of workers regarding safety and their working environment. Using a metaphor, organisational (safety) culture could be seen as the personality of an organisation, whereas (safety) climate as the organisation's mood." Thus, safety climate originates from a psychological approach towards safety culture. Eeckelaert et al. (2011) continued by saying, "Safety climate can be regarded as a more superficial and momentary reflection - a snapshot - of an organisation's safety culture." To assess the safety climate within organisations, Nordic countries have adopted a joint project known as the Nordic Safety Climate Questionnaire (NOSACQ), which has already been utilised in many Scandinavian countries such as in the Swedish chemical process industry (see Bergh, 2011).

Along on similar line, Glendon, Clarke, and McKenna (2006) suggested looking at quite specific topics within industrial organisations, such as the hierarchy, team structure, team performance, centralisation degree of the teams and networks, attitudes, and the quality of communication. More precisely, Glendon et al. (2006) encouraged researchers to study, e.g., the following aspects: adequate dissemination of top-down communications, but also bottom-up communications, ease worker relations, reduced status distinctions operate through encouraging communication, sharing ideas, and promoting greater concern and trust among workers. The aim of our paper is, first, to review definitions of safety culture, and, second, to deal with its practical links with safety management activities and results within the case companies we know on the basis of our former studies. Two of the three case companies are of specific interest due to applying a specific Health, Safety, Environment, and Quality (HSEQ) management model. A model used for HSEQ assessment has been developed in collaboration with, and applied within many major Finnish companies and their supplying networks, especially the ones of process, other manufacturing, and energy industries. This paper's case context covers as well the third company, representing land transport sector. We have analysed its occupational safety management and safety culture and experienced safety climate. As far as all the three cases, daily practices and actions of safety management and behaviour will be analysed for finding aspects that seem to promote more successful safety culture revealed by more positive safety performance.

2. MATERIALS AND METHOD

We describe quite widely and separately both the case companies and the methodology of this specific study. Partly we review our team's former study reports, because they are dealing with the basic backgrounds and facts that are useful and essential for this study, too. Though, many new analyses based new and former data and variables are needed and described.

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2.1. Case companies and their industrial contexts

The process industry typically consists of the pulp, paper, other wood- and bio-based industries, the chemical industry, and the metal processing industry. This paper's case context comprises two big Finnish process industry sites of two companies with global operations and units. Together, the number of employees at the two sites is many thousands. The staff is partly employed directly by the major process industry company but typically as well by the often smaller supplying companies. Supplying companies deliver a great variety of work activities at shared workplaces in the facilities of purchasing companies, like in our case 1 and case 2. People employed in the process industry are involved in either operating or maintaining the production system. Additionally, this paper's case context covers a third company (case 3), operating within the land transport sector mainly in Finland and employing around 10000 employees. The two big process industry sites and their supplying network belong to the Cluster for the HSEQ Assessment Procedure (HSEQ AP) (Koivupalo, Junno, & Väyrynen, 2015a; Koivupalo, Sulasalmi, Rodrigo, & Väyrynen, 2015b; Väyrynen, Hoikkala, Ketola, & Latva-Ranta, 2008; Väyrynen, Koivupalo, & Latva-Ranta, 2012; Väyrynen, Jounila, & Latva-Ranta, 2015). This HSEQ management approach utilises integrated management, which is one set of procedures for covering multiple management objectives and means (cf., Wilkinson & Dale, 2007; Kauppila, Härkönen, & Väyrynen, 2015). Our team acts as a research and development (R&D) partner within the HSEQ AP Cluster that is led by big companies (*N*=8). The Cluster's experts have conducted, or at least started, HSEQ AP auditing in around 150 supplying companies. Due to our membership as a research organisation in the Cluster, we have access to the data describing the enablers and performance of the two process industry companies and their supplying network (Figure 1) as well as to the data for the case 3 company.

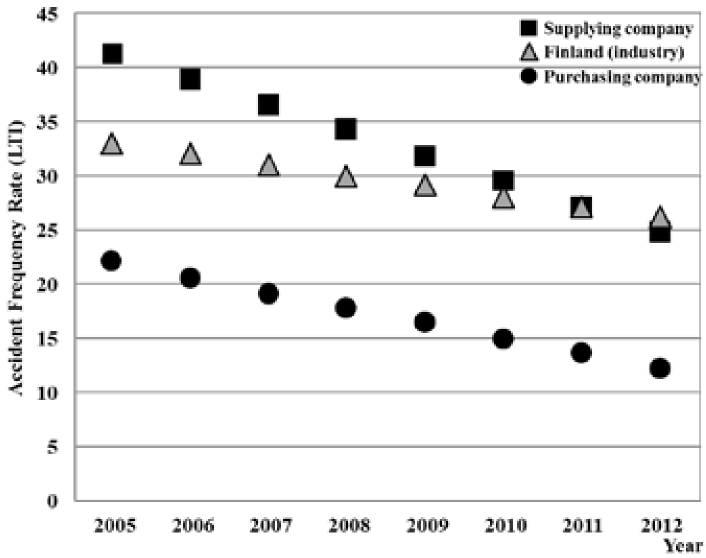

Figure 1 – Accident frequency rates, specifically lost-time injury (LTI, see 2.2) rate converted to a linear regression trend (supplying and principal [purchasing] companies) represent the HSEQ AP Cluster's 8-year results. The general trend of accidents in the Finnish industry can be seen as well.

Most typically, the suppliers are providing maintenance services to big purchasing HSEQ AP Cluster enterprises. In this regard, maintenance concerns all technical, administrative and managerial actions to keep or restore a production system to a state in which it can perform the required function (c.f., EN 13306, 2010). More specifically, the EURO OSHA (2015) described demanding and quite risky work activities related to maintenance in various industries and noted that:

- Accidents increasingly tend to happen not during normal operation, but rather during repair, maintenance, cleaning, adjusting, etc.;
- It is estimated that around 15% to 20% (depending on country) of all accidents and 10% to 15% of all fatal accidents are related to maintenance operations;
- The activities of maintenance, repair, tuning and adjustment are fourth on the list of top 10 working processes accounting for the highest number of fatal accidents from 2003 to 2005; and
- According to a survey conducted in 2005 in France, maintenance is the most subcontracted function in industry. An analysis of French work accidents showed that, in 2002, maintenance employees were the second most frequent victims of accidents related to subcontracting, just behind construction workers.

Lind-Kohvakka (2015) has concluded that the maintenance-related risk assessment and management has to be holistic, so that factors relating to technology, human and organisational viewpoints are considered. The risk assessment and management procedures must also take into account the work system's conditions, surrounding activities and structures, as well as fault manifestation in practice. The analyses may also need to pay attention to post-maintenance work system safety. Maintenance operations are conducted basically in all industrial environments, indoors and outdoors. The risks vary greatly, depending on the operating environment and conditions, and on the task involved. Some typical risk factors are poor system maintainability, defective task safety planning and shortcomings at sites of industry. Väyrynen, Pekkarinen, and Tornberg (1994) described the conditions in the chemical process industry where maintenance includes many physically heavy tasks. Risk assessment and management should pay attention to varying tasks and operating environments, as well as to careful task safety planning. Production employees working in control rooms of process industry have, generally speaking, much better physical work conditions.

Case 3, with current lost-time injury (LTI) rate between 15 and 20, represents the transport industry where occupational safety (OS) statistics reflect a relatively high number of accidents. As far as the 6-decade-long trend of the numbers of accidents of the case 3 shows very strong reduction (Figure 2). Nowadays, according to the European Statistics on Accidents at Work (European Agency for Safety and Health at Work, 2011), the incidence rate of non-fatal occupational accidents decreased in the total working population between 1994 and 2006. This was true for all the three transport subsectors (land transport including road, train and pipelines, water transport and air transport). In 2006, the average incidence rate of fatal accidents (i.e. cases per 100,000 workers) was 3.5 in the total working population, while in the land transport sector it was 14.7 and in the water transport sector it was 15.3 (European Agency for Safety and Health at Work, 2011). For instance lorry transport, one example of land transport, is characterised by combination of high physical work load and accidents (cf, Reiman, Putkonen, Nevala, Nyberg, Väyrynen, & Forsman, 2015).

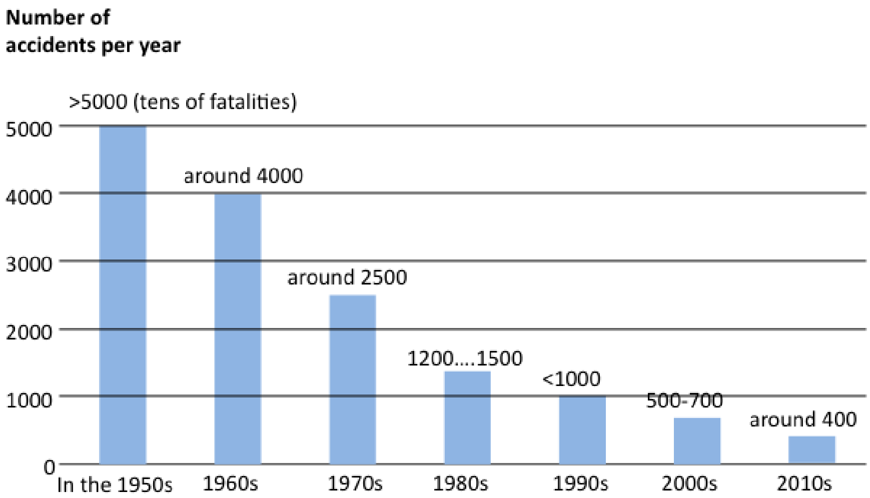

Figure 2 – The significant decrease in occupational accidents for a big land transport company (case 3) over the decades. Though the developments are positive, zero-accident goal thinking may be needed to progress further.

Another line of research uses a narrower scope to link safety culture and daily proactive actions and habits. For example, Reason's approach (1991) is more "daily-oriented" than those previously mentioned (e.g. Eeckelaert et al., 2011; Advisory Committee, 1993). Reason (1991) linked a practice-related, concrete daily phenomenon – i.e. near miss and related events – with the abstract concept of safety culture. Countries around the world have defined a near miss in various ways. For example, in the USA, a near miss is an unplanned event that did not result in injury, illness or damage, but had the potential to do so National Safety Council (NSC, 2013). In contrast, Finland's reporting systems also include even more static and potential hazard conditions and situations observed and reported by employees that could become an event concluding with a near miss or an accident. The NSC (2013) clearly stated that reporting near miss incidents can significantly improve employee safety and enhance an organisation's safety culture. Van der Schaaf (1991), like Reason (1991), described in many interesting ways how significant can be the links between the "abstract" concept of culture and "concrete" near miss incident reporting of everyday events and states with deviations. We identified that that key 8 points of van der Schaaf (1991) can be concluded:

1. An iceberg model has actual but rare accidents on the top, and an enormous number of errors and recoveries on the bottom;
2. An iceberg model includes accidents, near misses and behavioural acts like errors with largely overlapping root causes;
3. Near misses, which provide an optimum balance between rare visible accidents and frequent but invisible behavioural acts, are worth collecting and analysing;
4. Near misses usually occur one or two orders of magnitude more frequently than actual accidents;
5. The set of possible accident scenarios is enriched in all types of system failure modes;
6. From a safety management perspective, near misses can be considered precursors to future accidents;
7. An increased awareness of system defects results in an attitude of zero-defects goal-setting; and
8. A near miss investigation often provides a preventive perspective much more than accident investigation, which helps maintain the motivation that is crucial to safety culture.

2.2. Method to study

For cases 1 and 2, we gathered and dealt further with (a) statistics related to the companies and the HSEQ AP Cluster and (b) materials that our team members gathered for the earlier studies (Koivupalo et al., 2015a, 2015b; Kurppa, 2015; Väyrynen et al., 2008, 2012, 2015). We use the term indicators to describe accidents, observations of near miss incidents and hazards reported by employees, activity with safety toolbox meetings (Levitt and Samelson, 1993) and results in HSEQ AP audits. We used the LTI rate as a loss-based safety performance indicator (Kjellén, 2000). We defined the LTI rate as the number of lost-time injuries per one million hours of work. A lost-time injury is an injury that causes at least one whole day (or shift) absence from work. The amount of observations of near miss incidents and hazards is probably important, and so is their frequency in comparison with the accident frequency. We gathered changes in indicators, in which we hope to see progress based on the OS culture improvements. We wanted to check the possible role of the fact that over 330 organisations from all over Finland have joined the Zero Accident Forum, which is a national network of companies that share a common vision of becoming leaders in safety and are willing to share their experiences for the benefit of other members (Zero Accident Forum, 2015). We collected the data for case 3 from the workplaces with an inquiry on OS and related issues. The inquiry was directed to the whole staff of the land transport company, and approximately every third (*n*=3042) member of the staff answered it. We distributed the questionnaire both through the mail and over the Internet. The questionnaire used a 5-point Likert scale to assess 71 attitude claims divided into 12 essential theme areas. In addition to the inquiry, other parts of the study (i.e. interviews, focus groups, statistics related to the company and literature review) revealed as well a lot of various aspects, and generally the readiness and ideas of the company's staff to further develop OS culture as well as their expectations regarding it.

3. RESULTS

The case 1 purchasing company and its tens of suppliers show a quite consistent 8-year trend down in accident figures (LTI, years 2007–2014). The LTI for the purchaser lowered from 17 to 8, and the corresponding figures for case 1's supplying network were 38 and 13, respectively (Kurppa, 2015). The accident frequencies for the purchaser and the suppliers at the same shared workplace are coming nearer and nearer to each other (Kurppa, 2015). Table 1 shows the combined accident situation in case 2. The improvement is quite clear, continuous, and consistent.

Table 1 – Accident frequency LTI by 10 years presenting trends in a shared HSEQ AP Cluster workplace (case 2 combining the figures of the purchaser's own staff and suppliers' staff at the same shared workplace) (Koivupalo et al., 2015a).

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
LTI	26.0	22.0	18.7	13.8	12.7	9.0	6.7	8.2	7.0	6.2

Figure 3 shows that new companies due to be audited are showing relatively straightforward improvement every year. Figure 4 presents the total HSEQ scores as well as the separate scores for HS, E and Q respectively, showing clear improvements in all supplying companies. These numbers reveal the positive effects of the 3-year time span between the first assessments and the reassessments of the same companies.

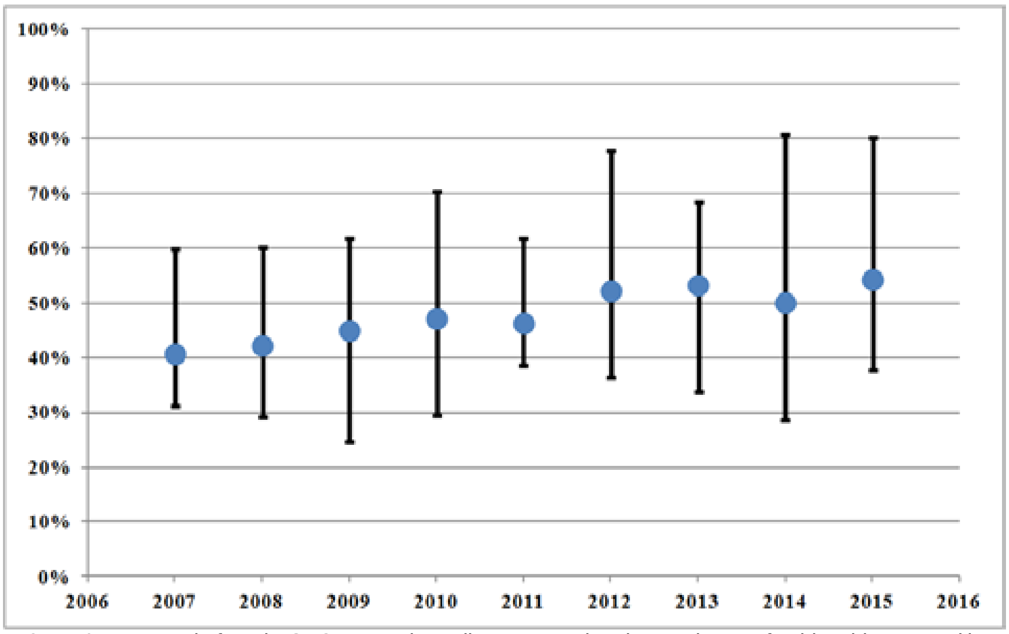

Figure 3 – A 9-year trend of total HSEQ scores in audits compared to the maximum of achievable scores (the yearly average in first assessments). The year 2015 includes only a half-year situation.

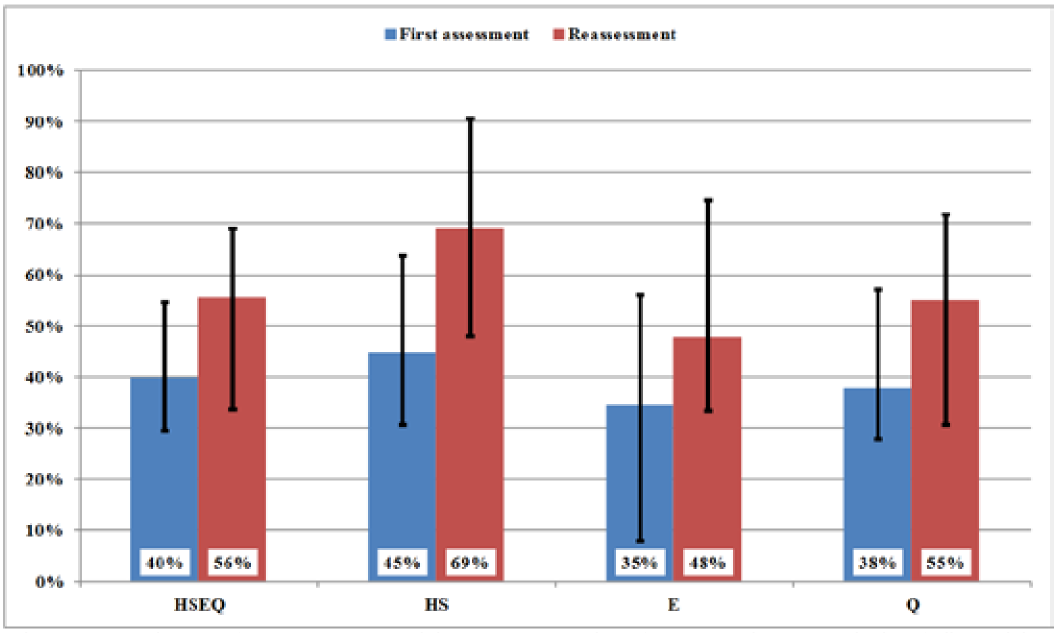

Figure 4 – Total sums of HSEQ scores, and the separate scoring of HS, E, and Q respectively, of all supplying companies; comparison (average, max and min) with the maximum of achievable scores is presented. The data reveals the situation during the 3-year time span between the first assessments and the reassessments of the same companies. The data covers time until June 2015.

Figures 5 and 6 focus on the amounts and especially the proportions of accidents (deviation events with loss) and near miss and hazard observations (deviation events and conditions without loss). As far as the case 2 (Figure 5) near misses are occurring two orders of magnitude, or even more, more frequently than actual accidents (n_2/n_1=652). The corresponding ratio for the suppliers of the case 2 (Figure 5) is 14. So, near miss and hazard observations of the suppliers are occurring around one order of magnitude more frequently than actual accidents. The corresponding ratios n_2/n_1 for the case 1 and 3 are 95 and 10 (Figure 6). Cases 1 and 2 especially, if we deal only with their own staff, are superior; apparently they prevent accidents because of the great amount of near miss and hazard observations reported by employees. The impression is that supplying companies of case companies 1 and 2, and case company 3 itself, could achieve better accident prevention performance by more actively detecting and resolving near miss and hazard observations.

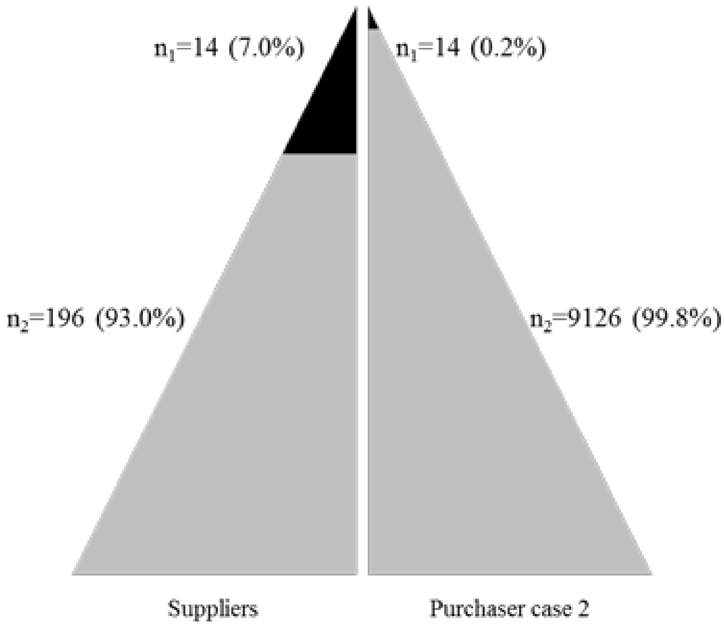

Figure 5 – Comparison of accidents (≥ 1 day absence due to injuries) (n_1) with near miss and hazard observations (n_2) in the same case companies (purchaser case 2 on the right, its suppliers on the left). The shares (%) of the sum n_1+ n_2 calculated for both types of incidents are presented as well.

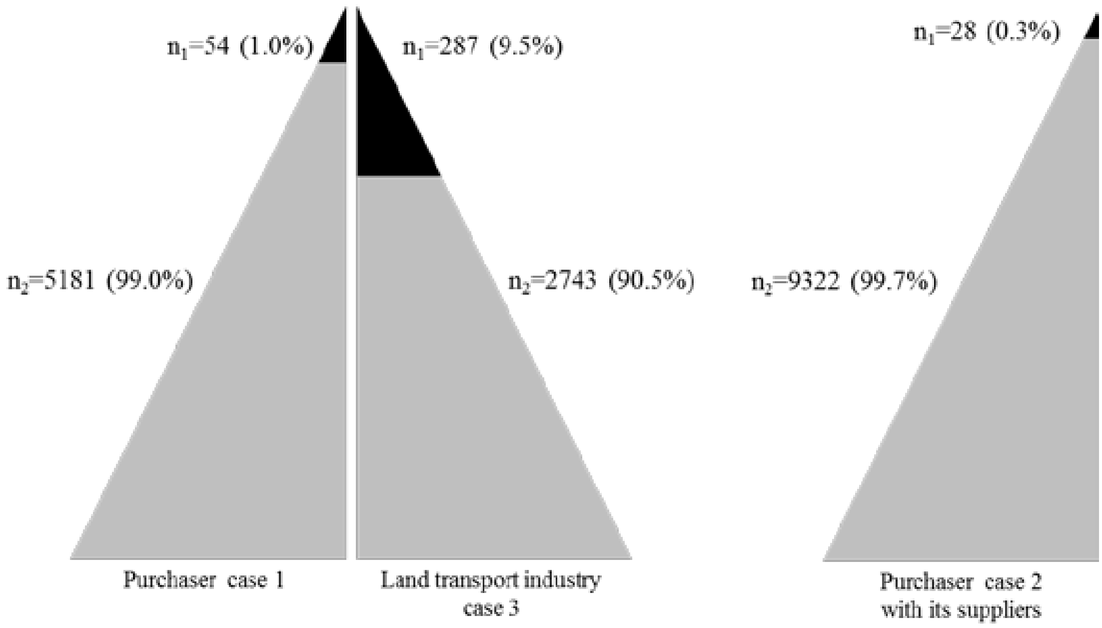

Figure 6 –Comparison of accidents (≥ 1 day absence due to injuries) (n_1) with near miss and hazard observations (n_2) in the case companies (case 2 with suppliers on the right, cases 1 and 3 on the left). The shares (%) of the sum n_1+ n_2 calculated for both types of incidents are presented as well.

Positive attitude, participation, conditions and equipment, own alertness and well-being are felt important, and, e.g., the roles of zero-accident mind-set, managers and foremen, behaviour at leisure, and subcontractors gain opinions expressing non-importance according to answers of the respondents of the case 3 (Figure 7). Table 2 shows that near miss observations and safety toolbox meetings were not as popular as in leading process industry workplaces, but more emphasis will be placed on those activities in the future.

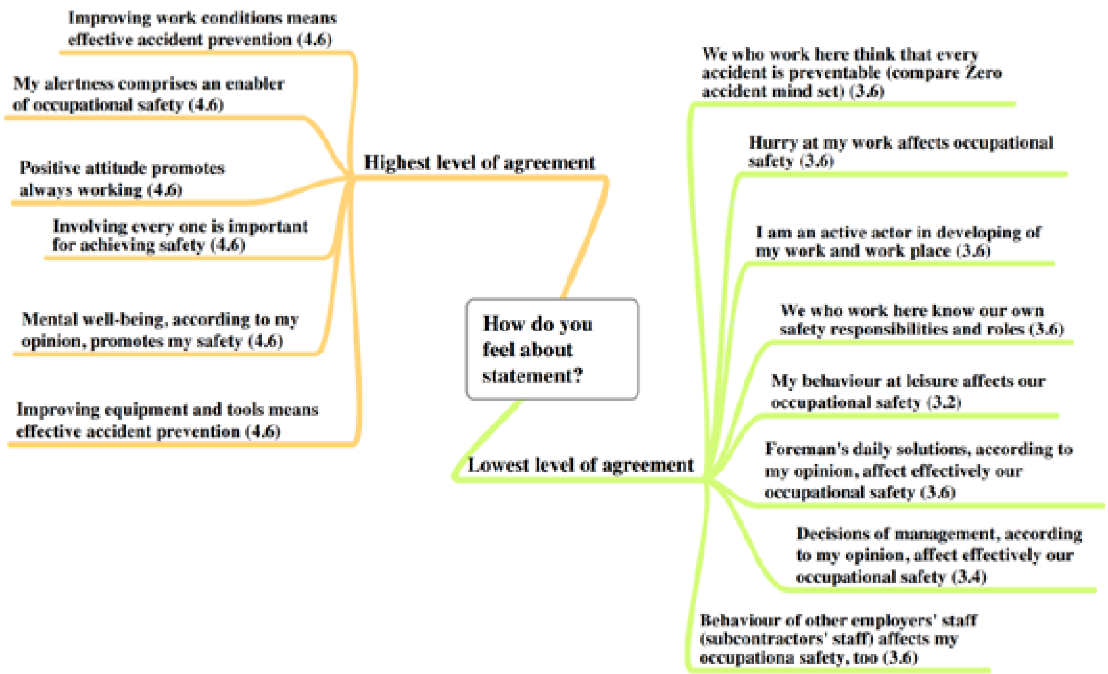

Figure 7 – OS attitude claims chosen based on the highest values of averages of staff agreement (n=around 3000), and on the other hand lowest values of averages in the case 3. The level assessment related to each statement was based on assessments according to the 5-point Likert scale.

Table 2 – Yearly number of near miss incident and hazard observations in the land transport company (case 3) with planned goals in the parentheses. The same indicators are presented for safety toolbox meetings that were started in 2009.

Year	Near miss incidents and hazard observations, n	Safety toolbox meetings, n
2009	1287 (-)	- (-)
2010	1032 (1500)	682 (200)
2011	1370 (2000)	833 (700)
2012	2061 (2000)	1606 (-)
2013	2743 (3500)	1674 (1800)

Safety toolbox meetings started between 1999 (case 1) and 2009 (case 3). All the case companies belong to the (Finnish) Zero Accident Forum. However, there is a significant difference when comparing the companies of the HSEQ AP Cluster: more than 60% of purchasing companies, like cases 1 and 2, belong to the Forum while only slightly more than 20% of supplying companies are members.

4. DISCUSSION AND CONCLUSIONS

Cases 1 and 2 belong to the HSEQ AP Cluster. In the near future, they can still utilise the probable route of continuous improvement of safety management and culture. We believe that the accident situation and other HSEQ indicators will continue to improve, though not without continuing successful practices and introducing new ones. Supplying companies are partly in need of effective follow-up and actions, though they have developed quite rapidly according to scorings in HSEQ AP audits during past years. The need for more effective follow-up and actions is based on the following aspects: the higher accident frequency, the lower active gathering of observations of near miss incidents and hazards, the greater frequency of accidents as compared to observations (this is a significant difference when comparing with purchasing companies themselves). Much more frequently suppliers are not members in Zero Accident Forum. Case 3 is in many ways more comparable with supplying companies than purchasing companies (cases 1 and 2). Still, it is worth mentioning that, for example, Kurppa (2015) has noted that the case 1 company should pay more attention to the quality of observations of near miss incidents and hazards coming from its supplying companies (the concern likely also applies to those gathered by the case company's own staff). The significant amount is obviously important, but the company should pay more attention to keep the quality high as well.

The Bradley Curve makes it simple for everyone to understand the shifts in mind-set and actions that need to occur over time to develop a mature safety culture (DuPont, 2015). In particular, the Bradley Curve describes the reactive stage (stage 0) as the one in which people do not take responsibility. They believe that safety is more a matter of luck than management and that "accidents will happen." In case 3, many people's first approach is the first one illustrated in Figure 8, i.e. the dependent stage (stage 1), which people see safety as a matter of following rules that someone else makes (DuPont, 2015). Management and staff believe that safety could be managed "if only all would follow the rules." The situation visualised by number two (Figure 8) is similar to the independent stage (stage 2), of the Bradley Curve (DuPont, 2015). Many individuals prioritise this stage in case 3, taking responsibility for themselves. People believe that safety is personal, and that they can make a difference with their own actions. The highest step (number three in Figure 8), Bradley's interdependent stage (stage 3), (DuPont, 2015), is not the first choice of many individuals in case 3. This "highest" stage can be characterised in the following way (DuPont, 2015):

- Teams of employees and supervisors feel ownership for safety and take responsibility for themselves and others;
- People do not accept low standards and risk-taking;
- They actively converse with others to understand their point of view; and
- They believe true improvement can be achieved only as a group, and that zero accidents is an attainable goal.

Specifically concerning case 3, we see all the following stages: dependent, independent and interdependent. So, we conclude that more trust in the zero-accident goal offers a probable route towards more rapid safety management and culture improvements (Figure 8). One mean we recommend is increasing activities related to observations of near miss incidents and hazards and, on the other hand, safety toolbox meetings. Integrated management (HSEQ-style) might also comprise one remedy opening broader views of sustainability and possibilities for synergy in management activities.

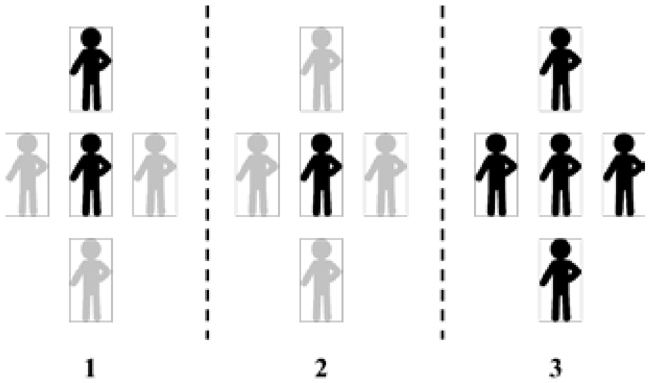

Figure 8 – Simplified visualisation of the Bradley Curve's three stages of the total four ones (dependent stage (1), independent stage (2), and interdependent stage (3)). Black humans show people involved.

In discussing the role of safety at DuPont sites, Mottel, Long, and Morrison (1995) described one approach:

"Safety is a powerful leadership tool that enables us to achieve excellence in all we do. High productivity, high quality, high morale, and associated low absenteeism are all products of, and interrelated with, a strong Safety program. During the many years of our careers with DuPont, we learned that Safety is our culture […] not just a priority in all industrial operations."

At DuPont, they began their commitment to a zero-accident goal policy 100 years ago, in 1915 (Mottel et al., 1995). This is "a strict rule" at DuPont, but it gives many wise messages to be considered in all work organisations.

Last but not least, we recommend that all individuals and organisations try to manage and construct a culture that involves people such as employees and supervisors as much as possible. Doing so brings into use powerful driving forces of potential benefits due to people's involvement in processes, motivation, competence and confidence (Wilson & Haines, 2000). Kath, Magley, and Marmet (2010) and Levitt and Samelson (1993) have likewise emphasised the role and power of confidence. The latter study offers many practical guides on how to tackle the lack of confidence, and how to utilise it in construction, whether on the part of workers, foremen, supervisors, managers, site managers or partners and their employees (e.g. contractors, sub-contractors). Levitt and Samelson (1993) strongly supported a wide base of information, communication and interaction, such as engaging in enough discussion with people in safety toolbox meetings instead of utilising only management by orders and rules given throughout chains of command.

Activities related to management and culture need to create an environment that fosters non-technical skills (NTS), too. Apart from natural specialist, technical and technological knowledge, employees, experts and managers also need a range of NTS to carry out tasks with success (e.g., Discussion Paper, 2010). These skills include the ability to take in information, focus, take decisions and communicate with others – all of which are necessary for progress in safety management and culture. Work conditions and systems are not only a daily question; for instance, Rajala and Väyrynen (2011) emphasised that this area with safety management and culture is an essential strategic issue. One operative conclusion is that our case analysis suggests consistently, though tentatively, that promotion of certain daily safety activities, especially those linked with bigger amounts of near misses, is an effective tool for accident prevention. So, emphasis based on van der Schaaf's (1991) report on near misses was a right choice.

We think we could find some aspects of daily activities and ways for improving to manage and behave in OS and HSEQ issues, ones that help to describe the model and level of safety management and culture in an organisation in question. The obvious links between activities and ways, first, and features of safety management and culture, second, should be further studied.

5. REFERENCES

Advisory Committee on the Safety of Nuclear Installations (1993). ACSNI study group on human factors. *Third report. Organising for safety, HSE Books,* 100 p.

Bergh, M. (2011). *Safety Climate, An evaluation of the safety climate at AkzoNobel Site Stenungsund*.

Master of Science Thesis. Department of Product and Production Development,

Division of Production Systems, Chalmers University of Technology, Göteborg, Sweden. 114 p.

DuPont (2015). http://www2.dupont.com/sustainable-solutions/en-us/sites/default/files/ua-2_dupont_DuPont_Bradley_Curve.gif

Discussion Paper (2010). *Associated Non-Technical Skills (ANTS).* Prepared by David Caple & Associates for the NSW Mine Safety Advisory Council (MSAC). NSW Government. 36 p.

Eeckelaert, L., Starren, A., van Scheppingen, A., Fox, D. & Brück, C. (2011). *Occupational Safety and Health culture assessment - A review of main approaches and selected tools*. European Agency for Safety and Health at Work (EU-OSHA), Luxembourg, ISBN 978-92-9191-662-7. doi 10.2802/53184.

EN 13306 (2010). *Maintenance. Maintenance terminology*. European Standard.

EURO OSHA (2015). https://osha.europa.eu/en/topics/maintenance

European Agency for Safety and Health at Work (2011). *OSH in figures: occupational safety and*

health in the transport sector—an overview. Publications Office of the European Union, Luxembourg. doi:10.2802/2218

Glendon, A. I. Clarke, S. & McKenna, E. F. (2006). *Human Safety and Risk Management*. 2nd ed., CRC Press, Taylor & Francis Group, 500 p.

Hale, A.R., v.d. Waterbeemd, H.A., Potter, R., Heming, B.H., Swuste, P.H.J.J. & Guldenmund, F.W. (2004) Developing an effective diagnosis for safety diagnosis in steelworks. *Occupational Ergonomics* 4, 229-240.

Hugnes, P. & Ferrett, E. (2003). *Introduction to health and safety at work*. Elsevier Butterworth-Heineman, Oxford.

Kauppila,O., Härkönen, J. & Väyrynen, S., (2015) Integrated HSEQ management systems: Developments and trends. *International Journal for Quality Research* 9(2) 231–242.

Kath L.M., Magley V.J. & Marmet M., (2010). The role of organizational trust in safety climate's influence on organizational outcomes. *Accident Analysis & Prevention* 42(5), 1488-1497.

Kjellén, U. (2000), *Prevention of Accidents through Experience Feedback.* Taylor & Francis, New York.

Koivupalo, M., Junno, H., Väyrynen, S. (2015a). Integrated Management Within a Finnish Industrial Network: Steel Mill Case of HSEQ Assessment Procedure In Väyrynen, S., Häkkinen, K., Niskanen, T. (Eds.), *Integrated Occupational Safety and Health Management - Solutions and Industrial Cases*. Springer, Production & Process Engineering. Cham, Heidelberg, New York, Dordrecht, London (pp. 41-67).

Koivupalo, M., Sulasalmi, M., Rodrigo, P. & Väyrynen, S. (2015b). Health and safety management in a changing organisation: Case study global steel company. *Safety Science* 74, April. http://dx.doi.org/10.1016/j.ssci.2014.12.009, 128–139.

Kurppa, N. (2015). *Management methods and tools for occupational safety of contractors*. Manuscript of MSc- Thesis. University of Oulu.

Levitt, R. & Samelson, N. (1993). *Construction Safety Management*, 2nd Edition. John Wiley & Sons, Inc, New York. 273 p.

Lind-Kohvakka, S. (2015). Application of Accident Information to Safety Promotion – Case Industrial Maintenance. In Väyrynen, S., Häkkinen, K., Niskanen, T. (Eds.), *Integrated Occupational Safety and Health Management - Solutions and Industrial Cases*. Springer, Production & Process Engineering. Cham, Heidelberg, New York, Dordrecht, London (pp 25-37).

Mottel, W.J., Long, J.F. & Morrison, D.E. (1995). *Industrial Safety is Good Business. The DuPont Story*. New York: John Wiley & Sons. 236 p.

NSC (2013). *How Do Near Miss Reporting Systems Prevent Future Incidents?* from http://www.nsc.org/WorkplaceTrainingDocuments/Near-Miss-Reporting-Systems.pdf.

Rajala, H-K. & Väyrynen, S. (2011). Participative Approach to Strategy Communication: A Case of Small- and Medium-Sized Metal Enterprises with a Review after Seven Years. *Human Factors and Ergonomics in Manufacturing & Service Industries.* DOI:10.1002/hfm.20322.

Reason, J. (1991). Too little and too late: a commentary on accident and incident reporting systems. In van der Schaaf, T., Lucas, D. A. & Hale, A.R. (Eds.). *Near Miss Reporting as a Safety Tool*. Butterworth-Heinemann, Oxford (pp. 9-26).

Reiman, A., Putkonen, A., Nevala, N., Nyberg, M., Väyrynen, S. & Forsman, M. (2015). Delivery Truck Drivers' Work Outside Their Cabs: Ergonomic Video Analyses Supplemented with National Accident Statistics. *Human Factors and Ergonomics in Manufacturing & Service Industries,* 25 (3), 340–352.

SBA Fact Sheet (2012). – Finland. The Small Business Act (SBA). Enterprise and Industry, European Commission

van der Schaaf, T. (1991). Introduction. In van der Schaaf, T., Lucas, D. A. & Hale, A. R. (Eds.). *Near Miss Reporting as a Safety Tool.* Butterworth-Heinemann. Oxford (pp. 1-8).

Smith, A.P. & Wadsworth, E.J.K. (2009). *Safety culture, advice and performance.* Report submitted to the IOSH Research Committee, Wigston UK. 84 p.

Väyrynen, S., Pekkarinen, A. & Tornberg, V. (1994). Some links between accidents, postural load and accessibility in chemical plant maintenance. *Safety Science* 18:2, 125-133.

Väyrynen, S., Hoikkala, S., Ketola, L. & Latva-Ranta, J. (2008). Finnish occupational safety card system: special training intervention and its preliminary effects. *International Journal of Technology and Human Interaction*, 4(1). 15–34.

Väyrynen, S., Jounila, H. & Latva-Ranta, J. (2015). ICT as a tool in industrial networks for assessing HSEQ capabilities in a collaborative way. Chapter 75. In Khosrow-Pour, M. (Ed), *Encyclopedia of Information Science and Technology.* 3rd ed. Vol. 10, Hershey, PA: IGI Global. doi:10.4018/978-1-4666-5888-2 (pp 787-797).

Väyrynen, S., Koivupalo, M. & Latva-Ranta, J. (2012). A 15-year development path of actions towards an integrated management system: description, evaluation and safety effects within the process industry network in Finland. *International Journal of Strategic Engineering Asset Management,* 1(1), 3-32.

Wilkinson, G. & Dale, B.G. (2007). Integrated management systems. In Dale, B.G., van der Wiele, T., Iwaarden, V.V. (Eds.), *Managing quality,* 5th ed.. Chichester, UK: Wiley-Blackwell (pp. 310-350).

Wilson, J. & Haines, H. (2000). Participatory Ergonomics, In Karwowski W. (Ed.). *International Encyclopedia of Ergonomics and Human Factors*, Taylor & Francis. Vol 2 (pp. 1282–1286).

Wilpert, B. (1998). Conclusions, After the event: What next? In Hale, A., Wilpert, B. & Freitag, M. (Eds.), *After the Event: From Accident to Organisational Learning*, Emerald Group Publishing Limited (pp 233- 244).

Zero Accident Forum (2015). http://www.ttl.fi/partner/nollatapaturmaa/liity_jaseneksi/Documents/foorumin_yleisesittely_englanti.pdf

A survey of health and safety practices in the Spanish research laboratories studying nanomaterials

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Abstract
Introduction: Workers, as the main risk group exposed to nanomaterials, are the aspect less studied by scientists and there is very limited information about which preventive measures are being taken by workers exposed to these materials. Objetives: The main objective of this research is to examine the current preventive practices of the Spanish workers exposed to nanomaterials on the working environments devoted to research and development: universities, public research organizations and research and development centers. Methodology: a specific methodology has been established: a quantitative technique (questionnaire via email) complemented with a qualitative technique (panel of experts). Results and discussion: Answers from 425 workers exposed to nanomaterials were obtained and descriptively analyzed Conclusions: According to data analyzed, respondents expressed a general ignorance about the fundamental issues of safety and health at work related to the use of nanomaterials. At the same time, most respondents take good work practices, take into account the treatment of nanowaste, use some kind of personal protection equipment and have collective protection measures when they work with nanomaterials.

Keywords: Collective protective and preventive equipment; personal protective equipment; safe working practices; emerging risk.

1. INTRODUCTION

The exposure to nanomaterials has become one of the most important emerging risks at work (Agencia Europea para la Seguridad y la Salud en el Trabajo (AESST), 2009). Currently, knowledge about practices regarding prevention related to nanomaterials are limited. Furtherthere is no specific regulatory framework for nanomaterials, so although many of the current regulations can be applied to nanomaterials, they must to be adapted with the knowledge advances (Tanarro & Gálvez, 2009).

It is interesting to find the answer to some questions: Are workers aware of the risks related to nanomaterials ?, or Are they protected from exposure to nanomaterials ?, and if so, in What way are they? Undoubtedly, all efforts engaged from the scientific and researchin this field will allow us to give criteria on how to benefit us from this new technology in a responsible way.

The main objective of this research is to examine the current preventive practices of the Spanish workers exposed to nanomaterials on the working environments devoted to research and development: universities, public research organizations and research and development centers. For that, it is necessary to discover nanomaterials to which workers are exposed to and their characteristics. As well as the information and the prevention training received by workers to work with nanomaterials. It is also intended to identify the preventive and protective measures from the exposure to nanomaterials, the good work practices and the personal protective measures for working with nanomaterials. Also, the consultation and the participation of workers in the planning, organization and implications for their health and safety are analysed. A scientific literature review it is done to discover the main aspects related to nanoproducts and the health and safety of workers.

2. MATERIALS AND METHOD

To achieve the objectives, a research methodology consisting of two phases has been followed.

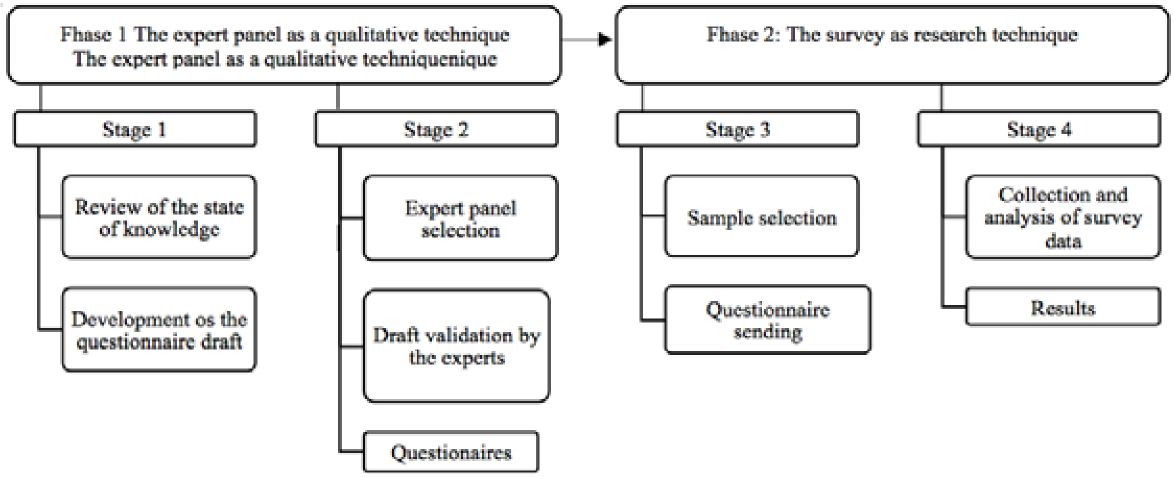


Figure 1 – Methodology.

In the second phase the questionnaire is done asa quantitative technique .The survey is asministered by email. because it permit to obtain information from people in other places, in a short time, compared with other tools and without resources investment. Moreover, it is less vulnerable to the effects of recency and primacy, since in many questions response options, you can view all the answer choices before responding. However, among other shortcomings, it is vulnerable to having low response rate (Cea d'Ancona, 2004). Each of the stages and steps are explained in Figure 1 forms.

2.1. Phase 1: The expert panel as a technique of qualitative investigation.
The first phase consisted of two stages. In the first stage, a review has been done of already existing studies from renowned scientific sources. A draft questionnaire was outlined after the analysis of the first aspects that should be consulted. The explanatory and response variables, as well as its different categories have been the result of scientific literature; *see Table 1*, and documentation of prestigious Institutes of Occupational Safety and Health (Gibbs, Lamba, Stoxkmeier, & Kojola, 2012; Occupational Safety and Health Administration (OSHA), 2008; Occupational Safety and Health Administration (OSHA), 2010; Ricaud & Witschger, 2012; Rosell & Pujol, 2008; Tanarro & Gálvez, 2009). In the second stage, a qualitative validation was performed on the draft questionnaire obtained in the first stage. Firstly, we proceeded to the selection of the participants of the expert panel. For such selection, it was taken into consideration the intellectual baggage on the studied matter, assessing its quality in function of parameters such as the years of experience, publications, prestige, professional position or academic ranking, as well as the situation and personal resources of the participants, which allows them to contribute and participate positively in the research (Landeta R., 1999). After contacting with diverse experts, finally nine participated, a sufficient number given that the areas of knowledge covered were considered being represented in the present investigation, in addition to a broad geographical dispersion between the components. Also if we take as reference the requirements for the expert panel, there is no existence of significant correlation between the number of expert panel and its own effectiveness (Boje & Murnighan, 1982; Brockhoff, 1975), being eight the required minimum (Rowe & Wright, 1999). The validation to the questionnaire consisted of a sent invitation via email to the experts participating in the process. The invitation was linked to an online questionnaire, in which they could make their contributions with respect to each question. The aspects of the questionnaire were rated in a global manner through a Linkert scale of 5 levels, such as structure, extension, clarity and concentration of the questions, also valuing the necessary time to complete the questionnaire and the level of the objectives achieved. As a result of the first phase, the definite questionnaire was obtained.

2.2 Phase 2: The survey as a technique of qualitative investigation
The second phase consisted of two stages. In the first stage we proceeded with the selection of the sample, obtaining a list of names of the individuals to be surveyed. A search through the major networks and technological platforms had been carried out to identify the major agents participatimg in Spain’s current nanotechnological scenario: Génesis Red, M4Nano, Materplat, NanoSpain, Red Nanolito, NanoBasque, Nanomed, Nanowerk, 3Neo, Bionanomed,

Nanoaracat, Ibernam, NanoICT, Train2, Ciber bbn, ETSF, Nanovalor and Red Nacional Nanomecánica. A detailed search was also performed through the web pages of university research centres, university departments and centres of public research, using “nano” as a key word of the search. In the second stage we proceeded by sending the online invitations. Three-spaced remainder were sent in the period of three weeks in order to obtain a higher response rate. The results of the questionnaire discussed though sections 3.5 to 3.9 and conclusions in section 4 were presented in conclusion to phase 2.

3. RESULTS AND DISCUSSION

The results and discussion obtained in the research are presented below.

3.1. Draft questionnaire

Table 1 below shows a summary of research on preventive matters and safe working practices in relation to investigation and development, as well as the industrial scope.

Table 1 – Findings from surveys and interviews in relation to potencial health and safety implications in nanotechnologies.

Title and authors	Summary/Main findings
European Survey on Success Factors Barriers an Deeds for the Industrial Uptake of Nanomaterials in SMEs (European Commission, 2005).	380 nano SMEs and startups were found. In conclusion we find there is a lack of awareness in the potential risk in aspects in the nanomaterial branch. The results indicated that the enterprises surveyed didn’t consider public social acceptance and environmental and health regulations important barriers for the use of nanomaterials by SMEs.
(European NanoBusiness Association, 2005) The European NanoBusiness Survey.	142 European enterprises were surveyed (SMEs accounted for about 18 % of the surveyed businesses). The results indicated that the vast majority of respondents affirmed that health and environmental impacts needed to be studied and that public social acceptance and environmental and health regulations are important barriers for launching products involving nanotechnologies.
Nanotechnology Startup Concerns, Information Needs, and Opportunities to Proactively Address En vironmental, Health, and Social Issues (Lekas, Lifset, & Rejeski, 2006).	Nine presidents and chief executive officers of nanotech startup firms of Connecticut and New York were interviewed via phone and email. In the research we found that companies confirmed the need of specific information on safety precautions, toxicity, and anticipated regulations. The firms also demonstrated a wide range of efforts made to proactively try to assess and address EHS issues, as well as varying levels of concern about environmental, health, and safety issues associated with their operations
A review of Current Practices in the Nanotechnology Industry (Gerritzen, Huang, Killpack, Murcheva, & Conu, 2006).	The survey was conducted through telephone interviews, written, and web-based surveys with 64 participants from North America, Europe, Asia (mainly Japan) and Australia. The surveyed belonged mainly to medium size business sectors (with less than 50 employees), as well as research and university laboratories. The questionnaire was designed specially for the study and inquire into current practices related to research, use and manufacture of nanomaterials in the following areas: environmental health and safety training, use of engineering controls, personal protective equipment (PPE) and clothing recommendations, exposure monitoring, waste disposal, product stewardship practices, and risk characterization. The survey results generally revealed that existing differences in EHS practices based on organizational characteristics such as geographical location, size, material handled and type of organization.
A Survey of Environmental, Health and Safety Risk	An online survey sent to 180 company managers from Massachusetts and New England, at the end they are proposed to complete the survey in more depth with a phone interview.

Title and authors	Summary/Main findings
Management Informtion Needs and Practices among Nanotechnology Firms in the Massachusetts Region (Lindberg & Quinn, 2007).	Only 43 responded the survey, 12 of them completing it with an interview. In this survey it was found that the main barrier for understanding and managing EHS risks associated with nanotechnologies is the lack of information, especially for small companies, who did not even recognize the presence of such risk. Most companies that found themselves at an R&D level applied more of the measures to manage nanotechnology EHS risks. Finally, it should be noted that most companies indicated having procedures against exposure control, but the EPIs used weren't nanospecific, in fact most control and risk protection measures established weren't the product of an initial evaluation of the risk.
Use of nanoparticles in Swiss industry: A targeted survey (Schmid & Riediker, 2008).	The main objective was evaluating the use, the protection measures, and number of potentially exposed workers to manufactured nanoparticles in the Swiss industry. For this, a telephone survey was performed on the representatives of 197 Swiss companies, where 43 declared using and producing nanoparticles, from which 11 of these imported and commercialized with nanoproducts. It should be highlighted that senior management of small and big companies have a higher involvement, instead of medium companies, in the subject of work risk prevention in relation to nanoparticles. On the other hand, most protection and prevention measures used seem to be adapted to the risk perceived in function of the type of application. For example for solid and liquid applications, airborne protection wasn't used.
Health and safety practices in the nanomaterials workplace: Results from an international survey (Conti *et al.*, 2008).	An international survey performed on nanomaterial firms and laboratories with 162 responses. The questionnaire consisted of a telephone interview containing 60 structures semistructured, and open-ended questions. The issues dealt with were: environmental health and safety (EHS) programs, engineering controls, personal protective equipment (PPE), exposure monitoring, waste disposal, product stewardship, and risk beliefs. Overall, this study suggests that nanomaterials firms and laboratories are already attentive to nanospecific EHS and product stewardship issues.
Precaution in practice: Perceptions, procedures, and performance in the nanotech industry (Helland, Kastenholz, & Siegrist, 2008).	Survey performed on 40 German and Swiss companies that worked with nanomaterials. It was found that twenty-six of these companies indicated that they did not perform any risk assessment of their nanomaterials.
Nano-products in the European Construction Industry (Broekhuizen & Broekhuizen, 2009).	Survey at a European scale to find out the businessmen´s and workers´ awareness on the nanoproducts´ applications in construction, obtaining a total of 28 surveys and 214 interviews. One of the results to highlight is that for the majority of the nanoproducts mentioned in the survey, the prescribed protective measures were described as 'no different from before' when non-nano products were used and that the work practice were indicated as not being influenced by their use.
Reported nanosafety practices in research laboratories worldwide (Balas, Arruebo, Urrutia,	A survey on 240 researchers at a global scale on nanosafety practices in university and public research laboratories. The questions covered: details of the materials and processing methods used, safety measures, waste disposal procedures, and

Title and authors	Summary/Main findings
& Santamaria, 2010).	knowledge of legislation for handling nanomaterials. The results of the survey indicate that environmental health and safety practice in many research laboratories worldwide is lacking in several important aspects. Besides the survey shows that most researchers do not use suitable personal and laboratory protection equipment when handling nanomaterials that could become airborne.
Feasibility of an Epidemiological Surveillance System for Workers Occupationally Exposed to Engineered Nanomaterials (Boutou-Kempf, 2010).	In France there was an attempt on performing a survey to explore the prevention risks in companies and research laboratories that used nanomaterials. The survey did not get good results since there was low participation, and in addition to companies, known for their use with nanomaterial, denied their use.
Governance implications of nanomaterials companies' inconsistent risk perceptions and safety practices (Engeman *et al.*, 2012).	A survey involving 65 workers in the industrial scope spread over 14 different countries. In the investigation it was manifested that there were high levels of ignorance towards nanomaterials´ risks. It was also pointed out that the lack of information was the major obstacle for the development of preventive practices specific to nanomaterials.
Repérage des salariés potentiellement exposés aux nanoparticules (Jacquet, 2012).	In France 7 prevention services, 18 occupational doctors and 2 human resources representatives were surveyed. The objective was to find workers exposed to nanomaterials and the situations that expose them, in order to find preventive measures to these exposures. The main conclusion was that the collective protective measures weren't enough in comparison to the risks as well as the information and formation received.
Current safety practices in nano-research laboratories in China (Zhang, Zhang, & Wang, 2014).	A survey that specifically examined in depth safety practices in the Chinese nano-laboratories. This study reports the results of a survey involving 300 professionals who work in research laboratories that handle nanomaterials in China. Results show that almost all nano-research laboratories surveyed had general safety regulations, whereas less than one third of respondents reported having nanospecific safety rules. General safety measures were in place in most surveyed nano-research laboratories, while nanospecific protective measures were implemented less frequently.

After performing a bibliographical review, a draft questionnaire was outlined divided into 11 sections: -General data, nanomaterials, Occupational Health, Regulations and Legislation, Information and Training, Protective Meaures, Collective Protection, Individual Protection, Good practices at work, assessments and hygienic measurements, Emergencies and Waste- 22 questions being the required mimimun to be answerd out of 63. This collection of questions correspond to the inclusion of filter questions.

3.2. Panel de expertos

The draft of the survey was submitted to an experts panel in order to validate it in relation to its structure, length, clarity and precision of the questions, assessment of the time required to conduct the survey and level of achievement of the objectives proposed in the questionnaire.

At this phase the following recommendations were obtained: change and revise aspects including legislation, to address the relationship between accidents and waste management, including prevention and protection measures and, finally, make some changes in the presentation context menus. In relation to the drafts aspects, its extentions and the time taken to reponded it were highlited by the experts as aspects to be corrected. Nevertheless, none suggested that questions should be elimated, but extending it by adding new questions. In the order hand, the concretion and the achivement of the objectives were the aspect best rated (see Figure 2).

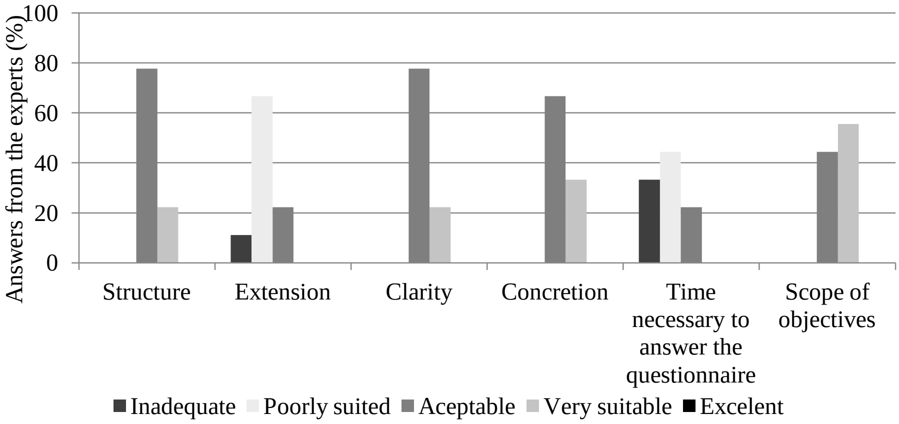


Figure 2 – Assessment on the draft questionnaire by the expert panel.

As a result of phase 1 the definite questionnaire was obtained. It was divided into 6 sections: General information, Health and Workplace Safety, Training and Information, Consultation and Participation, Technical Collective Control Measures, Best Practices in the Workplace and Individual Protection; with a total of 19 questions, none of the formulated as a filter. Finally an initial question was added in function of its workplace exposition with nanomaterials in order to discriminate the initially selected participants.

3.3. Summary and management of respondents

The authors of this investigation identified more than 3.000 workers involved in nanotechnology in Spain that developed their work in university and public research centres. This fact manifests a great activity of investigation and development in nanotechnology in Spain. Without the possibility of accessing all the emails of the identified workers, only 2.618 were invited to respond the online questionnaire. After a week after the first email, a second invitation was sent to those who didn't respond. A week after this was repeated. At last, after three weeks of the first invitation, another invitation was sent to those who didn't respond. Consequently, three emails were sent, the initial and tree remainders. As a result 578 completed surveys were completed, 495 of them indicated performing their work exposed directly or indirectly to nanomaterials, 83 of them participant perform in a theoretical manner, without direct exposure. Nevertheless, out the 495 completed surveys only 425 were validated. (Mainly due to coherence problems in some the answers, for example marking a response and "N/A" at the same time.)

3.4. Description of the surveyed

The geographic location of the surveyed is shown in Figure 3. Most of the Spanish territory is covered, being the communities of Madrid, Aragón, País Vasco, Andalucía, and Cataluña the most important centres of nanotechnological activities.

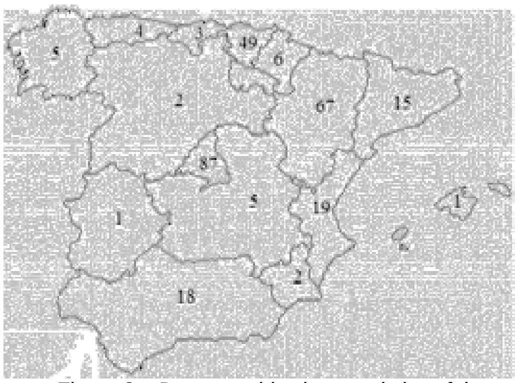


Figure 3 – Demographic characteristics of the participants.

On Figure 4 it is shown the surveyed industrial sectors and fields in relation to their activity in nanomaterials. Most surveyed belonged to the health sector, followed by Microscopy and Instrumentation, Electronics and Energy.

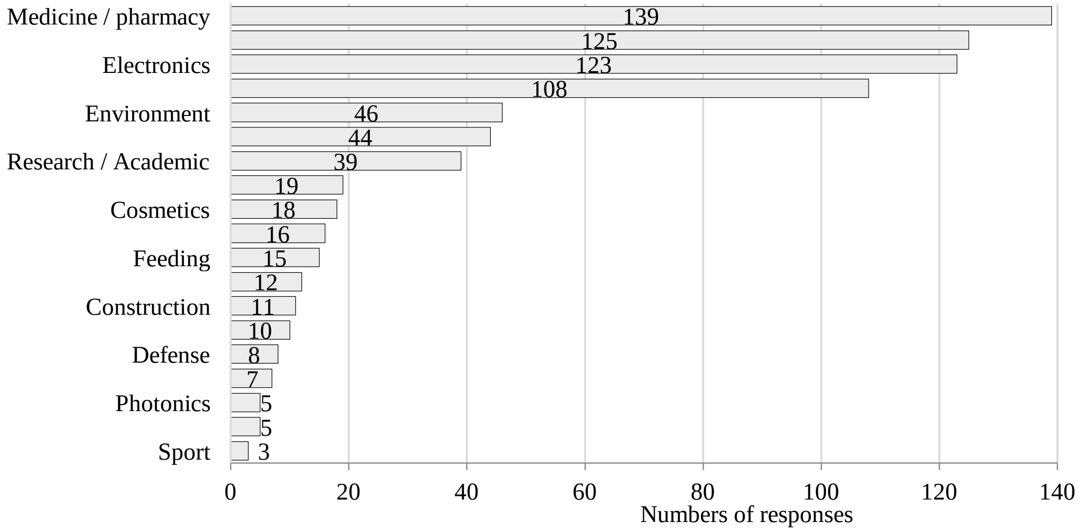


Figure 4 – Nanotechnology-related sector activity.

In Table 2, the sample is described examining the chosen descriptive variables: type of materials, number of workers exposed in the workplace to nanomaterials, characteristics of the nanomaterials, amount of nanomaterials handle at once, and number of hours exposed to nanomaterials.

Type of nanomaterial	Number of respondents	workers exposed to nanomaterials	Characteristics of nanomaterial *	of nanomaterials handled once	Exposure to nanomaterial monthly (h)
Au	212	10<x≤50	S	≤1	≤30
Fe	188			≤1 & 11<x≤999	
Graphene	163		F	1<x≤10	
Ag	155		S	≤1	
Polymers (not polystyrene)	152			11<x≤999	
Organic compounds	150	50<x≤250		1<x≤10	
SiO_2 /Si	149	10<x≤50			
MWCNT	129			≤1	
TiO_2 / Ti	116	50<x≤250			
Quantum dots	114				
CNT	113	10<x≤50			
Al2O3 / Al	83			1<x≤10	
ZnO	80	50<x≤250	F		≤30 & 30 < x ≤90
Polystyrene	60		S		30 < x ≤90
Fullerene	59			1<x≤10	≤30
Dendrimers	46	10<x≤50	S & SF	11<x≤999	
CeO	45		S	≤1 & 11<x≤999	
$CaCO_3$	40		SF	11<x≤999	
Carbon black	39				
Nanoclays	38				
Others	38			≤1	≤30 & 30 < x ≤90
Others transition metals	22	50<x≤250	SF & F		30 < x ≤90
$BaTiO_3$	19		F		≤30 & 30 < x ≤90

* S= In Suspension F= Fixed solid matrix or embedded on a surface SF= Solid freely mobile nanomaterials

1º The most nanomaterials used are gold (Au), Iron (Fe), grapheme and silver (Ag).
2º Most of the workers involved with nanomaterials are exposed in reduced work environments (10-50 workers)

3º Almost all nanomaterial are more frequently in the suspended state, and are practically always handle in small quantities (less than 1 mg) and at once.
4º Finally, the time of exposure is very small since most of the surveyed are exposed at most 30 hours each month.

3.5 Certainty about nanorisks

In figure 5 it graphically shown the surveyed beliefs on the risk that occur when exposed to nanomaterials. It can been seen that:

1º 48% ignore the existence of the risk associated with the toxicity of nanomaterials.
2º It can be highlighted that 13% are still not informed on nanorisks, but are aware of the problems related to the toxicity of nanomaterials. It can be conceived that the information was obtain by their means, rather than in the workplace.
3º 88% ignore the risk resulting from the explosion and burning of nanomaterials, even though 31% say to have received information or training on nanorisks, and 29% indicated having consulted the planning, organization, and implications for health and Safety for the use of nanomaterials. This indicated that most of the information, training or consultation by the workers were focused on workplace heath, ignoring safety towards fires and explosions. At the same, only 8% contemplated the risk of exposure to nanomaterials in the risk evaluation performed. Therefore, as a result of the investigation, it is concluded that it is necessary to reinforce the training and information programs, as well as involving the workers on issues that affect them in occupational risk prevention associated with nanomaterials.
4º The lack of specific regulation means there is no obligation to monitor the health of the worker. Consequently, it is not contemplated in the Royal Decree 1299/2006 of professional disease (Ministry of Labour and Social Affairs, 2006) nanomaterials as agents that could develop professional diseases. Nevertheless, the information in relation to the Nanotoxicology could be enough to justify the use of protocol in the health monitoring of workers (Schulte *et al.*, 2008). In Spain there yet to be developed protocols on the heath monitoring of worker exposed to nanoparticles (Secretaría de Política Sindical de UGT de Catalunya - Salut laboral, 2011), in is noted that the CSIC in Madrid is developing and applying specific medical protocols on health monitoring (Centro Superior de Investigaciones Científicas (CSIC), 2013). However, only 17% of the sample chosen in the research admitted having a specific test or medical examination after being exposed to the nanomaterials. Although it is a positive fact, the results were expected to be higher since most of the surveyed belong to the CSIC in Madrid.
5º Finally, it highlights that only 5% of the surveyed have certainty of accidents related to the use of nanomaterials.

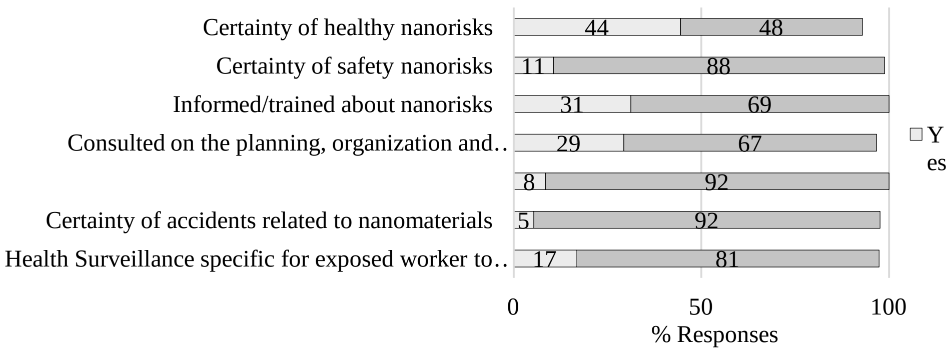


Figure 5 – Certainty about nanorisks

3.6 Good Practices

A 98% performed sometime of good practice specific for working with nanomaterials. The most highlighted practices are related with personal hygiene: showers or chaginfs clothes in the workplace after the workday; avoiding touch the face or other parts of the body; avoiding exposure of hands and touching nanomaterials; avoiding consuming food or drinks in the workplace; and washing your hands after leaving the workplace. In Figure 6 the percentages of good practices indicated are shown.

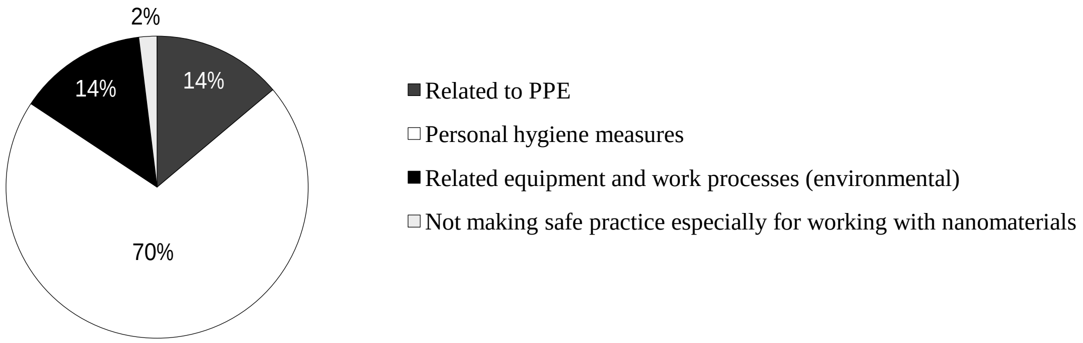


Figure 6 – Good Practices for working with nanomaterials.

3.7 Nanowastes

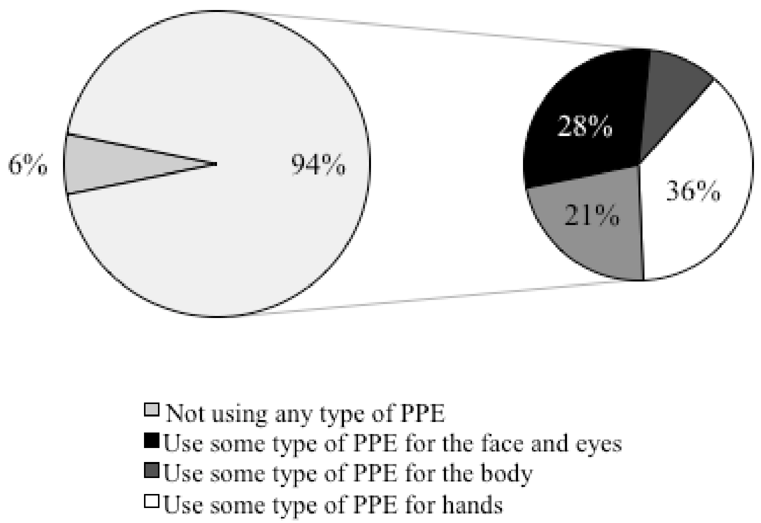
Currently there isn't any specific regulation on the treatment of nanowaste, although it is recommended that they be treated as hazardous waste (NEPHH'S CONSORTIUM, 2012).

Figure 7 – Treatment of nanowastes versus information and training received about it.

Almost half of the surveyed, a 49%, treat them with this condition. However, it is considered to be an autonomous initiative of the workers, since 78% of them point out having no information or training on the treatment of nanowaste. Its highlighted that 25% indicated treating them a non-hazardous, while 16% point out not generating nanowaste in the workplace (see Figure 6). However, it is possible to assume that the type of treatment of nanowaste responds to an individual and personal initiative, not being the result of a training or information carried out by the company. Consequently, the results of the investigation consider being urgent reinforcing information and training programs, as well as involving more personnel on issues of Occupational Risk prevention in the use nanomaterials.

3.8. Personal Protective Equipment

The use of personal protective equipment when working with nanomaterials was general among the surveyed, only 6% didn´t use any type of protection. (see Figure 8). 36% of the surveyed stated using the most as hand protection: gloves made of nitrile, latex, neoprene and polyvinyl chloride (PVC). Followed by 28% using face and eye protection: universal frame glasses, full frame grasses, and face shield. 21% stated using respiratory protection: disposable mask with filter FPP3, partial facemask respirator with filter, full facemask respirator with filter, and full face mask with external air supplier. Finally, only a 9% used body protection: protective suit against chemical agents (TYVEK), overshoe / shoe covers / shoe lab, and hood or cap.



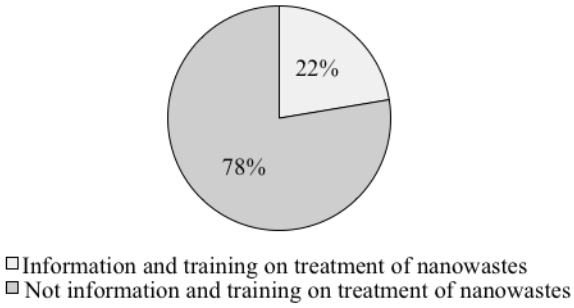


Figure 8 – Type and use of specific personnel protection for nanomaterials

3.9. Nano-specific facility design and engineering controls

In Figure 9 the frequencies of specific facility designs and engineering controls available to surveyed for working with nanomaterials. Stands out considerably that 235 of the surveyed indicated that the used ventilation by fume hood in the workplace, followed by 146 of them worked in process in wet and liquid mediums and 104 in glove box/glove bags. A very significant number of the surveyed (59) did not apply any type of specific facility design or engineering controls when working with nanomaterials. Finally, only 31 pointed out using ventilation by dilution and rooms with positive and negative differential pressure. In conclusion, although there is still uncertainty in risk prevention in the use of nanomaterials, preventive and protective measures applied follow a precautionary principle, sometimes not being enough.

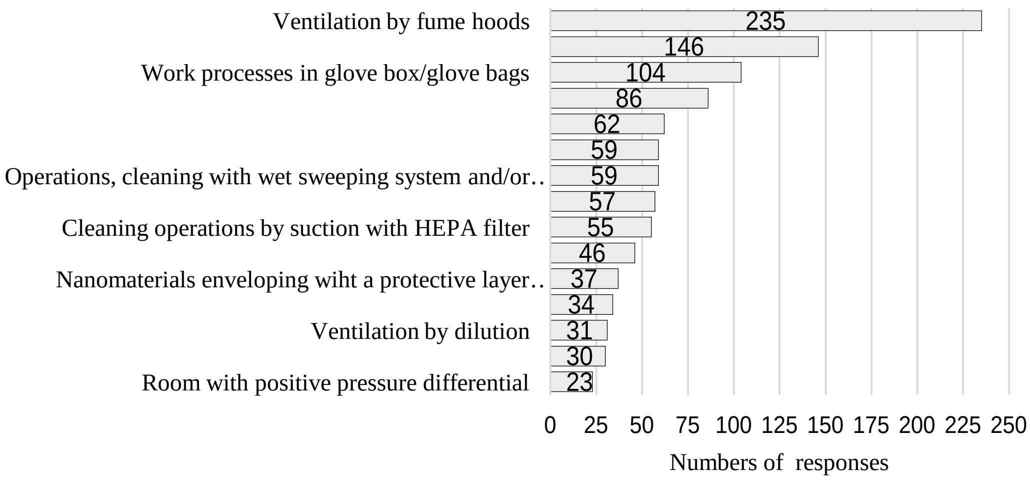


Figure 9 – Nano-specific facility design and engineering controls.

4. CONCLUSIONS

Numerous studies were identified dealing with preventive issue related with nanomaterials. 425 were surveyed in the sample, being the major investigation performed in Spain specifically on occupational hazards in the presence of nanomaterials. The results obtained in the survey were validated by an experts panel and revealed the following issues:

1º Most workers are not aware of risk associated with nanomaterials, in particular those of explosion and fire.

2º The majority has not been trained or informed on these risks. They have not consulted about planning, organization, and implications to health and safety for the use of nanotechnology in the workplace, neither the inclusion in the risk evaluations of the exposure to nanomaterials. In conclusion, the respondents manifest a widespread ignorance about the fundamental issues of safety and health at work arising from the use of nanomaterials. It is considered to be necessary to reinforce the training and information programs, as well as involving the workers on issues that affect them in occupational risk prevention associated with nanomaterials.

3º The vast majority of the surveyed performed good workplace practices. They treated nanowaste in an adequate manner, used some type of protective personal equipment, and collective protection equipment was available to them. Consequently, risk prevention and

protection measures take precedence to related preventive techniques addressing occupational risks in the use of nanomaterials.
4º It should be highlighted the certainty of surveyed on nanomaterial related workplace accidents. Therefore, it is to necessary to study the issue and check if any accidents have been notified or investigated.
5º Regarding the health surveillance of workers, it has been found that is still far from being incorporated as a general procedure.
6º Due to the results obtained in the survey, it has been concluded that is necessary to continue investigating the issue. A deep analysis of the various fields must be done and expanded at industrial scale in Spain, in order to know in all stages of a construction the actions in prevention carried out when working with nanomaterials.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Agencia Europea para la Seguridad y la Salud en el Trabajo (AESST). (2009). Previsiones de los expertos sobre los riesgos químicos emergentes en relación con la seguridad y la salud en el trabajo. *Facts, 84*

Balas, F., Arruebo, M., Urrutia, J., Santamaria, J. (2010). Reported nanosafety practices in research laboratories worldwide. *Nature Nanotechnology, 5*(2), 93-96. DOI:10.1038/nnano.2010.1

Boje, D. M., & Murnighan, J. K. (1982). Group confidence pressures decisions. *Manage Science, 28*(1), 1187-1196.

Boutou-Kempf, O. (2010). *Feasibility of an epidemiological surveillance system for workers occupationally exposed to engineered nanomaterials.*

Brockhoff, K. (1975). The performance of forecasting groups in computer dialogue and face-to-face discussion. *The Delhpi Method: Techniques and Applications,* 291-321.

Broekhuizen, F. V., & Broekhuizen, P. V. (2009). *Nano-products in the European construction industry.* European Federation of Building and Wood Workers and European Construction Industry Federation.

Cea D´Ancona, M. Á. (2004). *Métodos de encuesta. teoría y práctica, errores y mejora.* (Primera edición ed.). Vallehermoso, Madrid: Editorial Síntesis, S.A.

Centro Superior de Investigaciones Científicas (CSIC). (2013). Unidad de vigilancia de la salud y medicina del trabajo CSIC (madrid). Retrieved 9/1, 2013, from http://www.icb.csic.es/fileadmin/formacionOfertas/unidad_de_vigilancia_de_salud_laboral.pdf

Conti, J. A., Killpack, K., Gerritzen, G., Huang, L., Mircheva, M., Delmas, M., Harthorn, B. H.*et al.* (2008). Health and safety practices in the nanomaterials workplace: Results from an international survey. *Environmental Science & Technology, 42*(9), 3155-3162. DOI:10.1021/es702158q

Engeman, C. D., Baumgartner, L., Carr, B. M., Fish, A. M., Meyerhofer, J. D., Satterfield, T. A., Holden, P. A.*et al.* (2012). Governance implications of nanomaterials companies' inconsistent risk perceptions and safety practices. *Journal of Nanoparticle Research, 14*(3) DOI:10.1007/s11051-012-0749-0

EuropeAid. (2005). Panel de expertos. Retrieved 8/5, 2015, from http://ec.europa.eu/europeaid/evaluation/methodology/egeval/tools/too_pan_som_es.htm

European Commission. (2005). European survey on success factors barriers and deeds for the industrial uptake of nanomaterials in SMEs.

European NanoBusiness Association. (2005). The European NanoBusiness survey. *The European NanoBusiness Association,*

Gerritzen, G., Huang, L., Killpack, K., Murcheva, M., Conu, J. (2006). *A review of current practices in the nanotechnology industry* International Council on Nanotechnology (ICON).

Gibbs, L. M., Lamba, F., Stoxkmeier, B. C., Kojola, W. (2012). *General safe practices for working with engineered nanomaterials in research laboratories* National Institute for Occupational Safety and Health (NIOSH).

Helland, A., Kastenholz, H., Siegrist, M. (2008). Precaution in practice: Perceptions, procedures, and performance in the nanotech industry. *Journal of Industrial Ecology, 12*(3), 449-458. DOI:10.1111/j.1530-9290.2008.00053.x

Jacquet, F. (2012). *Repérage des salariés potentiellement exposés aux nanoparticules.*

Landeta R., J. (1999). In Talleres HUROPE S. L. (Ed.), *El método Delphi* (Primera ed.). Barcelona: Editorial Ariel, S.A.

Lekas, D., Lifset, R., Rejeski, D. (2006). Nanotechnology startup concerns, information needs, and opportunities to proactively address environmental, health, and social issues. Focus on firms in Connecticut and New York.

Lindberg, J., & Quinn, M. (2007). *A survey of environmental, health and safety risk management information needs and practices among nanotechnology firms in the Massachusetts region*

López, M. (2013). *Metodología para el análisis y el control de los costes relacionados con la seguridad y salud en las obras de construcción*

Real Decreto 1299/2006, de 10 de noviembre, por el que se aprueba el cuadro de enfermedades profesionales en el Sistema de la Seguridad Social y se establecen criterios para su notificación y registro. (2006).

NEPHH'S CONSORTIUM. (2012). *Guidelines for responsible management of waste nanomaterials*

Occupational Safety and Health Administration (OSHA). (2008). *CFR 1910.132. General Requirements: Personal protective equipment*. Washington D.C:

Occupational Safety and Health Administration (OSHA). (2010). Introduction to nanomaterials and occupational safety and health.*SH-21008-10-60-F-48*

Ricaud, M., & Witschger, O. (2012). *Les nanomatériaux: Definitions, risques toxicologiques, caractérisation de l'exposition professionnelle et mesures de prevention.* Institut National de Recherche et de Sécurité.

Rosell, M. G., & Pujol, L. (2008). *Nota técnica de prevención 797: Riesgos asociados a la nanotecnología*. Instituto Nacional de Seguridad e Higiene en el Trabajo.

Rowe, G., & Wright, G. (1999). The delphi technique as a forecasting tool: Issues and analysis. *International Journal of Forecasting, 15*(4), 353-375. DOI:10.1016/S0169-2070(99)00018-7

Schmid, K., & Riediker, M. (2008). Use of nanoparticles in Swiss industry: A targeted survey. *Environmental Science & Technology, 42*(7), 2253-2260. DOI:10.1021/es071818o

Schulte, P., Geraci, C., Zumwalde, R., Hoover, M., Castranova, V., Kuempel, E., Murashov, V.*et al.* (2008). Sharpening the focus on occupational safety and health in nanotechnology. *Scandinavian Journal of Work Environment & Health, 34*(6), 471-478.

Secretaría de Política Sindical de UGT de Catalunya - Salut laboral. (2011). Cuaderno preventivo: La nanotecnología un riesgo emergente. *ARA Prevenció,*

Tanarro, C., & Gálvez, V. (2009). *Nanopartículas: ¿un riesgo pequeño?* Instituto de Seguridad e Higiene en el Trabajo.

Zhang, C., Zhang, J., Wang, G. (2014). Current safety practices in nano-research laboratories in china. *Journal of Nanoscience and Nanotechnology, 14*(6), 4700-4705.

Challengers of building societal resilience through organizational security risk management

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Abstract
Several scholars have discussed and described two different regimes for regulating risk. Different terminologies have been used to describe these regimes, but Hopkins (2011) refers to these regimes as the “risk-management regime” and the “rule-compliance regime”. Although the use of risk management approaches for achieving protection against intentional crimes has increased in multiple sectors during the last decade, little attention has been paid to the consequences of the application of a risk management regulation regime in the context of building resilience against intentional crimes such as terrorism. This paper aims to describe and discuss challenges and advantages with applying a risk management regulation regime within the area of security, which is protection from terrorism or other intentional crimes, in contrast to safety witch implies protection from non-intentional acts. We discuss the characteristics of the area of security in contrast to safety, and we identify challenges organizations face when governing security risks in both regimes. The application of a risk management regime is discussed in light of dilemmas related to the current aviation security regime, the rebuilding of the Government complex in Oslo after the bombing on July 22 2011, and the implementation of security risk management in the Norwegian petroleum sector. We conclude that several aspects of security risks make the application of a risk-management regime challenging from an organizational perspective, both concerning the characteristics of security risks and for the risk analytical methodology currently available to organizations. Moreover, we conclude that the new role of organizations in security management is a novel trajectory that places a societal security responsibility on organizations, which they are not necessarily designed and equipped to address.

Keywords: security, terrorism, risk management, resilience, regulation regimes

1. INTRODUCTION

In recent years, the concept of resilience has been used on a societal level in reference to how societies can “bounce back” in the face of a disturbance. The image of an uncertain world, in which new types of risks and threats can become a reality in the future, has moved the focus away from security from one type of threat to society`s ability to tackle all kinds of possible scenarios that might unfold, including terrorism. Consequently, several governments and the United Nations have introduced the concept of resilience as a disaster preparedness strategy to enable countries to improve their ability to handle crises (Comfort, Boin, & Demchak, 2010). While security related to intentional acts, such as terrorism, used to be an area of secrecy where security services played the major part in prevention, the responsibility for creating resilience and managing the threat of terrorism have nowadays become an area where citizens, companies and different official bodies have a shared responsibility. This is reflected in the many official strategies against terrorism published in most Western countries in recent years (Aly, 2013).

In order to enhance societal resilience in regard to terrorism, governments in most Western countries have highlighted risk analysis as a tool in organizational security risk management, especially after the terrorist attack in the US on September 11 2001 (9/11) (Office U. S. G. A., 2005). This tendency to achieve societal resilience through organizational risk management is also present in Norway. In the aftermath of the 9/11 terrorist attack, the focus on terrorism as a risk against Norwegian society has gradually increased (Jore, 2012). The bombing of the Norwegian Government complex and the shooting massacre on the island of Utøya on July 22 2011 where a total of 77 people were killed, and the terrorist attack on the Algerian oil facility in In Amanas in January 2013 where 5 Norwegians employees in the Norwegian oil company Statoil were killed, have further increased the focus on protection from the threat of terrorism in Norway. After these two incidents, both evaluation reports concluded that there had not been sufficient focus on security from intentional acts, and that the attack could either have been avoided or the impacts could have been reduced if the companies or official bodies responsible had taken the necessary precautions (Gjørv, 2012; Statoil, 2013). In the aftermath of these events, new object security legislation based on a risk-management approach was passed in

January 2011 (Ministry of Defence, 2011), and in order to lay a foundation for better risk analysis of intentional acts, three new standards for protection against intentional acts were published (Standards Norway 2012; 2014a,b).

Several scholars over the years have discussed and described two different regimes for regulating risk. Different terminologies have been used for describing these two regimes (Ayres & Braithwaite, 1992; Gunningham & Rees, 1997; Baldwin & Cave, 1999; Hale et al., 2002; Hutter & O'Mahony, 2004; Hutter & Power, 2005; Hutter & Jones, 2007; Coglianese & Mendelson, 2010). Hopkins (2011) refers to these regimes as the "risk-management regime" and the "rule-compliance regime". The distinction and the balance between these two regimes have been extensively discussed, and most regulatory regimes today build on a mixture of the two. However, these discussions have mainly been related to the area of safety. The consequences of the two regulatory regimes have not been discussed in relation to security. In line with Piètre-Cambacédès & Chaudet (2010) we call protection from terrorism or other intentional crimes for security in contrast to safety which implies protection from non-intentional acts. Security risks have had a tendency to be governed through rule-compliance regimes. for example in the post 9\11 aviation security regime, but the introduction of new legislation and new risk management standards have required that security risks now are also governed through a risk management regime. This paper aims to describe the consequences of these two regimes in a security context, and to discuss some of the challenges of applying a risk-management regime within the area of security. The application of a risk management regime is discussed in light of the finding of previous studies that the author has been participating in: the current aviation security regime in Norway (Jore and Njå, 2012), the rebuilding of the Government complex in Oslo after the bombing on July 22 2011 (Berntsen et al., 2014; Meyer, Jore, & Johansen, 2015), and the implementation of security risk management in the Norwegian petroleum sector (Jore & Egeli, 2015). We conclude that several aspects with security risk make the application of a risk-management regime challenging from an organizational perspective, both concerning the characteristics of security risk and because of the status of the risk analysis methodologies currently available to organizations. Moreover, we conclude that the new role of organizations in security management is a novel trajectory that places a national security responsibility on organizations, which they are not necessarily designed and equipped to address.

2. SAFETY VS. SECURITY

Several scholars have claimed that it is meaningful to distinguish between safety and security in order to separate fields of handling risks and crisis (Piètre-Cambacédès, & Chaudet 2010; Reniers, Cremer, & Buytaer, 2011). Protection from terrorism or other intentional crimes is denoted security, while safety implies protection from unintentional acts. According to these scholars, the difference lies in whether the incident is inflicted intentionally or not; the characteristics of a safety risk bear the suggestion of being accidental and security is intentional or deliberate. This implies that, in the case of security, an aggressor is present who is influenced by the physical environment and by personal factors (Reniers, Cremer, & Buytaert 2011). This differentiation between safety and security are meaningful to many scholars and practitioners and are often used, for example in aviation, to describe two different approaches for handling risks.

The distinction between the role and the intent of humans in safety and security are, however, not necessarily as rigid as perceived at first glance The literature on organizational safety has for a long time acknowledged that accidents are not something that just happens (Perrow, 2011a, 2011b; Reason, 1990; 1997; Weick & Sutcliffe, 2011; Woods, Leveson, & Hollnagel, 2012). The role of human intent and action is discussed by Reason (1997) who claims that organizational accidents depend critically upon two kinds of failure: the failure of actions to go as intended and the failure of intended actions to achieve their desired consequences. In addition, he adds a category of intentional actions named violations. For violations, the error lies in having an intent not to follow the rules. Reason defines violations that do not involve the goal of system damage as exceptional, routine or reckless violations. This means that in contrast to what the definitions of safety and security suggest, human intent plays a role in both safety and security. Even though deliberate violations play a part in both safety and security, the distinction lays in the malicious intent of the aggressor who actually calculates and plans for a crisis to happen. In Figure 2, a continuum of the different human errors is visualized. Whereas safety events are frequently associated with the human errors on the left of the figure below, security events are associated with the violations characterized by ill intent on the right (Lilleby & Egeli, 2014). This continuum between the different types of errors places safety and security risks in a total risk picture.

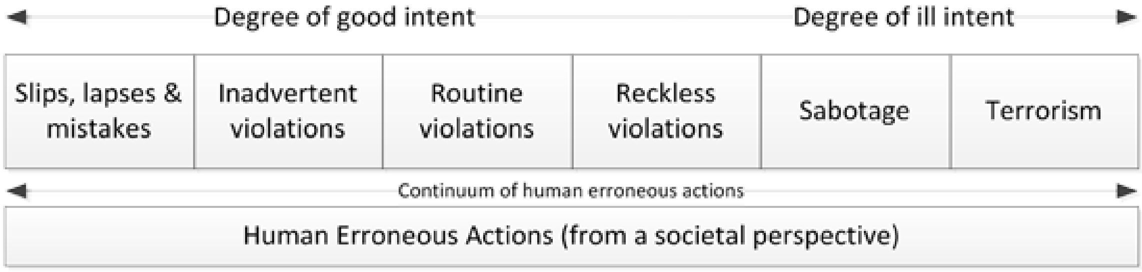

Figure 1: Continuum of human erroneous actions (Lilleby & Egeli, 2014)

In both safety and security incidents, there is a significant influence of human intent. Within safety research, it is acknowledged that humans intentionally take shortcuts, or do not follow procedures, which can eventually lead to accidents. While within security research, human intent is the main threat in itself. In both safety and security events, there is a violator. In security events, the threat actor has malicious intent.

Nowadays, both safety and security issues are considered to be risks that organizations have to deal with. From an organizational perspective, these risks are fundamentally different in nature. Safety is closely associated with the risk that the organization chooses to run while security involves the threat to which the organization is exposed. In regards to safety, it is the organization itself, with its internal management and production that is identified as the source of both the problem and the solution. Safety is therefore conceptualized as a relatively technical and controllable problem. Conversely, security problems are not necessarily directly linked to the actions of the company and are therefore conceptualized as less controllable (Petersen, 2011). Consequently, when organizations deal with security risks, they have to take into account that human malicious intent could by rooted both from someone inside and outside the organization, and these factors have to be considered during security assessments. Moreover, most organizations do not have the means to reduce the threat, and since the area of security is a new area in organizational risk management, the organizations do not necessarily have the means to reduce either the probability or the consequences of an attack.

For an organization that is doing a security risk analysis, probabilities are hard to determine because of the low frequency of such events, which means that a probability will always be of minor character, and there is often a lack of relevant historical data on which to build risk assessments. Hence, the identification of threats and the development of measures in terms of security is a challenging task that is often qualitative. This, however, is not necessarily the case for all security-related risks organizations deal with. The area of security spans from vandalism to terrorism or security political crises. For many security related risks, such as more “ordinary crimes,” historical data does exist that could be relevant to organizational security risk management.

To be safe and secure essentially means that nothing goes wrong and that technical systems, organizational systems and humans need to function optimally. All major organizational accidents, within both safety and security, have elements of technical, organizational and operational (human acts) nature. This means that both within the area of safety and security humans plays an important role in detection, mitigation and emergency management. For some safety and security scenarios, the consequences will be the same, for example a fire, and the same measures, for example a fire extinguisher, will reduce the consequences of both incidents. It is important, however, to keep in mind that criminals deliberately might search for the best manner to execute their plans and that their goal could be to cause as much damage as possible. Preventive safety measures may decrease security risks, but not always. An important exception is the availability of information. It is clear that safety measures such as risk maps and labeling of dangerous substances have a negative impact on security (Reniers, Cremer, & Buytaert, 2011). These means that organizations’ security concerns often are classified or not open to public scrutiny. To avoid these types of conflicting situations organizations should strive for having a holistic approach to safety and security.

3 THE RULE-COMPLIANCE REGIME

Historically, rule-compliance was the dominant approach to regulating hazardous activities. Governmental regulation of HSE during the first part of the 20th century was dominated by a top-down command and control-based regulatory model characterized by prescriptive regulations, involving detailed, specific and often technical requirements. During this period, the authorities met new risks related to technological development by applying more prescriptive regulations. In most industries, such as nuclear, oil and gas, risk management was traditionally based on this prescriptive regulating regime in which detailed requirements for design and operations were specified (Lindøe, Kringen, & Braut, 2012). Although this regime is often referred to as a historical regime, which today is challenged by the risk-management regime, this regime is still present in many sectors. In the area of security, this regime is applied for example in the post-9/11 aviation security regime.

3.1. Advantages with the rule–compliance regime

In the rule-compliance regime, the authorities set out detailed regulations in order to steer the direction of companies, or others, in their security work. This regime will lead to a uniform implementation of security measures, meaning that each organization covered by a specific regulation will have the same level of security independently of an organization's perception of available resources, threat picture and former experience with the threat of intentional crimes. In a security context, this means that organizations will implement the same level of security measures independently of whether an organization belongs to a sector that has historical experience with acts of intentional crimes or terrorism. The post 9/11 aviation security regime illustrates this. After the 9/11 terrorist attack, harmonization of airport security was the main goal of the European regulations. Consequently, all commercial airports in Europe had to follow the same security regime regardless of national or local threat assessments or previous experiences with acts of terrorism (Engen & Olsvik, 2010; Jore & Njå, 2012). The outcome of this regime was that small airports in rural parts of Norway were bound by the same regulations as giant airports in Europe.

The rule-compliance regime might lead to an easier management process within an organization because the government agencies or supranational official bodies have set the rules for when and how to implement security measures. The organization itself does not have to invest time and resources in evaluations of whether there should be implemented security measures or not. In aviation, the airports simply follow the regulations dictated on the European level. There is no decision-making process on each airport for deciding whether airports should implement measures or not.

The rule-compliance regime might simplify the job of the official bodies responsible for inspections since it is easier for official bodies to clarify whether a company has the expected level of security or not (Stålesen, 2011). The task of those who are doing inspections is to decide if the rules are to be followed or not, rather than deciding whether the security measures are effective and in line with the threat landscape.

3.2. Challenges with the rule-compliance regime

Despite these advantages with the rule–compliance regime, there are also some challenging aspects with this way of managing security risks. One challenging aspect with the rule-compliance regime is that the rules are in focus, not necessarily how to achieve the optimal level of security. Organizations and inspectors operating in this security regime will be concerned with whether the rules are followed rather than how to achieve the optimal level of security from intentional crimes. In aviation, the prescriptive and detailed regulation regime offers no opportunity to locally assess and mitigate the risk of terrorism, unless there is an assessment leading to a strengthening of security beyond minimum requirements. Studies of the post-9/11 security regime in aviation have showed that the industry informants have been sceptical to the actual risk-reducing effects of the new security regime. They described several areas where the detailed and stringent regulations were problematic or burdensome or did not make any logical sense (Engen & Olsvik, 2010; Jore & Njå, 2012). Moreover, if risk management is built on general rules rather than specific threat and vulnerability assessments for each organization; many organizations will implement security measures on a higher level than necessary and by this leading to an unnecessary level of costs and inconveniences for the company and its employees.

Another challenging aspect with this approach is that since the process of changing regulation takes time, this security regime does not facilitate quick changes in the regulations if the threat landscape changes. The rule-compliance approach has a tendency to involve a reactive response from the regulated organizations, meaning that rules are often made because a terrorist attack or a terrorist plot have revealed vulnerabilities of the current security system. In aviation, numerous regulations have been added to the existing regulations because perpetrators have tried, or carried through, attacks against the system or because of revealed plots; the 2001 “shoe bomber” incident led to the shoe removal and screening policy, the liquid and gel ban policy was instituted after the 2006 plot to blow up planes bound for the United States with liquid explosives, and the 2009 Christmas Day bomber incident, where the perpetrators were carrying explosives in their undergarments, led to the deployment of advanced imaging technologies and pat-downs for all passengers. In all these cases, the changes in the regulations were a direct response to the attempt to commit an intentional crime (Jacobson, 2012). In fact, the whole new security regime in aviation was a direct response to the 9/11 terrorist attacks (Birkland, 2004; Engen & Olsvik, 2010; Salter, 2008).

4. THE RISK-MANAGEMENT REGIME

As mentioned earlier, the authorities traditionally met new challenges of technological development related to risks and accidents by applying more prescriptive regulations. However, as time goes by more detailed regulations have been passed. The amount of regulations gradually increased to the point where it was completely unwieldy (Hale, Hopkins, & Kirwan, 2002; Lindøe, 2012). At the end of 1990`s a review of the law and management structure in HSE area in Norway displayed that there were over 60 laws and 1000 regulations governing this area (Lindøe, 2012). In the 1970`s, a new regulatory regime emerged, and the focus changed from detailed governmental control towards an internal control regime (Lindøe, 2012). In most industries, the rule-compliance regime was replaced with more goal-oriented regimes. Goal orientation and risk characterizations were two major components of this new regime that has been endorsed by international organizations and various industries (Aven & Renn, 2009).

The risk-management regime builds on the assumption that organizations have the necessary competence for knowing what type of risks the organization might face in the future, and knowing the appropriate means for how these threats should be met. Consequently, the assumption is that organizations have the ability to describe what may happen in the future, to assess associated risks and uncertainties, and to choose among relevant alternatives (Aven, 2003). The assumption is that risk assessments should function as decision support in a decision-making process in order to make ideal decisions about how to find the optimal level of security.

4.1.Security is an organization`s responsibility

In the area of security, the state has traditionally been responsible for protecting citizens from acts of terrorism and other intentional crimes. However, the introduction of the new Norwegian object security regulation passed in 2011 (Ministry of Defence, 2011), was based on what Hopkins (2011) refers to as a risk-management regime. This regulation gave the Ministries the responsibility of appointing critical objects within their jurisdiction. The object security regulation contains a risk-based approach to how to protect critical objects, and it is the owner of a critical object which is responsible for conducting a risk analysis of valuation of assets, threats and vulnerabilities that will lay the foundation for measures the organization should implement. Owners of critical objects are also responsible for the implementation of risk reducing measures and for bearing the associated costs. The implementation of the new object security regulation marked a shift in who bears the responsibility for protecting citizens from acts of terrorism and other intentional crimes. A regulation founded on a risk–management approach entails that the responsibility for societal resilience no longer is dictated from the state but is delegated to the organizations. This implies a change in the role of the state regarding security related issues. In a rule-compliance regime, the state is a protector of law and the primary task is, by the use of legitimate authority, to force organizations to fulfil their obligation of following laws and regulations within legal binding norms. Anyone violating laws can be sanctioned and punished. In the risk-management regime, the role of the state is not to enforce companies to follow certain rules, but to arrange for and assist organizations in finding the optimal level of security. This means that the official bodies responsible for inspection working in this regulation regime have a different role than the inspectors working in the rule-compliance regime. The role of the official bodies doing inspections in the risk-management regime is to check if the organizations have carried through risk assessments and implemented measures in accordance with the risk assessments. The role of the inspector has, thus, changed from a punisher to an adviser.

4.2 Flexible and in line with the current threat landscape

In the risk-management regime the knowledge that an organization has regarding its assets, values, vulnerabilities, and associated threats is in focus. This means that the organizations have more flexibility in how to arrange its security regime and can direct the security system against the threats that are considered to be most critical to the organization. Consequently, the organization can protect the assets assessed to be most valuable, and organizations can change and adapt security measures if the threat landscape changes. Despite these advantages, there are also some challenging aspects with the risk-management regime.

4.2.1 The risk-management regime is no practical guide

The role of human intent is often highlighted as problematic when conducting security risk analysis. For more than half a century, risk analysis has been an important tool in describing and managing safety risks. The use and development of risk analysis has been seen in both practical and academic fields. Within the area of security risks, on the contrary, the application of risk analysis has not traditionally been the subject of the same academic discussions. During the Cold War, the management of security risks was the responsibility of the police and the defence, which implied that security risk analysis was not subject to public or academic scrutiny and consideration. The application of risk analysis to protect society and organizations from intentional crimes, such as terrorism, has been the subject of extensive debate both in academia and practice in the aftermath of this event. Scholars and practitioners have discussed whether security risk can be expressed by traditional risk analytical tools, or whether it is necessary to develop new analytical tools capable of capturing the specific characteristics of such threats and challenges related to protecting from malicious acts. These issues have also been addressed in the Norwegian petroleum sector (Jore & Egeli, 2015). The three Norwegian standards for protection against intentional acts (Standards Norway 2012; 2014a, 2014b) define security risk as a combination of valuation of assets, threats and vulnerability (Standards Norway 2012). Thus, probabilities are left out of the risk analysis, and this is a contested topic within specialists in the petroleum sector. Specialists working with risk management in general and specialists working exclusively in the area of security have different opinions on the use of probabilities in security risk management. On the one hand, those working with risk management in general claim that probabilities can be used as long as they are expressed as subjective and knowledge-based probabilities. Informants working solely in security, on the other hand, reject the use of probabilities in security risk management. They argue that safety and security are fundamentally different areas and, consequently, need different risk management methodologies. There seems to be a tendency that the informants lack the expertise for the opposite discipline. Some specialists within the security field only associate the term probability with mathematical calculations and statistics. They tend to believe that probabilities are only understood in the positivist perspective to risk and use a frequentist approach to probabilities. They do not seem to be aware of the more updated constructivist perspective to risk where probabilities are seen as subjective and knowledge-based (e.g., Aven 2013; 2014). Since they associate probabilities with a classical positivist perspective to risk, they reject the use of probabilities because there will be a lack of data to base a risk assessment on. This means that today, the risk analysis used in safety and security are not harmonized, and that the new security standards are problematic for achieving a holistic approach to safety and security within an organization. Consequently, the organizations lack the necessary tools to conduct risk analysis.

4.2.2 No benchmarking for when to implement security measures

A risk-management approach is no practical guide; it does not give any clear guidance for what is an appropriate level of security or any benchmarking guides for when a company has achieved the “right” level of security. For a company standing in a concrete decision context, the risk level falls somewhere on a continuum from extreme to insignificant; if the threat is extreme, the company needs to eradicate the threat with every possible means. If the threat is insignificant, the organization can invest the money and resources on other things. However, for most organizations that conduct a security risk analysis the risk assessment will fall somewhere in between the risk continuum, and the organization will have to decide whether the risk is so severe that there is a need for implementing security measures or not. Regulations based on a risk-management regime do not give any clear guidance in the decision-making context. In each case, the risk has to be judged as falling on one or the other side of a line: on one side, a certain action is required; on the other, it is not. In other words, the risk continuum must be converted into a dichotomy for the purposes of decision-making. Thus, the risk-management approach does not in general provide much guidance to those faced with these decisions. It does not offer a way of deciding whether the risk is acceptable or not (Hopkins, 2011). In the area of security, this gets even more complicated; since most assessments and decisions regarding security measures are classified, an organization will in a concrete decision-making context often lack information about how other organizations have arranged their security system. This could also be a challenge for the directorates responsible for inspection. According to the object security regulation, it is the directorate in each sector that is responsible for the inspections within its jurisdiction. Most of these directorates do not have security as their main activity, and will probably lack the experience and the competence on how to deal with security threats. In the rebuilding of the government complex in Norway after the bombing on July 22 2011, the mandate of the commissions that where appointed was to protect the complex against a broad range of risks. The concept study mentioned intentional acts, such as crime, intelligence gathering, terrorism and sabotage, and other unwanted incidents, such as fire, water damage, and loss of electrical power. Elements in the government complex are classified as critical objects in accordance with the new security law and the object security regulation. The commission who was appointed found it difficult to interpret the risk-management regulation regime, so seven absolute security requirements were formulated (Metier, OPAK, LPO arkitekter, 2013). This example illuminates that a risk management regime might be challenging for an organization to deal with because no clear answers are given about when the right level of security is achieved.

4.2.3 Organizations can be tempted to lower the risk assessments to save money

The purpose of risk management is to ensure that adequate measures are taken to protect people, the environment, and assets from harmful consequences of human activities. The extent to which risk reducing measures are justified depends on the balance between costs and benefits in terms of safety and security gains (Aven & Renn, 2009). Organizations have become politically important to counterterrorism efforts, but the economic logic guiding the risk thinking of private companies is hardly compatible with the aim of providing national security. The separation of politics and the market was regarded a liberal construction intended to serve the ‘good life’ and peace, and to avoid a repressive state where security could be considered the main and overriding priority in all social affairs. Whereas companies previously understood security as a rather narrow, technical function – primarily constituting an additional cost to businesses – the contemporary view leans towards seeing national security as an integrated part of the overall business strategy (Petersen, 2008). Private companies take many risks associated with safety by making investments and doing business, and therefore risks are positively related to making a return. Security, on the other hand, has not historically been associated with economic prosperity, but with prevention and necessity (Petersen, 2008). Hence, corporate security is not, to the same extent as safety risks, easily reconciled with profit maximization. The dilemma between national security and business is even bigger, as we are not only talking about the costs of protecting the company, but also the costs of helping to protect the country. Handling security risks is not most organizations main activity, and most organizations will probably have other risk related areas that are assessed to have higher probabilities of occurring, such as non-intentional accidents. According to the Norwegian object security regulation, organizations themselves have to pay for security measures. The consequence of this could be that many companies can be tempted to lower the risk level to save investments in a security system. Thus, trust is a fundamental character of the risk-based regime. Such a regime is based upon a belief about the regulated wanting and pursuing the best solutions available.

4.2.4. In the risk management regime security becomes an ongoing process

A risk management regime is challenging for organizations because it requires that many efforts are put into the risk management process. This approach moves the focus from governmental inspections checking compliance with existing rules, towards inspiring the industry to develop their own systems of internal control and management. In this regime, the organizations are forced to evaluate and report upon their own self-regulatory strategies in order to enable the regulatory authority to judge if the objectives of the regulations are met. Thus, the risk management process becomes central. In other words, security in this perspective is not just a checklist that can be completed, but an ongoing process where the organizations have to continue to monitor that the security system is in accordance with the threat assessments.

However, many companies may not fully understand the threat situation or what measures could be implemented. Today, many Norwegian companies operate on an international or global basis. This means that organizations need to be updated on the local security situation and the threat assessments need to be updated. Still, even for organizations operating solely on the national level in Norway, most organizations will not have the necessary competence and means to conduct meaningful threat assessments. Consequently, the organizations will have to rely on risk assessments done by the authorities or other companies that sell risk assessments.

4.2.5. Organization lacks knowledge of the effect of counterterrorism measures

The objective of risk-based security management is to identify risks before they materialize in the form of an intentional crime. Once risks have been identified, preventive measures can be taken to eliminate the risks or to reduce the probability of the occurrence of such events. Although this is an attractive idea, little is known about how well security measures actually work. In research, minor attention has been paid to the effectiveness of counterterrorism measures. Lum, Kennedy and Sherley (2006) discovered an almost complete absence of research that evaluated counterterrorism measures. From the evaluations they found, it appeared that some interventions either did not achieve the outcomes sought or sometimes increased the likelihood of a terrorist attack. LePorte and Frederickson (2002) have demonstrated that it is almost impossible to measure the efficiency of counterterrorism measures because it is impossible to know if the absence of terrorist attacks means that the security measures are effective or whether there never existed a terrorist threat in the first place. This means that organizations will lack knowledge regarding the risk reducing-effect of counter measures, and also the means for evaluation of whether the measures are effective or not.

5. THE TWO REGIMES ARE NOT MUTUALLY EXCLUSIVE

In this paper we have presented the risk-management regulation regime as a contrast to the rule-compliance regime. However, Hopkins (2011) claims that these are not mutually exclusive approaches; they are complimentary. This is also the case for the area of security in Norway. Organizations who work under the rule-compliance regime also work under a regime that acknowledges that security risks can be assessed and managed. In order to determine the appropriate rules, a risk-assessment is most likely behind that decision. This risk-assessment is just removed one step from the end point decision-maker. In the case of airport security, the risk-assessments are done by the European Aviation authorities, and not by national or local assessors. Furthermore, behind the introduction of a risk-management security regime lays another rule, this time a legislative requirement that risk-assessments should be conducted. Behind the risk-management regime introduced in Norway lies the Security Act that demanded that owners of critical objects need to carry through the risk-management regime. Moreover, the security risk analysis standards that have been developed and are in progress can be seen as a guide for helping companies to interpret and deal with risk-management regulation –because organizations still need rules to guide them in their security work. From this point of view, risk-management and rule-compliance are intertwined and complementary strategies.

6. CHALLENGERS OF BUILDING SOCIETAL RESILIECE THROUGH ORGANIZATIONAL SECURITY RISK MANAGEMENT

This paper has described the consequences of the rule-compliance and the risk-management regime in a security context, and discussed some challenges of applying a risk-management regime within the area of security. We conclude that several aspects of security risks make the application of a risk-management regime challenging from an organizational perspective, both concerning the characteristics of security risks and the risk analysis methodologies currently available to organizations. Moreover, we conclude that the new role of organizations in security management is a novel trajectory that places a societal security responsibility on organizations, which they are not necessarily designed and equipped to address.

In today's fight against terrorism, national security concerns cannot be reduced to external threats and handled by diplomatic or military means alone. Counterterrorism are based on the active involvement of civil society, including private companies. The central role of private companies in contemporary security policies can be seen in the increased political focus on the security of airports, airlines, ports and food production in both American and European counterterrorism policies (Petersen, 2008). However, current counter-terrorism strategies put the responsibility for counter-terrorism on so many different actors in society that it is difficult to appoint who actually is responsible for particular actions.

Organizations have become politically important to counter-terrorism efforts, but the economic logic guiding risk prevention in private companies is hardly compatible with the aim of providing national security. For most organizations, security is a minor activity, and there is a knowledge-gap concerning what effective measures are and what an ideal level of security should be. Additionally, current security risk analysis tools are not compatible with safety risk analysis tools, and this hampers a holistic approach to security in an organization. There is still lack of understanding on how private business conceptualizes this role on national resilience and an understanding of the judgements involved in the private companies' selection and classification of these dangers. This is a topic future research should address.

6. REFERENCES

Aly, A. (2013). The policy response to home-grown terrorism: Reconceptualising prevention and resilience as collective resistance. *Journal of Policing, Intelligence and Counter Terrorism*, *8*(1), 2-18. doi: 10.1080/18335330.2013.789594

Aradau, C., & van Munster, R. (2007). Governing terrorism through risk: Taking precautions, (un)knowing the future. *European Journal of International Relations, 13*(1), 89-115.

Aven, T. (2003). *Foundations of risk analysis: a knowledge and decision-oriented perspective*. Chichester: Wiley.

Aven, T. (2011). *Quantitative risk assessment: the scientific platform*. Cambridge: Cambridge University Press.

Aven, T. (2013). Probabilities and background knowledge as a tool to reflect uncertainties in relation to intentional acts. *Reliability Engineering & System Safety, 119*(0), 229-234. doi: http://dx.doi.org/10.1016/j.ress.2013.06.044.

Aven, T., & Renn, O. (2009). The role of quantitative risk qssessments for characterizing risk and uncertainty and delineating appropriate risk management options, with special emphasis on terrorism risk. *Journal of Risk Analysis, 29*(4), 587-600.

Ayres, I. & J. Braithwaite (1992). *Responsive regulation: transcending the deregulation debate*. New York, Oxford University Press.

Baldwin, R. & M. Cave (1999). *Understanding regulation: Theory, strategy and practice*. New York: Oxford University Press Inc.

Berntsen, S., Sunde, T., Rosseland. K.M., Johansen, K.W., Meyer, S.F., Jore, S.H., Aven, T., Bratseth, I., Finsveen, J., Lolleng, J., Steenberg, G. (2014). *Fremtidig Regjeringskvartal - Kvalitetssikring av Beslutningsunderlag for Konseptvalg (KS1)*. Dovre Group and TOI, Oslo.

Bier, V. M., & Von Winterfeldt, D. (2007). Meeting the challenges of terrorism risk analysis. *Risk Analysis: An International Journal, 27*(3), 503-504.

Bigo, D. (Ed.). (2010). *Europe's 21st century challenge: Delivering liberty*. Farnham: Ashgate.

Birkland, T. A.. (2004). Learning and policy improvement after disaster: The case of aviation security. *American Behavioural Scientist*.

Burgess, P. J. (2007). Social values and material threat: the European programme for critical infrastructure protection. *International Journal of Critical Infrastructures 3*(No 3/4), 471-487.

Coglianese, C. & E. Mendelson (2010). Meta-regulation and self-regulation. In the Oxford handbook of Regulation. R. Baldwin, M. Cave and M. Lodge. Oxford: Oxford University Press.

Comfort, L. K., Boin, A., & Demchak, C. C. (2010). *Designing resilience: Preparing for extreme events*. University of Pittsburgh Press.

Crelinsten, R. D. (2009). *Counterterrorism*. Cambridge: Polity.

Deisler Jr, P. F. (2002). A Perspective: Risk Analysis as a tool for reducing the risks of terrorism. *Risk Analysis: An International Journal, 22*, 405-414.

Engen, O. A., & Olsvik, E. A. (2010). Security in civil aviation post 9/11 (pp. S. 2323-2329). Boca Raton, Fla.: CRC Press.

Frederickson, H. G., & LaPorte, T. R. (2002). Airport security, high reliability, and the problem of rationality. *Public Administration Review, 62*, 33-43.

Gjørv, A. B. m. f. (2012). Rapport fra 22. juli-kommisjonen: oppnevnt ved kongelig resolusjon 12. august 2011 for å gjennomgå og trekke lærdom fra angrepene på regjeringskvartalet og Utøya 22. juli 2011. Avgitt til statsministeren 13. august 2012 (Vol. NOU 2012:14). Oslo: Statens forvaltningstjeneste. Informasjonsforvaltning.

Gunningham, N. & J. Rees (1997). Industry self-regulation: An institutional perspective. *Law and Policy, 19*(4), 363-414.

Hale, A. R. & Baram, M. S. (1998). *Safety management: the challenge of change.* Oxford: Pergamon.

Hale, A. R., Hopkins, A., & Kirwan, B. (2002). *Changing regulation: controlling risks in society*. Amsterdam: Pergamon.

Hopkins, A. (2011). Risk-management and rule-compliance: Decision-making in hazardous industries. *Safety Science, 49*(2), 110-120. doi: http://dx.doi.org/10.1016/j.ssci.2010.07.014.

Hutter, B. M. & Jones, C. J. (2007). From government to governance: External influences on business risk management. *Regulation & Governance,* 1, 27-45.

Hutter, B. M. & O'Mahony, J. (2004). The role of civil cociety organisations in regulating business. ESRC Centre for Analysis of Risk and Regulation: London.

Hutter, B. M. & Power, M. (2005). *Organizational Encounter with Risk*. Cambridge: Cambridge University Press.

Jackson, R., Jarvis, L., Gunning, J., & Smyth, M. B. (2011). *Terrorism A Critical Introduction*. New York: Polgrave Macmilian.

Jacobson, S. (2012). Watching through the "I"s of aviation security. *Journal of Transportation Security, 5*(1), 35-38. doi: 10.1007/s12198-011-0078-z

Jore, S. H. (2012). Counterterrorism as risk management strategies (PhD Thesis. no. 178). University of Stavanger.

Jore, S. H., & Egeli, A. (2015). Risk Management Methodology for Protecting Against Malicious Acts -Are Probabilities Adequate Means for Describing Terrorism and Other Security Risks? Accepted for publication in the proceedings of the European Safety and Reliability (ESREL) Conference 2015, Zurich, Switzerland.

Jore, S. H., & Njå, O. (2008). Protection from half-criminal windows breakers to mass murderers with nuclear weapons: Changes in the Norwegian authorities' discourses on the terrorism threat, *4*, 3077-3084).

Jore, S. H., & Njå, O. (2010). Risk of terrorism – a scientifically valid phenomenon or a wild guess? The impact of different approaches to risk assessment. *Critical Approaches to Discourse Analysis across Disciplines*, *4*(2), 197 – 216.

Jore, S. H., & Njå, O. (2012). A discussion on small countries' adaptation to globalised security in aviation. Paper presented at the 11th International Probabilistic Safety Assessment and Management Conference and the Annual European Safety and Reliability Conference 2012 PSAM & ESREL

Karlsen, J. E., & Jore, S. H. (2013). When hindsight is utterly wrong - how to overlook a non-plausible future. Paper presented at the 22nd SRA-E Conference.

Lilleby, J. & Egeli, A. (2014). Achieving common ground for safety and security risk analyses using Human Reliability Assessment. (Bridging the gap between safety and security risk analysis using Human Factors). Paper presented at the NEON-Conference, Stavanger.

Lindøe, P. (2012). Risikoforståelse og myndighetskontroll Risiko og Tilsyn Oslo: Universitetsforlaget AS.

Lindøe, P., Kringen, J., & Braut, G. S. (2012). Risiko og tilsyn: risikostyring og rettslig regulering. Oslo: Universitetsforlaget.

Lum, C., Kennedy, L., & Sherley, A. (2006). Are counter-terrorism strategies effective? The results of the Campbell systematic review on counter-terrorism evaluation research. *Journal of Experimental Criminology, 2*(4), 489-516. doi: 10.1007/s11292-006-9020-y.

Ministry of Defence (2011) *Forskrift om objektsikkerhet* (2011). LOV-1998-03-20-10-§17.

Metier, OPAK, LPO arkitekter (2013) *Konseptvalgutredning for Fremtidig Regjeringskvartal.* Metier, Oslo.

Meyer, S. F., Jore, S. H., & Johansen, K. W. (2015). Troublesome trade-offs: Balancing urban activities and values when securing a city-centre governmental quarter. *City, Territory and Architecture, 2*(1), 1-15.

Office, U. S. G. A. (2005). GAO Report to Congressional Requesters, RISK MANAGEMENT Further Refinement Needed to Assess Risks and Prioritize Protective Measures at Ports and Other Critical Infrastructure.

Perrow, C. (2011a). *The next catastrophe: Reducing our vulnerabilities to natural, industrial, and terrorist disasters. Princeton University Press.*

Perrow, C. (2011b). *Normal accidents: Living with high risk technologies*. Princeton University Press.

Petersen, K. L. (2011). *Corporate risk and national security redefined.* Routledge.

Piètre-Cambacédès, L., & Chaudet, C. (2010). The SEMA referential framework: Avoiding ambiguities in the terms "security" and "safety". *International Journal of Critical Infrastructure Protection, 3*(2), 55-66. doi: http://dx.doi.org/10.1016/j.ijcip.2010.06.003.

Petersen, K. L. (2011). *Corporate risk and national security redefined*. Routledge.

Reason, J. (1990). *Human erro*r. Cambridge university press.

Reason, J. T., & Reason, J. T. (1997). *Managing the risks of organizational accidents* (Vol. 6): Ashgate Aldershot.

Renn, O. (2008). *Risk governance: coping with uncertainty in a complex world*. London: Earthscan.

Salter, M. B. (2008). *Politics at the airport*. Minneapolis: University of Minnesota Press.

Statoil. (2013). The In Amenas Attack -Report of the investigation into the terrorist attack om In Amenas. Prepared for Statoil ASA`s Board of directors.

Stålesen, J. S. (2011). Security styring i petroleumssektoren. Master Thesis, Uniersity of Stavanger.

Van Asselt, M. B. A., & Renn, O. (2011). Risk governance. *Journal of Risk Research, 14*(4), 431-449. doi: 10.1080/13669877.2011.553730.

Viscusi, W. K., & Zeckhauser, R. J. (2003). Sacrificing Civil Liberties to Reduce Terrorism Risks. *Journal of Risk & Uncertainty, 26*(2/3), 99-120.

Weick, K. E., & Sutcliffe, K. M. (2011). *Managing the unexpected: Resilient performance in an age of uncertainty (Vol. 8)*. John Wiley & Sons.

Willis, H. H. (2007). Guiding resource allocations based on terrorism risk. *Risk Analysis. An International Journal, 27*(3), 597-606. doi: 10.1111/j.1539-6924.2007.00909.x.

Woods, D. D., Leveson, N., & Hollnagel, E. (2012). *Resilience engineering: concepts and precepts*. Ashgate Publishing, Ltd.

State of Play in the OSH Field regarding ICT Adoption

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Abstract

The field of Occupational Safety and Health (OSH) has not traditionally been associated with technological advances. Based on National, European and International legislation, norms, guidance and good practice, OSH is usually conceived as regulating workplace conditions, including facilities and equipment as well as human behaviour, more often than not, by setting minimum acceptable standards for both workplaces and employers / employed persons.

The enormous advances in Information Communication Technology (ICT) are now having a profound effect on all aspects of OSH, effectively transforming the reach and scope of OSH, in a similar way as ICT is changing other sectors.

In the broadest sense, ICT is transforming OSH by helping raise awareness and inform employers / employees and the public at large via the World Wide Web – websites, emails, bulletin boards, online databases (usually accessible by subscription). More recently, through Web 2.0 technologies, such as interactive apps and social media (facebook, tweeter, youtube) OSH has been truly brought into the mainstream, immediately accessible to millions of employers / employees as well as other involved parties (competent authorities, social partners, etc.). The application of ICT to OSH can be further subdivided into open-access and purpose built limited-access ICT systems. As a general rule, closed ICT OSH systems refer to competent OSH authority tools, subscription only OSH databases, university and research centres collecting and processing OSH data. Open ICT systems on OSH comprise websites, free apps, open databases on OSH topics and, by their nature, online social media.

As with other fields of economic activity, standardization of OSH data collection remains an issue, especially when attempting to draw meaningful inferences from statistical OSH data being collected. Within the European Union, standardization on OSH data being collected by the member states' competent authorities falls under the framework directive 89/391/EEC and, specifically, the 2007/30/EC (20 June 2007) amendment which obliges member states to prepare and submit practical implementation reports on a five year basis. Member states OSH competent authorities, not only need to adopt ICT systems to implement the above directive requirements on OSH, but also need to collect a plethora of other OSH (and in some cases non OSH) data, interface with other ICT systems in the public sector, such as social insurance data and company registers at the same time, be transparent, so that citizens are kept informed of OSH legislation requirements, such as risk assessments, of occupational accidents and diseases and relevant statistics, while at the same time, respecting personal data protection measures.

Some competent authorities are utilizing tablets and wireless networks to relay OSH data collection to their servers for safe keeping and further processing. In general, web based solutions are gaining ground, compared to legacy systems, in the quest of competent authorities for efficiency, accuracy and data sharing.

An example of an ICT OSH tool, which is both open source and freely available to interested employers, is the Online interactive Risk Assessment tool, popularly known as OiRA. The platform for this tool was developed by the European Agency for Safely and Health at Work (EU OSHA) and is being customized by various member states' competent authorities for a selected number of sectors of economic activity. It is an excellent example of win-win use of ICT in OSH benefitting both the regulator (state labour inspectorates) and the employer (implementing a meaningful risk assessment to safeguard OSH levels in the enterprise) in a quick and interactive way.

Concluding the above research, the need for further development of ICT tools such as OiRA, of mutual benefit to all concerned parties is clearly evident. Online apps which can comprehensively combine the national regulators' requirements with the real OSH needs of

businesses, delivered in an easy to adopt format, while utilizing the latest online social media capabilities, will truly transform the OSH field.

Keywords: Occupational Safety and Health (OSH); Technology (ICT), web tools, OiRA, social media.

1. INTRODUCTION

The development of ICT is by its very nature, a work in progress and in constant evolution. Such is the nature and pace of technological development that the traditional field of OSH, especially the work carried out by competent authorities such as National OSH Inspectorates, will inevitably go through a complete transformation when ICT is applied to it.

This paper examines the impact of ICT on both internal structures of OSH authorities and on those which competent authorities strive to protect – persons at work whose safety and health must be safeguarded at all times.

The internet revolution has enabled competent authorities to develop websites to help inform employers and employees on a wide range of OSH topics, additional dynamic web content has enabled two-way interaction and the explosion of social media has generated increased communication with stakeholders and awareness-raising on OSH issues.

At the same time, competent authorities have taken steps to modernize and streamline their internal functioning with the gradual introduction of ICT, first with desktop publishing software, followed by the upgrade of legacy systems to the latest internet-enabled applications to seamlessly automate data collected during OSH inspections and related activities, computer databases build-up, subsequent data analysis and strategic decision making utilising ICT.

2. MATERIALS AND METHOD

Relevant research was carried into current ICT adoption, usage and with regard to tools being utilised in the OSH field today – a combination of legislation, norms, procedures and good practice, guidance (traditional and interactive) which employers must follow to safeguard their employees safety and health. The latter included a look into OSH statistics collected by EU member states competent authorities, on occupational accidents and workers' health. This data is published on the European Statistical Service (Eurostat). With a focus on EU member states, where the relevant competent authorities such as Labour Inspectorates must adhere to Community mandated legislation on OSH, it was found that there is very little uniformity in the use of ICT by the authorities. This applies to both internal use of ICT by the Labour Inspectorates and to the adoption of technology to benefit external stakeholders of OSH authorities – employers, employees and the public at large.

The information collected was categorized into two broad categories – internal ICT usage by Labour Inspectorates for the conduct of their OSH related work and, external ICT usage which directly impacted stakeholders such as employers, employees and the public at large. A closer look at EU member states OSH authorities' websites indicated the ways and means of OSH information dissemination to the stakeholders were assessed.

2.1. Materials and Methods

Utilization of internet resources, the European Commission's Senior Labour Inspectors Committee (commonly known as SLIC) website information, as well as EU collaboration tools (such as CIRCABC - Communication and Information Resource Centre for Administrations, Businesses and Citizens) constituted the primary research methods and materials used for the present paper. At the same time, literature and products developed by Agencies such as EU OSHA and US OSHA (the United States of America's Occupational Safety and Health Administration) where ICT is utilised, were looked into. Finally, the websites of Labour Inspectorates (mostly those of EU member states' OSH authorities) were examined so as to assess the various ways ICT was promoted. Agencies' websites such as EU OSHA and third party tools / subscription only databases on OSH were also scrutinized for content delivery.

2.2. Subtitles

N/A

3. RESULTS AND DISCUSSION

The first part of the research dealing with internal ICT usage by OSH Authorities utilised information collected primarily from EU SLIC CIRCABC collaboration website for EU member states and data listed by the Authorities themselves. Whilst all EU member states must enforce the same OSH Directives, the way they actually do this differs from state to state according to national legislation, OSH priorities, degree of ICT adoption, and collaboration with other national bodies on ICT and OSH enforcement methodologies. So it follows, differing ICT models are used by each OSH Authority.

Some member states utilise software which draws on the national OSH historical data collected, usually in legacy systems, in order to help select those work activity sectors where greater inspection / investigation / training efforts on OSH is necessary. Such collected data is made up of workplace accidents and occupational disease statistics, risk level of the sector as well as complaints expressed by employees regarding OSH. A major concern has been to make the legacy system data readily accessible and meaningful to the OSH authority at each level (inspectors, managers, strategic decision makers). Other authorities have invested in new web and mobile technologies to better plan their inspectors' OSH activities and focus on providing the inspector with 'real-time' OSH data regarding the targeted enterprises / work activity sectors. This has succeeded in saving time and effort and leads to better follow-ups by the inspectors on the state of OSH compliance in each work activity sector. A major challenge faced by most OSH Authorities is achieving meaningful and correct data interconnections with other state authorities existing technologies to avoid data duplication and receive a more complete view of each sector / workplace under inspection, thus achieving continuous OSH compliance of employers with reduced cost. Other OSH Authorities are developing internal ICT systems with a focus on real-time online collaboration among inspectors, managers and top decision makers with access to constantly updated OSH data of employers / enterprises / reports, so that each hierarchical level can effect measures/actions which need to be taken. The monetary cost involved in building new ICT systems from scratch is substantial, but when the requirements are clearly stated and data interconnections within and among the various authorities involved are meaningful, the result is well worth the time and cost invested.

The external ICT usage by OSH Authorities was, in general terms, more uniform and streamlined than internal ICT usage. Social media such as facebook, twitter, instagram were selected for official use in a minority of the EU member states OSH Authorities (only 11 Authorities, 39%). Of those OSH authorities which did use social media, the preferred media were facebook and youtube, with a few using more than one of the social media. Those Authorities who adopted social media expressed mostly positive views on the media's impact upon employers, employees, social partners such as trade unions, journalists, politicians, researchers and the public at large regarding OSH attitudes. They also stated the need for prompt updates and replies to keep social media users interested. The majority of member states OSH authorities which did not adopt social media stated that various reasons influenced their decision – such as legal limitations, overall government policy, non-familiarisation with such technologies.

However social media is only one of the ways in which ICT is used by each OSH Authorities to promote OSH to external stakeholders - static or dynamic information dissemination on OSH is part of each and every OSH Authority's website. This may be in the form of plain electronic publications, legislative and explanatory texts, guidances in plain language, sample Risk Assessments (usually containing checklists for various types of work activities), illustrations, posters as well as interactive tools and even online OSH related games.

One of the most publicised and promoted interactive OSH tool is the EU OSHA's OiRA – Online interactive Risk Assessment tool. This is a free open-source ICT tool to help employers and especially micro-enterprise employers to deal with safety and health issues in their workplaces and comply with relevant national legislation in an easy manner. By providing the technology platform, EU OSHA has enabled many member states OSH Authorities and / or sectoral Social Partners (employers' and employees' organisations) to tailor the tool for use by employers of various sectors such as cleaning, road transport, catering, office work, and others. The platform is flexible enough to allow customization according to member states' national OSH legislation and supports multiple languages. OiRA saves time for all stakeholders since OSH legislation compliance of micro-enterprises becomes a straight forward do-it-yourself task for employers, OSH authorities are, thus, better positioned to focus their resources on those sectors where the OSH statistics are such that extra attention is needed, e.g. increased workplace accidents in specific sectors. EU OSHA provides the OSH authorities and social partners with ongoing technical support and community support. More sectoral OiRA tools are planned by the various member states OSH Authorities and/or the social partners in the near future.

Another ICT tool increasingly adopted by OSH authorities is Applications (apps) for mobile phones. An excellent example of this is US OSHA's Heat Safety Tool which enables supervisors and employees to find the heat index for their worksite during hot weather outdoor work and, based on this, determine the risk level for them, thus enabling them to take measures to protect their safety and health in real time.

4. CONCLUSIONS

As stated in the Abstract, ICT has irrevocably entered the field of OSH in various forms and is already bringing about a transformation in the field. Every stakeholder in the field of OSH will experience, to a certain extent, the impact of ICT in the work he or she carries out on a daily basis. A (state) OSH inspector will now have new tools at his disposal to effectively carry out inspection duties and bring about compliance with OSH legislation in a more timely and streamlined manner, thus preventing workplace accidents and ill health. An employer will have at his disposal many ways to easily and quickly identify risks to life and limb and take measures to comply with OSH legislation, all due to ICT transformation. Likewise, a worker will be better informed and ready to carry out his work duties, due to the OSH interactive training he has already received, and the prepared risk assessment steps guiding him to work as safety as possible – all thanks to ICT. The benefits to social partners and the public at large will be the increased OSH awareness provided by various social media helping to develop an OSH culture in our society.

On a more practical note, the way forward to encourage ICT adoption by OSH authorities and their stakeholders (both internally and externally) is the collaboration of all in developing online tools such as OiRA which can be quickly customized to suit member states attributes / legal provisions / languages / work sectors / business types / other particularities and their successful promotion (e.g. via social media) and subsequent use by the employers they aim to target.

Similarly, an EU Working Group could be established to help develop an EU wide electronic platform, preferably with the use of open-source software, to enable member states' OSH authorities to internally collect, assess and put to good use the data necessary to carry out their OSH duties under law. The EU OSH Framework Directive and its aforementioned amendment obliging all member states competent authorities to prepare and submit practical implementation reports can serve as the starting point for such a common e-platform, at the same time affording each OSH authority enough flexibility to customize the platform to its national needs.

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6. REFERENCES

EU SLIC website-
http://ec.europa.eu/social/main.jsp?catId=148&intPageId=685
EU CIRCABC collaboration website of the Senior Labour Inspectors Committee of the European Union – 64th SLIC-
https://circabc.europa.eu/sd/a/c4fab7a8-0d0b-46ac-8bad-54cc398f43c7/2013%20-%20Dublin%20-%20ICT%20Systems%20and%20Labour%20Inspection.xps
European Agency for Safety and Health at Work (EU-OSHA), Online interactive Risk Assessment (OiRA) tool
http://www.oiraproject.eu/
Eurostat, OSH data (workplace accidents and ill-health)
http://ec.europa.eu/eurostat/web/health/health-safety-work/data/database
US OSHA – Heat Safety App
https://www.osha.gov/SLTC/heatillness/heat_index/heat_app.html

Building Information Modeling and Safety: a review.

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Abstract

Introduction: Occupational Health and Safety (OHS) in building construction remains a worldwide problem considering workplace injury, illness and fatality statistics. Construction Safety requires care and planning throughout the project life-cycle, from design to maintenance. Initial approaches for improving OHS consider the Safety aspects in the design phase and the development of manual Safety processes in the execution phase.

The application of Building Information Modeling (BIM) is currently increasing rapidly in construction operations planning and management and also in Safety Management. It is expected to change the way that Safety is addressed thanks to the use of this new tool, as seen in the literature review, based on the large number of contributions in recent years.

Objective: This study reviews the existing literature about BIM and Construction Safety to explore useful findings and the knowledge gaps for a future researc.

Methodology: A systematic review has been done though the databases, ISI Web of Science (WOS) and Scopus.

Results and discussion: Recent advancements of BIM technologies are providing decent starting points for the development of solutions for pro-active site Safety planning and Management. This means that the user is not just a passive observer of potential problems but has all necessary functions available as efficient solutions enablers for improving the working conditions. Compared with the earlier research it considers that the selected research approach having collaborative safety planning and safety awareness building as starting points can result in novel contributions by combining safety management functions with appropriate BIM solutions.

Conclusions: BIM capabilities and versatility will allow current Safety practice in Construction improvement, as well as an easier Safety Management implementation on site as well as workers and consultants training.BIM development and it use in this area will therefore contribute to reduce accidents.

Keywords: Building Information Model, Construction, Safety, Management, Schedule

1. INTRODUCTION

When comparing workplace accidents in the EU in the 2008-2015 period, it is in the construction sector where we find the highest number of mortal accidents (Eurostat, 2015). The factors that have contributed to this statistic are different (Haslam *et al*., 2003; Gibb, Haslam, Gyi, Hide & Duff, 2006) and result in many safety hazards manifesting themselves at any given stage during the construction process (Gibb *et al*., 2006; Qi, Issa, Olbina & Hinze, 2014).

In recent years, different technologies and execution methods are developed to provide new opportunities to enhance Safety Management throughout the whole project life cycle, which enhance Management-driven Safety, rather than replace (Teizer, Allread, Fullerton & Hinze, 2010). For example, they serve as support to timely identify human errors and deal with them in order to prevent construction accidents, predicting, planning, and controlling the schedule. Since 1991, different studies highlight the possibility of doing so linking the CAD and planning process (Cherneff, Logcher & Sriram, 1991) as a mockup alternative, and looks to the opportunities that are available in the near term data (Tatum, Byrum & Rourke, 1994).

The most flourishing technology in the Construction sector is Building Information Modelling (BIM). BIM is a new approach to design, construction, and facilities management in which a digital representation of the building process is used to facilitate the exchange and interoperability of information in a digital format (Eastman, Teicholz, Sacks & Liston, 2011). Due to the increasing power of BIM concept, it has also been adopted by most of the commercial CAD software (Autodesk Revit, ArchiCAD, Allplan, etc.). Shou *et al.* (2015) show the utility of BIM during the construction project life cycle throughout the definition of the workplace, visualization of quality 3D drawings, 3d model planning (that is defined as 4D) and lastly the addition of the costs estimation (5D) in order to optimize and facilitate the maintenance and the management.

Mattila *et al*. (1994) affirmed that there was a need to study the connections between good management, in general, and Safety. Since then lots of studies and researches about safety management have been developed. The overall interest around BIM and its applications have created wide variety of attempts some of which have also addressed occupational safety issues.

The main objective of this paper is to make a literature review existing in this field of research in order to identify the applications and evolution of BIM for safety management in the construction domain. This study might have utility to new researches in aiding them to obtain a wider perspective of new methods of construction safety management.

2. BACKGROUND

Several studies show BIM could bring important benefits in the AEC industry as a tool that add safety management, e.g.: scheduling, clash detection, construction progress tracking, design consistency and visualization, data integration, cost estimations, implementation of lean construction or improved stakeholder collaboration, etc.

In a recent review in safety studies from 1978 to 2013, where 1628 documents are analyzed, it is shown that BIM is not the unique tool for this purpose. The study identifies 21 types of innovative technologies applied and only 6 documents related to the BIM uses.

In a recent survey (Issa & Suermann, 2009), instrument collected data regarding perceptions about the effects of BIM on commonly accepted construction Key Performance Indicators (KPIs) that were defined by Cox *et al*. (2003): quality control, on time completion, cost, safety, \$/unit, units/manhour. The authors maked a Survey was advertised in different ways. The results indicated that between 46% or 53% respondents also felt that BIM has “No Effect” on safety or lost man-hours in construction projects, making it the KPI that in their perception is the least impacted by BIM. Ding *et al*. (2014) make a study that shows the percentages of BIM publications from the viewpoint of project management domain, with a 7% related to Safety management and 17% schedule management.

In the next paragraphs, the main highlights taken into account by different researches are shown.

2.1. 4D = 3D + schedule

Unsatisfactory architectural and/or organizational options or poor planning of the works at the project preparation stage have played a role in more than half of the occupational accidents occurring on construction sites in the UE (Council Directive 92/57/EEC, 1995). Effective safety planning contributes in the prevention of accidents and ill health of site personals. Planning well for safety plays an important role in reducing unnecessary cost and delays (Sulankivi, Mäkelä & Kiviniemi, 2009; Saurin, Formoso & Guimaraes, 2004; Bansal, 2011). If some activities are constructed adjacent to the overlap period, the workspace for those activities may be conflicting and accidents can occur (Moon, Dawood & Kang, 2014).

Already in 1994, Euler (1994) indicated the need to consider the schedule for the control of accidents and their integration in graphics programs. Kartam (1997) develops a framework for a computerized safety and health knowledge-intensive system that has been implemented and integrated with current Critical Path Method (CPM) scheduling software.

The term 4D is used by McKinney *et al*. (1996), defined as 3D plus time. In 1998 (McKinney & Fischer, 1998) insist on the construction perspective is often neglected because an important dimension for construction-time-is missing and the necessary efforts to develop 4D tools that generate 4D + x models that more realistically represent the construction process. (S. Guo, 2001; Koo & Fischer, 2000) conclude that 4D models are a useful alternative to project scheduling tools like CPM.

Since 2005, publications take the term BIM as we know it today (Tse, Wong & Wong, 2005). Software are commonly known as BIM, Virtual Building, Parametric Modelling, or Model-Based Design. Many authors have defined 4D as 3D plus schedule from the beginning of the BIM studies. It can be shown in studies from 2008 (Z. Hu, Zhang & Deng, 2008) until more recent works (Z. Hu & Zhang, 2011; S. Zhang *et al*., 2015; Y. Zhou *et al*., 2015). Moreover the concept 4D is related to others concepts too, not only to BIM, as it is reflected in a recent work (Trebbe, Hartmann & Doree, 2015). So the potential of 4D CAD models to avoid costly on-site improvisation by providing possibilities to anticipate conflicts better in the planning phase has been widely acknowledged.

Finally, the literature review about the research on automation in construction scheduling from 1985 to 2014, (Faghihi, Nejat, Reinschmidt & Kang, 2015), shows the dominant distribution of the genetic algorithm method (mainly focused on resource optimization and levelling by integrating the concepts of CPM and line of balance) as an optimization tool used by researchers to solve scheduling problems, specifically in the field of construction.

2.2. Safety and use of other innovative technology application

Construction safety and digital technologies are - Virtual Reality, 4D CAD, BIM, etc., -widely applied in these tools for site hazard prevention and safe project delivery (W. Zhou, Whyte & Sacks, 2012)

The use of new technologies for these objectives is earlier than BIM. In 1992, Yamazaki (1992), and later Jung and Gibson (1999), related the use of *Computer Integrated Construction* to maximize the integrated utilization of information systems throughout the project's entire life cycle to different functions, among them is safety.

Seo *et al*. (2015) review the literature about studies for computer vision-based Safety and Health monitoring, identifying it 22 studies from 2007 to 2013.

Otherwise, the use of simulation and virtual construction method earlier than the generalization of BIM for automate modification of schedules to minimize spatial conflicts (Akinci, Fischer & Kunz, 2002; Clayton, Warden & Parker, 2002; Dawood, Sriprasert, Mallasi & Hobbs, 2003; Waly & Thabet, 2003) adding the possibility of being a tool that would permit management for construction projects (Chau, Anson & De Saram, 2005; Chau, Anson & Zhang, 2005; Kang, Anderson & Clayton, 2007; Ma, Shen & Zhang, 2005; H. J. Wang, Zhang, Chau & Anson, 2004).

After that, many authors combine BIM with different technologies, e.g. location tracking, augmented reality (AR) and game technologies (Park & Kim, 2013), VP-based (H. L. Guo, Li & Li, 2013); RFID (or WSN in a broader scope) (Motamedi & Hammad, 2009) Moreover, different researches combine schedule and BIM and simulation as a tool able to predict risks and to minimize conflicts at the workplace, as well as an active schedule management (K. Kim & Teizer, 2014; Moon *et al*., 2014; Moon, Kim, Kim & Kang, 2014). Lastly, it is interesting to show the use of other technologies for simulation of construction safety management, as a virtual prototyping (VP) (H. L. Guo *et al*., 2013) or SimSAFE (W. Wang, Liu & Chou, 2006).

2.3 Collaboration, communication and life-cycle

Shen *et al*. (2010) consider that these technologies can provide a consistent set of solutions to support the **collaborative** creation, management, dissemination, and use of information through the entire product and project **life-cycle**, they are believed to be the key enabling technologies that drive the construction industry in improving productivity and efficiency.

New directions of research on construction safety and digital design could, for example, focus on technologies that enable constructors to share their knowledge with designers (W. Zhou *et al*., 2012).

The prevention, from the first stages of the life cycle of the project, is related to the decrease of sinistrality (Gibb, 2004; Gibb *et al*., 2006; Martínez Aires, Rubio Gámez & Gibb, 2010) so the use of the BIM from the design and in the last stages of the project is use for the safety management.

The implications of BIM adoption across the life-cycle of a project the stakeholder collaboration aspects related to its adoption produce the highest positive financial impact (Gu & London, 2010; Eadie, Browne, Odeyinka, McKeown & McNiff, 2013). Otherwise BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition (Ding *et al*., 2014), the use of BIM was mainly related to the construction stage (Shou *et al*., 2015). Moreover it can be shown that BIM is getting more useful, due its use in the pre-construction phase as a tool that improved the collaboration (Succar, 2009; Succar & Kassem, 2015; X. Wang & Chong, 2015).

3. MATERIALS AND METHODS

Systematic review is a specific and reproducible approach for identifying, selecting and appraising all the literature of a certain agreed level of quality that is relevant to a research question (Booth, Papaioannu & Sutton, 2012).

This study adopts the systematic review as a methodological approach to review the existing Construction Safety literature about BIM to explore useful findings, identify and to link in a table the knowledge gaps for a future research program. The databases sources used were the ISI

Web of Science (Wos) and Scopus. The period studied ranges from 1981 until 2015. The search was implemented using the ''Title/Abstract/Keyword'' field of the databases. The full search is ''Title/Abstract/Keyword *Construction* and *BIM* and *Safety*" or ''Title/Abstract/Keyword *Construction* and *Building Information Modeling* and *Safety*". After removing uplicates, a total of 145 documents has remained,from which 75 were Conference Paper and 52 Articles. After reviewing all the information, the structural Safety based texts have been removed. A group of ten more articles has also been added and studied, linked to the subject. Eventhow they do not match the Title/Abstract/Keyword criterion established for the research, they are still providing relevant information on the subject. The final number of articles reviwed is 55. The Bibliography research scheme is presented in Figure 1.
The number of publications found on the databases visited dealing with *BIM* or *Building Information Modeling* on the area of Engineering linked to *Construction-AEC*, is of 673. They belong to the period between 2005 and 2015. Those related to safety represent an 8,2%.

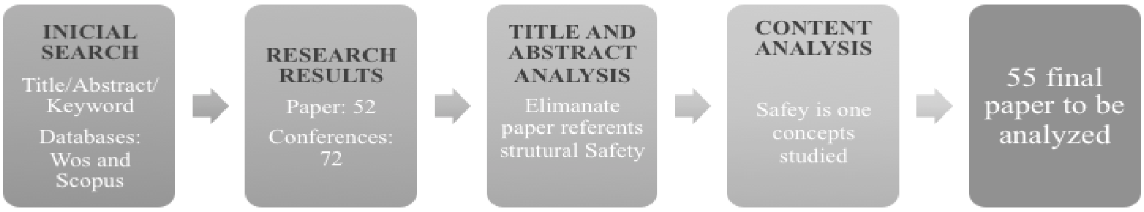

Figure 1 – Bibliography research scheme.

Taking into account the results presented at point 2, five highlights have been identified, which define BIM use as a Safety Management tool: Construction or Safety Management, 4D Schedule and Planning, Visualitation/simulation, Collaboration and Communication and Identifying hazards.
The 55 articles have been analysed through following protocol: (1) work title; (2) year of publication; (3) magazine title; (4) country; (5) Project phase identification where BIM is used: Desing, Constrution, Maintenance y project whole life cycle; (6) highlights identification; (7) innovative technology use identification and other differentiating aspects. The information gathered at each step has been presented in a database, which has enable to reach the results

4. RESULTS AND DISCUSSION

Based on the literature review and after applying the analysis protocol explained before, the results obtained have been classified in 2 sections. At the first Section 4.1, results from steps 1 to 4 are presented, and allow to establish the publishing framework of the texts being analysed. At section 4.2, results from steps (5) to (7) of the analysis method have been gathered in table 3, aiming to organise Construction Safety and BIM content proposed by authors., identifying the highlights addressed as well as certain diferenciating aspects, such as Lean, GIS, RFID, etc.

4.1. Publishing framework

Figure 2 presents anual distribution of magazines from articles selected for the study, which link BIM and Construction Safety. At a first sight it is clear that the number of articles related to this subjet has increased in 2014, and 2015 trend allows to see the interest in this line of research still growing.

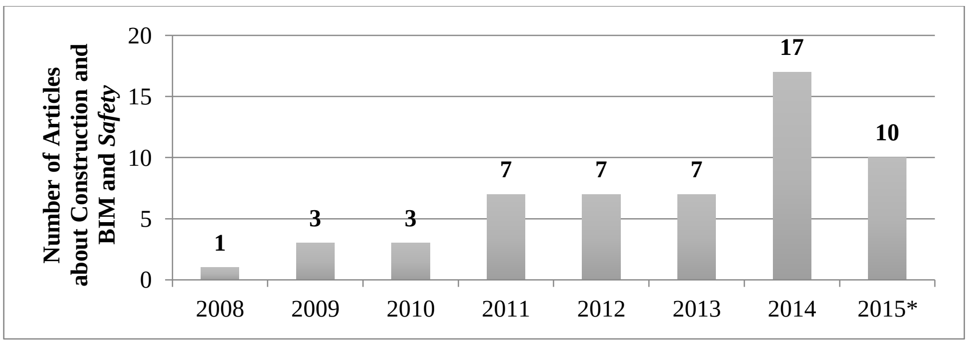

*Figure 2 – Year profile of articles (*2015 until July 2015).*

The Table 1 shows the number of publications distributed by country/region. This information is in line with the research carried by Porwal and Hewage (2013) - which proves that, even if BIM implementation is still a challenge for the North American Construction Industry, the Canadian Construction Industry for instance, still is well behind it. Moreover, Succar (2009) shows a non-exhaustive list of publicly-available guides, reports and visions relating to BIM, which demonstrate that USA is the country where a greater number of Construction Safety and BIM research are published since 2009.

*Table 1 – The number of publications about **Construction Safety and BIM** distributed by country/region.*

Country/Territory	Documents	Country/Territory	Documents
United States	21	India	2
China	14	Israel	2
Australia	8	Pakistan	2
South Korea	7	Taiwan	2
Germany	5	Hungary	1
United Kingdom	5	Netherlands	1
Finland	2	Puerto Rico	1
Hong Kong	2		

Table 2 gathers the journals where at least 2 articles on Construction Safety and BIM have been published, including JCR® Impact Factor and SJR Impact Factor.

Table 2 – Number of documents about Construction Safety and BIM by Source and Impact Factor.

Source	Documents	JCR® Impact Factor	SJR Impact Factor
Automation in Construction	18	1,812	1,572
Journal of Construction Engineering and Management - ASCE	5	0,842	1,199
Advanced Engineering Informatics	3	1,627	1,218
Electronic Journal of Information Technology in Construction	3	-	0,841
Safety Science	3	1,831	0,965
Journal of Computing in Civil Engineering	2	1,268	0,908

4.2. Highlights Comparative Review

Table 3 has seven columns. On the first one, each article is presented through autor and year of publication. The next five present the five highlights established for this study: Construction or Safety Management, 4D Schedule and Planning, Visualitation/simulation, Collaboration and Communication and Identifying hazards. The seventh column gathers other diferenciating aspects from the research published in the articles.

Figure 3 shows the percentage of articles which addressed the five highlights defined. The 61,82% of the Works have as main focus the Safety Management, followed by 50,91% which refer to BIM use for Visualitation or Simulation. The identification of hazards is a key objective, present in 50% of the documents. Falls are one of the main risks analysed (Melzner, Zhang, Teizer & Bargstädt, 2013; S. Zhang, Teizer, Lee, Eastman & Venugopal, 2013) and scaffolds one of the most studied systems (Clevenger, Del Puerto & Glick, 2015; Z. Hu, Zhang & Zhang, 2010; K. Kim & Teizer, 2014).

BIM use as a tool to promote/enable collaboration and communication, these topics are today's active research topics and will still be active within next 5–10 years (Shen *et al*., 2010).

Often many proposals explorea combined application of techniques due to different functions of same innovative technologies such as GIS (Bansal, 2011; Bansal & Pal, 2011; Min & Zhao, 2014), RFID (Arslan, Riaz, Kiani & Azhar, 2014; H. Li, Lu, Chan & Skitmore, 2015; Xu, Wang & Yao, 2011; Y. Zhou *et al*., 2015), GPS (Akula *et al*., 2013) or Sensors (Riaz, Arslan, Kiani & Azhar, 2014; Arslan *et al*., 2014; Teizer, 2015).

On the other side, the increasing concern for Safety training, results on it being the objective of a great number of research studies about the use of BIM to improve workers education or training (Becerik-Gerber, Jazizadeh, Li & Calis, 2012; Clevenger, Glick & del Puerto, 2012; Eadie *et al*., 2013; Park & Kim, 2013; Korman & Huey-King, 2014; Clevenger *et al*., 2015).

Table 3 –Highlights Comparative Review

Source	Safety manageme nt	4D Schedule/ Planning	Visualitatio n/Simulatio n	Collaboratio n/ Communicati on	Identifyin g hazards	Other
(Z. Hu *et al*., 2008)			Yes		Yes	
(Sacks, Treckmann & Rozenfeld, 2009)	Yes		Yes			Lean
(Suermann & Issa, 2009)						Research
(Sulankivi *et al*., 2009)	Yes	Yes	Yes	Yes	Yes	Recording & verification of inspections
(Dossick & Neff, 2010)				Yes		Research
(Z. -. Hu *et al*., 2010)			Yes		Yes	Scaffold
(Z. Hu, Zhang & Zhang, 2010)			Yes		Yes	Developed algorithm
(Bansal & Pal, 2011)	Yes	Yes	Yes			BIM & GIS
(Bansal, 2011)	Yes	Yes	Yes		Yes	BIM & GIS
(Golparvar-Fard, Peña-Mora & Savarese, 2011)		Yes		Yes	Yes	BIM & Photographs & Point-cloud models. RM
(J. P. Zhang & Hu, 2011)	Yes	Yes	Yes		Yes	4D space–time model
(Xie, Shi & Issa, 2011)	Yes		Yes			RFID & Real-Time Vistual Reality
(Xu *et al*., 2011)				Yes		Integrated Project Delivery
(Z. Hu & Zhang, 2011)	Yes	Yes	Yes		Yes	4D space–time model. Conflict analysis
(Barlish & Sullivan, 2012)						Review Article
(Becerik-Gerber *et al*., 2012)	Yes					Facilities management. Trainning
(Chavada, Dawood & Kassem, 2012)	Yes	Yes	Yes			CPM & BIM. 4D/5D. Real-time management
(Clevenger *et al*., 2012)			Yes			Construction education
(Hartmann, Van Meerveld, Vossebeld & Adriaanse, 2012)	Yes	Yes				
(Nawari, 2012)	Yes			Yes		BIM standard in Off-Site Construction
(W. Zhou *et al*., 2012)				Yes		Review Article
(Akula *et al*., 2013)	Yes		Yes		Yes	Real-time. GPS
(Eadie *et al*., 2013)	Yes			Yes		Facilities Management. Education and Training
(Kraatz & Hampson, 2013)						Audit and analysis R&D investment
(Melzner *et al*., 2013)		Yes			Yes	PtD. Fall protection. Decision-making
(Park & Kim, 2013)	Yes		Yes	Yes	Yes	BIM & AR. Mobile screen. Education and Training
(S. Zhang *et al*., 2013)	Yes	Yes	Yes	Yes	Yes	PtD. Fall protection. Automated rule-based safety
(Y. Wang, Wang, Wang, Yung & Jun, 2013)	Yes		Yes		Yes	Facilities Management
(Arslan *et al*., 2014)	Yes		Yes			BIM & RFID & Sensors. Real-time
(Chen & Luo, 2014)	Yes	Yes				BIM & Quality control process

Source	Safety manageme nt	4D Schedule/ Planning	Visualitatio n/Simulatio n	Collaboratio n/ Communicati on	Identifyin g hazards	Other
(Choi, Lee, Park, Cho & Kim, 2014)	Yes	Yes				Work-space plan. Preconstruction phase
(Ding *et al*., 2014)	Yes	Yes			Yes	Review Article. Quantify and analyze quality
(Forsythe, 2014)					Yes	Real-time audio warnings
(K. Kim & Teizer, 2014)	Yes	Yes	Yes			Temporary facilities. Scaffolding systems
(Korman & Huey-King, 2014)				Yes		Engineering education
(Le & Hsiung, 2014)	Yes	Yes		Yes	Yes	Mobile web servisse. GIS. Decision making
(Luo & Gong, 2014)					Yes	Compliance checking
(Min & Zhao, 2014)	Yes					GIS. 3D model library
(Moon *et al*., 2014)		Yes	Yes			Workspace conflict. Bounding box model
(Moon *et al*., 2014)	Yes	Yes	Yes			BIM & Genetic algorithm. 4D CAD
(Qi *et al*., 2014)	Yes				Yes	PtD
(Riaz *et al*., 2014)					Yes	BIM & Wireless sensor. Confined spaces
(Volk, Stengel & Schultmann, 2014)						Review Article
(W. -. Wang, Weng, Wang & Chen, 2014)	Yes	Yes	Yes			BIM & MS Access & MS Excel & MS Project.
(Clevenger *et al*., 2015)			Yes			Education and training. Scaffolds
(Ganah & John, 2015)	Yes			Yes		
(H. Kim, Lee, Park, Chung & Hwang, 2015)	Yes				Yes	Accident cases. Retrieval system
(H. Li *et al*., 2015)	Yes		Yes			Training. Real-time location system. VC & RFID
(H. Li, Lu, Hsu, Gray & Huang, 2015)	Yes		Yes		Yes	VC System. Safety training
(S. Zhang *et al*., 2015)	Yes	Yes	Yes		Yes	PtD
(S. Zhang, Boukamp & Teizer, 2015)	Yes		Yes		Yes	Automated safety planning .
(Teizer, 2015)	Yes		Yes		Yes	Machine learning .Sensor & photo & video cameras
(X. Wang & Chong, 2015)						Review Article
(Y. Zhou *et al*., 2015)		Yes	Yes		Yes	RFID
(Z. Zhou *et al*., 2015)	Yes					Review Article

ACRONYM		ACRONYM	
AR	Augmented reality	PtD	Prevention through Design
BIM	Building Information Modeling	R&D	Research and Development
CPM	Critical Path Method	RM	Reality Model
GIS	Geographic Information System	VC	Virtual Construction
GPS	Global Positioning System	VR	Virtual reality

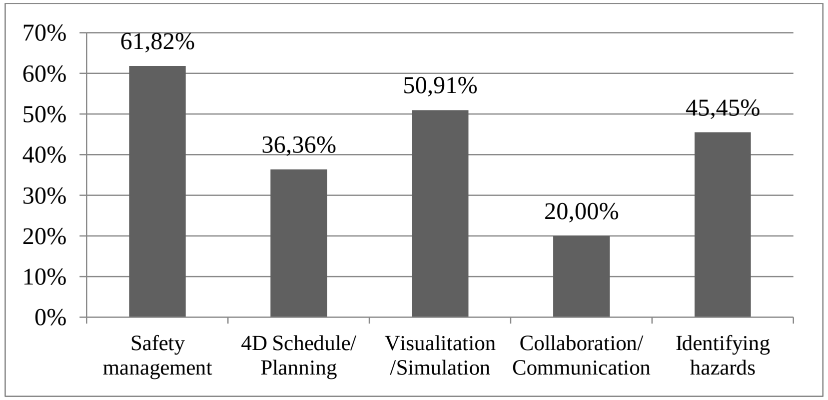

Figure 3 – Highlights and his Percentage of BIM publications.

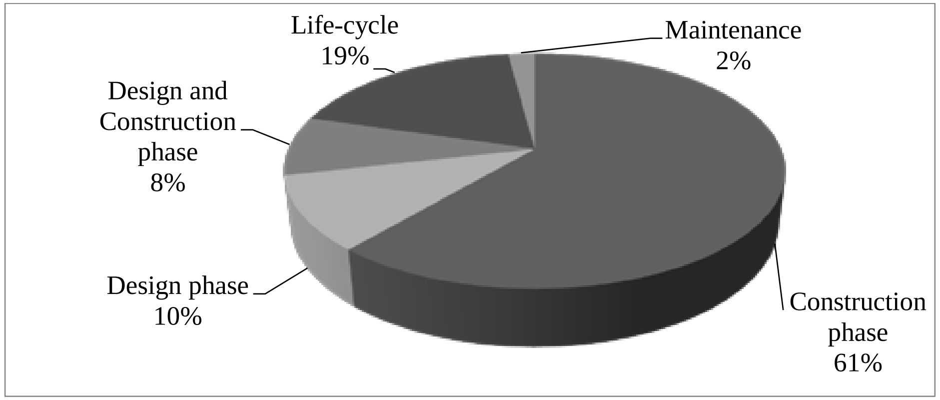

Figure 4 – Percentage of BIM publications from the viewpoint of project life cycle.

Figure 4 shows the percentage of publications about BIM from the point of view of project life-cycle. The majority of projects uses BIM at construction phase (Z. Zhou, Goh & Li, 2015). Nevertheless, 37% of works, refer to design phase as well: Life-cycle, Design phase or Desgin and Construction phase. This in fact is a proof of BIM usefulness regarding Prevention through Design (Melzner *et al*., 2013; Qi *et al*., 2014; S. Zhang *et al*., 2013; S. Zhang *et al*., 2015).

Last but not least, different research studies have highlighted, current existing gaps The main reason for not adopting BIM on current projects relates to the lack of expertise within the project team and external organisations (Eadie *et al*., 2013). Li *et al*. (2012). Some of the main challenges for implementing BIM applications are generating the 3D models, retrieving the job site environmental information and updating actual data from the job site, within the 3D models, as the construction process moves forward. Other of the remaining gaps to be bridged is a hybrid approach toward addressing multiple objectives associated with scheduling (Faghihi *et al*., 2015). An example is the need for a new hybrid tool that can automate schedules by ensuring the structural stability of the project while optimizing its schedule and cost.

The study carried by Wang and Chong (2015) concludes that BIM must evolve to be fully integrated with other technologies, thereby contributing to project performance in various stages of project life-cycle.

5. CONCLUSIONS

ICT (Information & Communication Tools) use has been a key factor in AEC industry for the last decades. BIM capabilities and versatility have allowed its use in different areas of AEC industry, and specifically in Safety Management. According to research results BIM can help to improve Safety in Construction in the followings aspects:

1. Identify potential hazards through 4D scheduling: Using 4D model and 4D scheduling and sequencing with site logistics planning can easily help identify potential hazards and eliminating hazards early. The control program identifies the conflicts generated in the workplace activities to be implemented simultaneously.
2. Visual representation of site conditions: BIM provides with a solid visual understanding of a site and the working conditions before they even begin construction. Moreover, the combined application due to different functions of various innovative technologies -such as GIS, Augmented Reality (AR)- allows visualization work site in real time.
3. Identify each task and work area with its hazards: BIM helps to identify the risks, prepare for the work at hand and, therefore, complete the task more efficiently and safely.
4. Enables Communication and Collaboration between different the stakeholders present both at the desing stage and construction.
5. Can be used in worker safety training and education, design for safety, safety planning (job hazard analysis and pretask planning), accident investigation, and facility and maintenance phase safety.

The research studies show that early adoption of BIM in design stage can significantly reduce accident and allows all stakeholders to get important information before the building is completed. This includes all agents involved in the life cycle project: clients, designers, engineers, builders, workers, tenants, service agents as well as maintenance personnel.

6. REFERENCES

Akinci, B., Fischer, M. & Kunz, J. (2002). Automated generation of work spaces required by construction activities. *Journal of Construction Engineering and Management, 128*(4), 306-315.

Akula, M., Lipman, R., Franaszek, M., Saidi, K., Cheok,G. & Kamat,V. (2013). Real-time drill monitoring and control using building information models augmented with 3D imaging data. *Automation in Construction, 36*, 1-15.

Arslan, M., Riaz, Z., Kiani, A. & Azhar, S. (2014). Real-time environmental monitoring, visualization and notification system for construction H&S management. *Journal of Information Technology in Construction, 19*, 72-91.

Bansal, V. K. (2011). Application of geographic information systems in construction safety planning. *International Journal of Project Management, 29*(1), 66-77.

Bansal, V. K. & Pal, M. (2011). Construction projects scheduling using GIS tools. *International Journal of Construction Management, 11*(1), 1-18.

Barlish, K. & Sullivan, K. (2012). How to measure the benefits of BIM — A case study approach. *Automation in Construction, 24*, 149-159.

Becerik-Gerber, B., Jazizadeh, F., Li, N. & Calis, G. (2012). Application areas and data requirements for BIM-enabled facilities management. *Journal of Construction Engineering and Management, 138*(3), 431-442.

Booth, A., Papaioannu, D. & Sutton, A. (2012). *Systematic approaches to a successful literature review*. United States.: SAGE Publications Ltd., Thousand Oaks, CA.

Chau, K. W., Anson, M. & De Saram, D. D. (2005). 4D dynamic construction management and visualization software: 2. site trial. *Automation in Construction, 14*(4), 525-536.

Chau, K. W., Anson, M. & Zhang, J. P. (2005). 4D dynamic construction management and visualization software: 1. development. *Automation in Construction, 14*(4), 512-524.

Chavada, R., Dawood, N. & Kassem, M. (2012). Construction workspace management: The development and application of a novel nD planning approach and tool. *Electronic Journal of Information Technology in Construction, 17*, 213-236.

Chen, L. & Luo, H. (2014). A BIM-based construction quality management model and its applications. *Automation in Construction, 46*, 64-73.

Cherneff, J., Logcher, R. & Sriram, D. (1991). Integrating CAD with construction-schedule generation. *Journal of Computing in Civil Engineering, 5*(1), 64-84.

Choi, B., Lee, H., Park, M., Cho, Y. K. & Kim, H. (2014). Framework for work-space planning using four-dimensional BIM in construction projects. *Journal of Construction Engineering and Management, 140*(9)

Clayton, M. J., Warden, R. B. & Parker, T. W. (2002). Virtual construction of architecture using 3D CAD and simulation. *Automation in Construction, 11*(2), 227-235.

Clevenger, C., Del Puerto, C. L. & Glick, S. (2015). Interactive BIM-enabled safety training piloted in construction education. *Advances in Engineering Education, 4*(3)

Clevenger, C., Glick, S. & del Puerto, C. L. (2012). Interoperable learning leveraging building information modeling (BIM) in construction education. *International Journal of Construction Education and Research, 8*(2), 101-118.

Council directive 92/57/EEC of 24 june 1992 on the implementation of minimum safety and health requirements at temporary or mobile construction sites (eighth individual directive within the meaning of article 16 (1) of directive 89/391/EEC) (1995). . Official Journal L 245 , 26/08/1992 P. 0006 - 0022:

Cox, R. F., Issa, R. R. A. & Ahrens, D. (2003). Management's perception of key performance indicators for construction. *Journal of Construction Engineering and Management, 129*(2), 142-151.

Dawood, N., Sriprasert, E., Mallasi, Z. & Hobbs, B. (2003). Development of an integrated information resource base for 4D/VR construction processes simulation. *Automation in Construction, 12*(2), 123-131.

Ding, L., Zhou, Y. & Akinci, B. (2014). Building information modeling (BIM) application framework: The process of expanding from 3D to computable nD. *Automation in Construction, 46*, 82-93.

Dossick, C. S. & Neff, G. (2010). Organizational divisions in bim-enabled commercial construction. *Journal of Construction Engineering and Management, 136*(4), 459-467.

Eadie, R., Browne, M., Odeyinka, H., McKeown, C. & McNiff, S. (2013). BIM implementation throughout the UK construction project lifecycle: An analysis. *Automation in Construction, 36*, 145-151.

Eastman, C., Teicholz, P., Sacks, R. & Liston, K. (2011). *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors* Wiley.

Euler, J. K. (1994). Advantages of using 3-D CAD plant models on the construction site. *Microcomputers in Civil Engineering, 9*(6), 435-444.

Eurostat. (2015). European statistics official. Retrieved from http://ec.europa.eu/eurostat/web/main

Faghihi, V., Nejat, A., Reinschmidt, K. F. & Kang, J. H. (2015). Automation in construction scheduling: A review of the literature. *International Journal of Advanced Manufacturing Technology,*

Forsythe, P. (2014). Proactive construction safety systems and the human factor. *Proceedings of Institution of Civil Engineers: Management, Procurement and Law, 167*(5), 242-252.

Ganah, A. & John, G. A. (2015). Integrating building information modeling and health and safety for onsite construction. *Safety and Health at Work, 6*(1), 39-45.

Gibb, A. (2004). Designing for safety and health in construction-a european/UK. *Designing for Safety and Health in Construction: Proceedings from a Researc,* Portland, OR, USA. 44-57.

Gibb, A., Haslam, R., Gyi, D., Hide, S. & Duff, R. (2006). What causes accidents?*159*(2), 46-50.

Golparvar-Fard, M., Peña-Mora, F. & Savarese, S. (2011). Integrated sequential as-built and as-planned representation with D 4AR tools in support of decision-making tasks in the AEC/FM industry. *Journal of Construction Engineering and Management, 137*(12), 1099-1116.

Gu, N. & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction, 19*(8), 988-999.

Guo, H. L., Li, H. & Li, V. (2013). VP-based safety management in large-scale construction projects: A conceptual framework. *Automation in Construction, 34*, 16-24.

Guo, S. (2001). Integrating CAD and schedule for identification and resolution of work space conflicts between subcontractors. *Canadian Journal of Civil Engineering, 28*(5), 759-768.

Hartmann, T., Van Meerveld, H., Vossebeld, N. & Adriaanse, A. (2012). Aligning building information model tools and construction management methods. *Automation in Construction, 22*, 605-613.

Haslam, R. A., Hide, S. A., Gibb, A. G. F., Gyi, D. E., Atkinson, S., Pavitt, T. C., . . . Suraji, A. (2003). In Prepared by Loughborough University and UMIST (Ed.), *Causal factors in construction accidents* (HSE Report, RR 156 ed.). London: Health and Safety Executive.

Hu, Z., Zhang, J. & Deng, Z. (2008). Construction process simulation and safety analysis based on building information model and 4D technology. *Tsinghua Science and Technology, 13*(SUPPL. 1), 266-272.

Hu, Z., Zhang, J. & Zhang, X. (2010). Construction collision detection for site entities based on 4-D space-time model. *Qinghua Daxue Xuebao/Journal of Tsinghua University, 50*(6), 820-825.

Hu, Z., Zhang, J. & Zhang, X. (2010). 4D construction safety information model-based safety analysis approach for scaffold system during construction. *Gongcheng Lixue/Engineering Mechanics, 27*(12), 192-200.

Hu, Z. & Zhang, J. (2011). BIM- and 4D-based integrated solution of analysis and management for conflicts and structural safety problems during construction: 2. development and site trials. *Automation in Construction, 20*(2), 167-180.

Issa, R. R. & Suermann, P. (2009). Evaluating industry perceptions of building information modeling (BIM) impact on construction. *Journal of Information Technology in Construction,* (14), 574-594.

Jung, Y. & Gibson Jr., G. E. (1999). Planning for computer integrated construction. *Journal of Computing in Civil Engineering, 13*(4), 217-225.

Kang, J. H., Anderson, S. D. & Clayton, M. J. (2007). Empirical study on the merit of web-based 4D visualization in collaborative construction planning and scheduling. *Journal of Construction Engineering and Management, 133*(6), 447-461.

Kartam, N. A. (1997). Integrating safety and health performance into construction CPM. *Journal of Construction Engineering and Management, 123*(2), 121-126.

Kim, H., Lee, H., Park, M., Chung, B. & Hwang, S. (2015). Information retrieval framework for hazard identification in construction. *Journal of Computing in Civil Engineering, 29*(3)

Kim, K. & Teizer, J. (2014). Automatic design and planning of scaffolding systems using building information modeling. *Advanced Engineering Informatics, 28*(1), 66-80.

Koo, B. & Fischer, M. (2000). Feasibility study of 4D CAD in commercial construction. *Journal of Construction Engineering and Management, 126*(4), 251-260.

Korman, T. M. & Huey-King, L. (2014). Industry input for construction engineering and management courses: Development of a building systems coordination exercise for construction engineering and management students. *Practice Periodical on Structural Design and Construction, 19*(1), 68-72.

Kraatz, J. A. & Hampson, K. D. (2013). Brokering innovation to better leverage R&D investment. *Building Research and Information, 41*(2), 187-197.

Le, H. Q. & Hsiung, B. -. B. (2014). A novel mobile information system for risk management of adjacent buildings in urban underground construction. *Geotechnical Engineering, 45*(3), 52-63.

Li, B., F.F. Fu, Zhong, H. & H.B. Luo. (2012). Research on the computational model for carbon emissions in building construction stage based on BIM. *Structural Survey, 30*(5), 411-425.

Li, H., Lu, M., Chan, G. & Skitmore, M. (2015). Proactive training system for safe and efficient precast installation. *Automation in Construction, 49*(PA), 163-174.

Li, H., Lu, M., Hsu, S. -., Gray, M. & Huang, T. (2015). Proactive behavior-based safety management for construction safety improvement. *Safety Science, 75*, 107-117.

Luo, H. & Gong, P. (2014). A BIM-based code compliance checking process of deep foundation construction plans. *Journal of Intelligent and Robotic Systems: Theory and Applications,*

Ma, Z., Shen, Q. & Zhang, J. (2005). Application of 4D for dynamic site layout and management of construction projects. *Automation in Construction, 14*(3), 369-381.

Martínez Aires, M. D., Rubio Gámez, M. C. & Gibb, A. (2010). Prevention through design: The effect of european directives on construction workplace accidents. *Safety Science, 48*(2), 248-258.

Mattila, M., Hyttinen, M. & Rantanen, E. (1994). Effective supervisory behaviour and safety at the building site. *International Journal of Industrial Ergonomics, 13*(2), 85-93.

McKinney, K. & Fischer, M. (1998). Generating, evaluating and visualizing construction schedules with CAD tools. *Automation in Construction, 7*(6), 433-447.

McKinney, K., Kim, J., Fischer, M. & Howard, C. (1996). Interactive 4D-CAD. *Computing in Civil Engineering (New York),* , 383-389.

Melzner, J., Zhang, S., Teizer, J. & Bargstädt, H. -. (2013). A case study on automated safety compliance checking to assist fall protection design and planning in building information models. *Construction Management and Economics, 31*(6), 661-674.

Min, S. & Zhao, L. -. (2014). The application of 3D GIS technology in the whole life cycle of railway. *Journal of Railway Engineering Society, 31*(10), 15-20.

Moon, H., Dawood, N. & Kang, L. (2014). Development of workspace conflict visualization system using 4D object of work schedule. *Advanced Engineering Informatics, 28*(1), 50-65.

Moon, H., Kim, H., Kim, C. & Kang, L. (2014). Development of a schedule-workspace interference management system simultaneously considering the overlap level of parallel schedules and workspaces. *Automation in Construction, 39*(0), 93-105.

Motamedi, A. & Hammad, A. (2009). Lifecycle management of facilities components using radio frequency identification and building information model. *Elec. J. of Information Technology in Construction, 14*, 238-262.

Nawari, N. O. (2012). BIM standard in off-site construction. *Journal of Architectural Engineering, 18*(2), 107-113.

Park, C. & Kim, H. -. (2013). A framework for construction safety management and visualization system. *Automation in Construction, 33*, 95-103.

Porwal, A. & Hewage, K. N. (2013). Building information modeling (BIM) partnering framework for public construction projects. *Automation in Construction, 31*, 204-214.

Qi, J., Issa, R. R. A., Olbina, S. & Hinze, J. (2014). Use of building information modeling in design to prevent construction worker falls. *Journal of Computing in Civil Engineering, 28*(5)

Riaz, Z., Arslan, M., Kiani, A. K. & Azhar, S. (2014). CoSMoS: A BIM and wireless sensor based integrated solution for worker safety in confined spaces. *Automation in Construction, 45*, 96-106.

Sacks, R., Treckmann, M. & Rozenfeld, O. (2009). Visualization of work flow to support lean construction. *Journal of Construction Engineering and Management, 135*(12), 1307-1315.

Saurin, T. A., Formoso, C. T. & Guimaraes, L. B. M. (2004). Safety and production: An integrated planning and control model. *Construction Management and Economics, 22*(2), 159-169.

Seo, J., Han, S., Lee, S. & Kim, H. (2015). Computer vision techniques for construction safety and health monitoring. *Advanced Engineering Informatics, 29*(2), 239-251.

Shen, W., Hao, Q., Mak, H., Neelamkavil, J., Xie, H., Dickinson, J., Xue, H. (2010). Systems integration and collaboration in architecture, engineering, construction, and facilities management: A review. *Advanced Engineering Informatics, 24*(2), 196-207.

Shou, W., Wang, J., Wang, X. & Chong, H. Y. (2015). A comparative review of building information modelling implementation in building and infrastructure industries. *Archives of Computational Methods in Engineering, 22*(2), 291-308.

Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. *Automation in Construction, 18*(3), 357-375.

Succar, B. & Kassem, M. (2015). Macro-BIM adoption: Conceptual structures. *Automation in Construction, 57*, 64-79.

Suermann, P. C. & Issa, R. R. A. (2009). Evaluating industry perceptions of building information modeling (BIM) impact on construction. *Electronic Journal of Information Technology in Construction, 14*, 574-594.

Sulankivi, K., Mäkelä, T. & Kiviniemi, M. (2009). BIM-based site layout and safety planning. *VTT Symposium (Valtion Teknillinen Tutkimuskeskus),* (259), 125-140.

Tatum, S. A., Byrum, J. C. & Rourke, P. W. (1994). Design validation using computer models in lieu of full-scale mockups. *Marine Technology, 31*(3), 225-230.

Teizer, J. (2015). Status quo and open challenges in vision-based sensing and tracking of temporary resources on infrastructure construction sites. *Advanced Engineering Informatics,*

Teizer, J., Allread, B. S., Fullerton, C. E. & Hinze, J. (2010). Autonomous pro-active real-time construction worker and equipment operator proximity safety alert system. *Automation in Construction, 19*(5), 630-640.

Trebbe, M., Hartmann, T. & Doree, A. (2015). 4D CAD models to support the coordination of construction activities between contractors. *Automation in Construction, 49*, 83-91.

Tse, T. K., Wong, K. A. & Wong, K. -. F. (2005). The utilisation of building information models in nD modelling: A study of data interfacing and adoption barriers. *Electronic Journal of Information Technology in Construction, 10*

Volk, R., Stengel, J. & Schultmann, F. (2014). Building information modeling (BIM) for existing buildings — literature review and future needs. *Automation in Construction, 38*, 109-127.

Waly, A. F. & Thabet, W. Y. (2003). A virtual construction environment for preconstruction planning. *Automation in Construction, 12*(2), 139-154.

Wang, H. J., Zhang, J. P., Chau, K. W. & Anson, M. (2004). 4D dynamic management for construction planning and resource utilization. *Automation in Construction, 13*(5 SPEC. ISS.), 575-589.

Wang, W., Weng, S., Wang, S. & Chen, C. (2014). Integrating building information models with construction process simulations for project scheduling support. *Automation in Construction, 37*, 68-80.

Wang, W., Liu, J. & Chou, S. (2006). Simulation-based safety evaluation model integrated with network schedule. *Automation in Construction, 15*(3), 341-354.

Wang, X. & Chong, H. -. (2015). Setting new trends of integrated building information modelling (BIM) for construction industry. *Construction Innovation, 15*(1), 2-6.

Wang, Y., Wang, X., Wang, J., Yung, P. & Jun, G. (2013). Engagement of facilities management in design stage through BIM: Framework and a case study. *Advances in Civil Engineering, 2013*

Xie, H., Shi, W. & Issa, R. R. A. (2011). Using rfid and real-time virtual reality simulation for optimization in steel construction. *Electronic Journal of Information Technology in Construction, 16*, 291-308.

Xu, Y., Wang, Y. & Yao, B. (2011). Study on the construction project IPD collaborative management based on building information model. *Tumu Gongcheng Xuebao/China Civil Engineering Journal, 44*(12), 138-143.

Yamazaki, Y. (1992). Integrated design and construction planning system for computer integrated construction. *Automation in Construction, 1*(1), 21-26.
Zhang, J. P. & Hu, Z. Z. (2011). BIM- and 4D-based integrated solution of analysis and management for conflicts and structural safety problems during construction: 1. principles and methodologies. *Automation in Construction, 20*(2), 155-166.
Zhang, S., Boukamp, F. & Teizer, J. (2015). Ontology-based semantic modeling of construction safety knowledge: Towards automated safety planning for job hazard analysis (JHA). *Automation in Construction, 52*, 29-41.
Zhang, S., Sulankivi, K., Kiviniemi, M., Romo, I., Eastman, C. M. & Teizer, J. (2015). BIM-based fall hazard identification and prevention in construction safety planning. *Safety Science, 72*, 31-45.
Zhang, S., Teizer, J., Lee, J., Eastman, C. & Venugopal, M. (2013). Building information modeling (BIM) and safety: Automatic safety checking of construction models and schedules. *Automation in Construction, 29*, 183-195.
Zhou, W., Whyte, J. & Sacks, R. (2012). Construction safety and digital design: A review. *Automation in Construction, 22*, 102-111.
Zhou, Y., Ding, L., Wang, X., Truijens, M. & Luo, H. (2015). Applicability of 4D modeling for resource allocation in mega liquefied natural gas plant construction. *Automation in Construction, 50*(C), 50-63.
Zhou, Z., Goh, Y. M. & Li, Q. (2015). Overview and analysis of safety management studies in the construction industry. *Safety Science, 72*(0), 337-350.

The evaluation of psychosocial risk factors: between the frameworks of diagnosis and prevention

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Abstract

Psychosocial risk factors, its diagnosis and better understanding, have, in recent years, occupied a central place in the societal debates, setting new demanding to the ones involved in the field of occupational safety and health, in order to ensure these risks prevention. Apparently, the sub-categorization of these work-related risks as of "psychosocial" nature seems to justify a type of intervention, potentially "psychologizing", to which we critically position ourselves - an intervention in which the individual behaviour level is favoured, leaving aside the work activity and its conditions. In fact, it is the concrete work activity and the options on work organization that should assume the centrality in the analysis of these risks - which, actually, interact with other risks, making them, in the majority of the cases, more worrisome. Indeed, it is no coincidence that the visibility given to psychosocial risks arises in an historical context marked by the intensification of work rhythms and by a certain naturalization of physical and emotional exhaustion, together with a professional activity whose complexity has also increased significantly. The concerns of evaluation and diagnosis of psychosocial risk factors boosted the development of several questionnaires, their widespread dissemination, and even their "exportation", not always sensitive to the specificities of local realities. Beyond the issue of assessment and "diagnosis", the purpose of this paper is also to discuss the prevention practices that have been privileged in this area, particularly questioning the limits of a type of usage of statistics, as if the results had worth alone. The methodology used was articulated on the comparison of two reference instruments in this area and the theoretical and epistemological approaches that underlie them: (i) the Copenhagen Psychosocial Questionnaire (COPSOQ) - available in more than 25 languages, and used as a support to comparative studies among various countries in Europe and abroad - that was applied to 116 workers in the furniture industry; and (ii) the Health and Safety Survey (INSAT) - developed in Portugal, but widely used abroad, particularly in Brazil and Angola - that was applied to 99 workers in the cork and in the automobile industries. The results and its discussion reinforce the importance of a contextualized approach in work situations, as well as in the perspective of the workers themselves about the risks to which they are exposed to - beyond what is and what is not significant from the statistical point of view, or what can be normatively defined as an “acceptable risk”.

Keywords: Employment and working conditions, Risk assessment, Questionnaires, Intervention.

1. INTRODUCTION

Psychosocial risk factors, its diagnosis and better understanding have, in recent years, occupied a central place in the societal debates, setting new demanding to the ones who intervene in the field of occupational safety and health.

Apparently, the sub-categorization of these work-related risks as of “psychosocial” nature seems to justify the fact that psychologists are increasingly called upon to respond to such requests. These requests often reflect an expectation that the intervention will contribute to help workers, victims of such risks, to take ownership of other strategies, suitable of allowing them to react more positively to the "work demands".

So, in this type of interventions, potentially "psychologizing", to which we critically position ourselves, an intervention at the individual behaviour level is favoured, leaving aside the collective difficulties (Loriol, 2005).

It is the concrete work activity and the options on work organization that should assume the centrality in the analysis of these risks - which, actually, interact with other risks, making them,

in the majority of the cases, more worrisome. Indeed, it is no coincidence that the visibility given to psychosocial risks arises in an historical context marked by the intensification of work rhythms and by a certain naturalization of physical and emotional exhaustion (closely associated with increasingly precarious labour relations), together with a professional activity whose complexity has also increased significantly.
The concerns of assessment and diagnosis of psychosocial risk factors boosted the development of several questionnaires, their widespread dissemination, and even their "exportation", not always sensitive to the specificities of local realities (and working situations).
Beyond the issue of "diagnosis", the aim of this study is to discuss the type of assessment and prevention practices that have been privileged in this area, particularly questioning the limits of a type of usage of statistics and individual approaches.

2. MATERIALS AND METHODS

The analysis here pursued is sustained on the comparison of two reference instruments in this area and the theoretical and epistemological approaches underlying them. The first instrument is the Copenhagen Psychosocial Questionnaire (COPSOQ) and, the second one, is the Health and Work Questionnaire (INSAT: Inquérito Saúde e Trabalho).
The COPSOQ was developed and validated by Kristensen and cols. (Danish National Institute of Occupational Health), in 2005 (Kristensen et al., 2005) and, recently, was revised (COPSOQ II) (Petjersen et al., 2010). It is a questionnaire broadly used in the assessment of psychosocial risks, which integrates in its conception the influence of dominant psycho-sociological theories, among which: the work characteristics model, the Michigan organizational stress model, the demand-control-support model, the sociotechnical approach and the effort-reward theory (Kristensen et al., 2005; Pejtersen et al., 2010).
The Portuguese translation and adaptation of COPSOQ (Sílvia et al., 2011), and its three versions are available: the long version for researchers (41 scales and 128 questions); the medium version for occupational health professionals (28 scales and 87 questions); and the short version, used in work places (23 scales and 40 questions).
The psychosocial dimensions are analysed through questions (using Lickert scales) reported to the evaluation of: cognitive and emotional demands, rewards, interpersonal conflicts, stress and harassment in the workplace. The order of the questions follows this structure: assessment of *health and wellbeing* items; *relationship with the labour market*; *employment conditions*; *work and private/family life*; *psychosocial work environment*; *workplace as a whole*; *conflicts and offensive behaviour*.
The INSAT (Barros-Duarte, Cunha & Lacomblez, 2007; 2010; 2013) main aim is to analyse the relation between working conditions and health and wellbeing. It's a questionnaire developed in Portugal, and conceived from the contribution of European surveys. Its first version appeared in 2007 (Barros-Duarte, Cunha & Lacomblez, 2007) and it was updated in 2010 (Barros-Duarte & Cunha, 2010), and again in 2013 (Barros-Duarte & Cunha), with the contribution of the experience acquired through its application in different sectors of activity, in Portugal (Barros, Carnide, Cunha, Santos & Silva, 2015). The usage of this instrument has, since then, been required not only in national context, but equally in Portuguese-speaking countries, such as Brazil and Angola.
Since its conception, INSAT integrates questions from epidemiological studies (Cassou et al., 2001) and from work psychology and ergonomics scientific tradition (Lacomblez, 2005) that have contributed for a better understanding of the relationships between health and work.
From the standpoint of its structure, INSAT follows a coherent and integrative logic – from work to the effects of work in health and wellbeing (in a total of 145 items) – allowing the worker, in the auto-filling of the questionnaire (in most items using Lickert scales), a reflection and a progressive awareness of the consequences of work in health and wellbeing. It focuses on the interaction of physical, cognitive, organizational and psychosocial dimensions of work activity, as well as on its effects on physical health and social and psychological wellbeing.
It is organized into seven axes: The *work*; *work conditions and characteristics* (Environment and physical constraints; Organizational and relational constraints; Work characteristics); *Life conditions outside work*; *Training and work*; *Health and work*; *My health and my work*; *My health and my wellbeing*.
To discuss the potentialities and singularities of these two reference instruments in the assessment of psychosocial risk factors, we developed a comparative analysis from three case studies in the context of industrial sectors: furniture, cork and automobile industries. The sample was composed of 215 Portuguese workers from north and center regions: 116 from the furniture

industry, which answered to COPSOQ; and 99 workers which answered to INSAT questionnaire – 43 of these from the cork industry, and 56 from the automobile industry.

3. RESULTS AND DISCUSSION

3.1 Study 1: contributions of risk factors evaluation with COPSOQ in the furniture industry

The results of the COPSOQ questionnaire are frequently expressed under the shape of mean values, being its discussion instigated from the comparison with "averages of reference", as defined by its theoretical framework.

In tables 1 and 2, are presented the results of the application of COPSOQ in the furniture industry: the comparison of the means obtained in this study (second column) and the "average of reference" (last column) corresponds, according to that theoretical framework, to the privileged standpoint that can be assumed in the interpretation of the results. High values are considered "positive" and "healthy" (Kristensen et al., 2007; Petjersen et al., 2010), and low values considered as "threateners". However, there are a considerable number of exceptions as portrayed by table 1.

Table 1: COPSOQ results: dimensions related to individual factors

Dimensions	Mean	Standard Deviation	Minimum	Maximum	Average of reference
General Health	44,82	23,19	0	100	66,0
Sleeping troubles	38,45	20,99	0	100	21,3
Stress	38,64	19,77	0	87,50	26,7
Burnout	45,65	20,62	0	100	34,1
Depressive symptoms	28,31	15,51	0	75	21,0
Somatic stress	28,55	19,59	0	94	17,8
Cognitive stress	31,63	18,93	0	75	17,8
Self-efficacy	68,99	19,09	14	100	67,5

Observing the results in table 1, it can be said, for example, that these workers evidence a general health state worse than the reference value, and a self-efficacy perception higher than the normative value.

Table 2: COPSOQ results: dimensions related to work environment

Dimensions	Mean	Standard Deviation	Minimum	Maximum	Average of reference
Quantitative Demands	30,66	15,19	0	75	40,2
Cognitive Demands	45,26	21,36	0	99	63,9
Emotional Demands	42,94	16,06	0	88	40,7
Work rhythm	56,90	15,55	25	92	59,5
Development possibilities	62,12	18,38	0	100	65,9
Rewards	57,97	25,02	0	100	66,2
Paper conflicts	47,41	18,78	0	99	42,0
Colleagues social support	52,58	25,59	0	100	57,3
Superiors social support	53,05	31,78	0	100	61,6
Work insecurity	56,95	28,87	0	100	23,7

None the less, if table 2 show apparently favourable results – less quantitative and cognitive demands, a work rhythm considered "acceptable" (Cadet & Kouabénan, 2005) – the analysis of the questions that compose these dimensions reveals both the presence of items related to work constraints and items that refer to individual assessment criteria. For example, the "quantitative demands" dimension integrates, namely, a question related to work constraints (workload) and a question based on the assumption that the person, by itself, tends to accumulate work.

3.2 Study 2: evaluation of risk factors with INSAT in the cork industry

The INSAT results, opposed to the COPSOQ's, are expressed in terms of frequency of exposure to different risk factors – environmental risk factors, physical constraints, psychosocial factors of risk – as it is illustrated in tables 3, 4 and 5, respectively.

Table 3: Frequency of workers self-declarations to environmental risk factors

Exposure to:	Number of workers (%)
Harmful noise	40 (97,6)
Temperature variations (heat/cold)	38 (92,7)
Dust or gases	33 (80,5)
Chemical products	21 (51,2)
Other dangerous situations	8 (19,5)

One of the INSAT particularities is its conceptual framework that conceives the work situation as a whole, besides its specific risks. For example, the identification of "other dangerous situations" corresponds, in this case, to the work with certain type of machines (e.g., laminators). This information comes from other complementary methods of analysis - such as the analysis of the work activity in real context (Lacomblez, 2005) -, assuming that INSAT results are not self-explanatories, but have to be articulated with other data sources, namely from qualitative analysis.
Besides this, it is also visible in the interpretation of INSAT results the concern about the options on work organization and not about the individuals' performance (tables 4 and 5).

Table 4: Frequency of workers self-declarations to physical constraints

Exposure to:	Number of workers (%)
Repetitive gestures	32 (78%)
Precise gestures	23 (56,1%)
Harmful postures	33 (80,5%)
Intense physical effort	30 (73,2%)
Standing up at same position for a long period of time	24 (58,5%)
Standing up with displacements	30 (73,2%)

Table 5: Frequency of workers self-declarations to work rhythm constraints

Exposure to:	Number of workers (%)
Intense rhythm	23 (56,1)
Production norms or strict deadlines	31 (75,6)
Having constantly to adapt to method changes or work tools	25 (61)
Manage contradictory instructions	22 (53,7)
Hyper-request	26 (63,4)

Another data that deserves to be highlighted in the usage of INSAT is related to health issues. On the one hand, these arise in this instrument after the exploration of work risks and, on the other hand, the confrontation between data of the following tables make visible how contrasting the results can be – when the question is more abstract (table 6) (the reference to health in a more global way) or when it is contextualized in the relation with work situation (table 7).

Table 6: Frequency of workers self-declarations to the effects of work in health

Work affects my health…	Number of workers (%)
Not at all	16 (39)
Yes, mainly negatively	5 (12,2)
Yes, mainly positively	19 (46,3)

Table 7: Frequency of workers self-declarations to health problems related to work

Health problem	Number of workers (%)	Relationship with work (%)	
		Caused	Aggravated
Back pain	31 (75,6)	48,8	19,5
Musculoskeletal diseases	28 (68,3)	46,3	19,5
Anxiety/Irritability	17 (41,5)	14,6	19,5
Generalized fatigue	18 (43,9)	22	19,5

3.3 Study 3: evaluation of risk factors with INSAT in the automobile industry

The third study was developed in the automobile industry, and highlights another specificity of INSAT further explored in this context, which enriches the debate about the instruments in the assessment of psychosocial risk factors. The INSAT includes a discomfort scale (Lickert scale), to which the worker answers every time he marks being exposed to a certain risk factor. Tables 8, 9 and 10 are an example of this.

Table 8: Frequency of discomfort degree concerning physical constraints (%)

Degree of discomfort in exposure to:	Precise gestures	Painful postures	Intense physical efforts	Standing up at same position for a long period of time
Severe discomfort	4 (13,3)	7 (19,4)	11 (26,8)	7 (19,4)
Moderately severe discomfort	5 (16,6)	15 (41,7)	16 (39,0)	16 (44,4)
Discomfort	10 (33,3)	11 (30,6)	9 (22,0)	8 (22,2)
Minimal discomfort	11 (36,7)	3 (8,3)	5 (12,2)	4 (11,1)
No discomfort	0 (0,0%)	0 (0,0)	0 (0,0)	1 (2,7)

Table 9: Frequency of discomfort degree concerning work intensification constraints (%)

Degree of discomfort in exposure to:	Intense rhythm	Follow production norms or meet strict deadlines	Hyper-request
Severe discomfort	5 (12,2)	1 (2,0)	2 (9,0)
Ioderately severe discomfo	11 (27,5)	11 (22,4)	6 (27,3)
Discomfort	16 (40,0)	15 (30,6)	5 (22,7)
Minimal discomfort	8 (20,0%)	15 (30,6)	8 (36,4)
No discomfort	0 (0,0%)	7 (8,1)	1 (4,5)

Table 10: Frequency of discomfort degree concerning social work relationships (%)

Degree of discomfort in exposure to:	Not having my opinion taken into consideration	Lack of recognition from managers
Severe discomfort	4 (18,2)	10 (45,5)
Moderately severe discomfort	4 (18,2)	7 (31,8)
Discomfort	3 (13,6)	4 (18,2)
Minimal discomfort	1 (4,5%)	1 (4,5)
No discomfort	4 (18,2%)	1 (4,5)

On the one hand, it is visible in INSAT's analysis the attempt to express results in frequencies and not using averages, trying to highlight the weight of the exposure to different risk factors, more than trying to identify the "acceptability of the risk", with reference to standard mean values.

In fact, observing the results in table 9, it is possible to note the variability of workers self-declarations concerning the degree of discomfort when exposed to intense rhythm, to production norms or rigid deadlines, or situations of hyper-request.

Besides that, it is the knowledge of the work activity, in the real context, as well as the knowledge of the options on work organization, that allows us to understand that in the case of an assembly line - with strong time constraints - , a high percentage of workers declare discomfort due to the adoption of painful postures, the intense physical efforts and having to remain a long time up with displacements (table 8). Furthermore, the lack of recognition from managers considering the work done (table 10), and the lack of "power to act" (Clot, 2008) according to their own opinions about the working methods, were pointed as harmful among these workers.

It is in this perspective that INSAT tries to exceed the traditional practices of risks assessment, reinforcing an approach more "comprehensive" than "explanatory", when assuming in the interpretation of its results, a coherent combination between the analysis of the activity and the use of a quantitative method of analysis.

4. CONCLUSION

Besides the diversity of themes framed under the notion of "psychosocial risks" – and, sometimes, confusing its causes with its effects (Nasse & Légeron, 2008) – the principle we assume in the analysis of the psychosocial risk factors is to anchor their assessment and prevention in the work analysis, trying to understand the risks in the scope of a contextualized approach and considering, at the same time, the interaction between them, that is, without treat them isolated.

The approach was developed, in the pathway of a greater recognition of these risk factors and its prevention, corroborates the perspective of using questionnaires that allow an analysis more centred on the work situation - in the context of a certain work activity, of a concrete enterprise, of a professional group, in view of the working conditions improvement.

The debate concerns also the passage from diagnosis to intervention (Lacomblez, 2012) and, in this sense, the proposal of questions that sustain the dialog with the actors of prevention in work safety and health domains: quantifying risks is a mean of giving them visibility, but how to use statistics taking into account the singularities of the work situation, as well as what escapes to a certain "statistical orthodoxy" (Volkoff, 2010)?

5. REFERENCES

Barros, C., Carnide, F., Cunha, L., Santos, M., & Silva, C. (2015). Will I be able to do my work at 60? An analysis of working conditions that hinder active ageing. *WORK: A Journal of Prevention, Assessment & Rehabilitation*, 51, 579-590. DOI: 10.3233/WOR-152011

Barros-Duarte, C., & Cunha, L. (2014). Avaliação dos fatores psicossociais de risco: contributos do Inquérito INSAT (333-346). In H.V. Neto, J. Areosa, & P. Arezes (Org). *Manual sobre Riscos Psicossociais no Trabalho*. Vila do Conde: Civeri Publishing.

Barros-Duarte, C., & Cunha, L. (2010). INSAT2010 - Inquérito Saúde e Trabalho: outras questões, novas relações *Laboreal, 6*, (2), 19-26 http://laboreal.up.pt/revista/artigo.php?id=48u56oTV6582234;5252:5:5292

Barros-Duarte, C., Cunha, L., & Lacomblez, M. (2007). INSAT: uma proposta metodológica para análise dos efeitos das condições de trabalho sobre a saúde. *Laboreal, 3*, (2), 54-62. http://laboreal.up.pt/revista/artigo.php?id=37t45nSU547112311:499682571

Cadet, B., & Kouabenan, D. R. (2005). Assessing and modelling risks: the contributions and limits of several paradigms in security diagnosis. *Le Travail Humain*, 68, 1, 7-35.

Cassou, B., Buisset, C., Brugère, D., Davezies, P., Derriennic, F., Desplanques, G., Laville, A., Marquié, J-C., Touranchet, A., & Volkoff, S. (2001). *Travail, Santé, Vieillissement: relations et évolutions*. Toulouse: Éditions Octarès.

Clot, Y. (2008). *Travail et pouvoir d'agir*.Paris: P.U.F.

De Keyser, V., & Leonova, A. (2001). *Human error prevention and well-being at work in Western Europe and Russia*. Kluwer Publisher.

Eurofound (2012). *Fifth European Working Conditions Survey*. Luxembourg: Publications Office of the European Union.

Gollac, M., & Bodier, M. (2011). *Mesurer les facteurs psychosociaux de risque au travail pour les maîtriser*. Rapport du Collège d'expertise sur le suivi des risques psychosociaux au travail, faisant suite à la demande du Ministre du travail, de l'emploi et de la santé, Avril.

Kristensen, T.S., Hannerz, H., Hogh, A., & Borg, V. (2005).The Copenhagen Psychosocial Questionnaire - a tool for the assessment and improvement of the psychosocial work environment. *Scandinavian Journal of Work, Environment & Health, 31* (6): 438-49.

Lacomblez, M. (2012). Enjeux pour la santé – présentation. In P. Desmarez, M. Stroobants, M. Alaluf, *Mesures et démesures du travail* (pp.179-184). Bruxelles: Les Éditions de L'Université de Bruxelles.

Lacomblez, M. (2005). *Ergonomie de l'activité et francophonie: héritages, réalités, perspectives*. Retirado de http://www.ergonomie-self.org/diffusion/contributions.pdf, a 5 de Setembro de 2006.

Loriol, M. (2005), Les ressorts de la psychologisation des difficultés au travail. *Cahiers de recherche sociologique*, 191-208.

Molinié, A-F., & Volkoff, S. (2002). *La démographie du travail pour anticiper le vieillissement*. Paris: ANACT.

Nasse, P., & Légeron, P. (2008). *Rapport sur la détermination, la mesure et le suivi des risques psychosociaux au travail*. Paris: La Documentation française.

Pejtersen, J.H., Kristensen, T.S., Borg, V., & Bjorner, J.B. (2010).The second version of the Copenhagen Psychosocial Questionnaire. *Scandinavian journal of public health*, *38*(3), 8-24.

Silvia, C. F., Amaral, V., Pereira, A., Bem-Haja, P., Pereira, A., Rodrigues, V, Cotrim, T., Silvério, J., & Nossa, P. (2012). *Copenhagen Psychosocial Questionnaire. COPSOQ. Portugal e países africanos de língua oficial portuguesa*. 1st Portugal, FCT: PTDC/SAL – ESA/661613/2006.

Volkoff, S. (2010). Statistiques "ouvertes" et ergonomie "myope": combiner les niveaux d'analyse en santé au travail. *Sciences Sociales et Santé*, 28, 2, 11-30.

Occupational accidents investigation and prevention: analysis of Labour Inspection practices in Brazil

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Abstract
One of the tasks of the Brazilian Ministry of Labour and Employment (MLE) Labour Inspectors (LIs) is to investigate and to analyze the causes of occupational accidents (OA) as well as the conditions that may produce them. This paper describes a case study regarding some accidents that took place in the metal-mechanic industry and which were analyzed by the LIs, of Minas Gerais Labour and Employment Regional Superintendence in the years 2011 to 2012. The study aimed at analyzing how effective the accident investigations carried out to prevent such events were. The main sources of information were the accident analysis reports issued by the inspectors, the inspection reports kept in the files of the Federal Labour Inspection System, MLE computerized system, and semi-structured interviews with eleven inspectors. The results were presented and discussed according to the "Chain Model", developed to evaluate the effectiveness of the labour accident investigations produced by the Swedish Work Environment Authority (SWEA) inspectors. The model consists of five links: notification, selection, investigation, dissemination and prevention. This paper concentrates on the findings and their implications regarding the dissemination and prevention links. The lessons learned during the accident analysis process have not been disseminated neither among the LIs, nor outside the MLE. Prevention resulting from monitoring implementation measures does not usually take place. Considering the "Chain Model", a contribution of the OA investigations carried out by the LIs is not effective enough for preventing similar events. Therefore, it is necessary that MLE adopts measures to strengthen the dissemination and prevention links.

Keywords: metal-mechanic industry; chain model; Labour Inspector; dissemination of knowledge.

1. INTRODUCTION
Labour related accidents can cause physical injuries to workers, distress to their families, as well as determine high costs for companies and society. In Brazil, one of the tasks of the Ministry of Labour and Employment (MLE) Labour Inspectors (LIs), is to investigate and analyze the causes of serious and fatal occupational accidents (OA) as well as the conditions that may produce them (Brazil, 2002). A report for each accident analyzed must be issued. It must include of the accident causes and the actions employers must take to avoid the repetition of the undesired event. An OA's analysis does not finish after the report is issued, it is necessary to go further (Drogaris, 1993). Lessons learned during the analysis must be propagated and, to avoid new occurrences, companies must comply with the preventive measurements outlined in the report (Human Reliability Associates [HRA], 2001; Jacobina et al., 2002; Almeida, 2006).
This paper describes a case study concerning OA which occurred in the metal-mechanic industry and which was analyzed by the LIs from the Minas Gerais Regional Labour and Employment Superintendence (SRTE/MG), in the cities of Belo Horizonte, Betim and Contagem, from 2011 to 2012,
Workers from metal-mechanic industries are exposed to several dangers, especially those resulting from operating mechanical conformation machines, such as metal presses, folders, cutters, calenders, among others (Park, 1998; Federação das Indústrias do Estado do Rio Grande do Sul, 2006; Nobre Junior, 2009).
The metal-mechanic industry activities range from producing food aluminum packages to assembling large vehicles. The typical occupational accident incidence rate in these activities is higher than procedures in other important economic sector in Minas Gerais (Brasil, 2012a), such as iron ore extraction or coffee plantations. In 2011, in Minas Gerais, 28,07% of the issued Occupational Accident Communication referred to typical occupational accidents which had happened in the cities of Belo Horizonte, Betim and Contagem (Brasil, 2012a).
The objective of this paper is to analyze to what extent the OA investigations carried out by the LIs contributed to prevent new accidents. It features the procedures prescribed by the LIs

concerning accident analysis, and checks if the practices adopted can contribute to prevent new events.

2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Several authors have shown that new accidents can only be avoided if knowledge obtained during the accident analysis is disseminated among all stakeholders and if implementation of the measures proposed by the investigators is monitored.

Nine basic requirements for a successful accident investigation are described in a study conducted by HRA (2001) for the United Kingdom Health and Safety Executive (HSE), among them:

> […]
> e) Carrying out of recommendations that enclose both immediate and underlying causes;
> f) Implementation of these recommendations and updating of relevant risk assessments;
> g) Monitoring to insure that actions succeed in reducing risks of new accidents;
> h) *Feedback* for stakeholders to allow them to share the obtained knowledge;
> i) Development of an easy-access database.

Jacobina et al. (2002) show that after ranking by priority the control and prevention measures, the investigating team, with the supervision of the union and workers, must put forward to the company an executive plan, where deadlines and monitoring schemes must be detailed. They emphasize the importance of publicizing the information produced for the various stakeholders.

For Almeida (2006), the process of accident analysis systematization can be characterized by the following structure:

> 1. Analysis preparation, definition of the event that will be analyzed and its consequences;
> 2. The strictly speaking analysis, including amend proposals and written report;
> 3. Implementation of amends an its follow-up; and
> 4. System feedback with updates based on lessons learned during analysis.

Almeida (2006) understands that it is necessary to follow-up the impact of the implemented measures with regard to the occurrence of accidents that have almost the same aspects as those intended to be controlled by the adopted standards. Initially, Almeida assumes that the feedback phase aims at sharing immediate findings with the other members of the system. He highlights the importance of their contributions for the system improvement. Subsequently, feedback becomes an updating source and a continuous improvement for the system risk assessment.

Lindberg e Hansson (2006) estimated the effectiveness of the OA investigation produced by Haverikommissionen – HAKO, of the Swedish Work Environment Authority – SWEA. The study was commissioned by SWEA itself one year after HAKO's initial activities.

This was the reason for researchers to develop the "Chain Model", which consists of a five link chain as described below (Lindberg et al., 2010):

- Link 1: Notification

Workplace accidents and incidents must be notified to the person in charge of selecting the events that will be investigated in depth. This should happen as soon as possible after the occurrence. Notifications must have all the information needed for selecting the events that will be analyzed.

- Link 2: Selection

Notifications are used to select the accidents and incidents needing an investigation. The chosen events should be those owning the biggest amount of useful information to be extracted for preventive work.

- Link 3: Investigation

It is the main step in an accident analysis and has been the focus of most of the approaches on the topic.

- Link 4: Dissemination

Information obtained in OA investigations must be shared with everyone who can use it to prevent future accidents.

- Link 5: Prevention
An accident investigation process does not come to an end before its recommendations have been implemented to insure the future safety of the system to be protected.
The “Chain Model” was also used to assess the contribution of the occupational accidents analysis carried out by the LIs from the Minas Gerais Regional Labour and Employment Superintendence (SRTE/MG) to prevent further accidents.

3. METHODOLOGY

The qualitative research was conceived as a case study related to 23 typical OAs which occurred at the metal-mechanic industry and which were analyzed by the LIs of the Regional Minas Gerais Labour and Employment Superintendence (SRTE/MG) in the cities of Belo Horizonte, Betim and Contagem, in 2011 and 2012.
The sources of information for the procedures regarding the OA analysis prescribed for the LIs were the MLE internal regulations: Decree No. 4.552, from December 27th, 2002, establishing Labour Inspection rules (Brasil, 2002); Instruction No. 88 from November 30th, 2010, establishing the guidelines for OA analysis and the report template used by LIs (Brazil, 2010b), as well as the OA analysis Guide prepared by MLE in 2010 (Brasil, 2010a).
With regard to the approaches and practices effectively adopted by the LIs, the main sources of information were the OA analysis printed reports, SFIT (Labour Inspection Federal System) constant inspection reports, OA analysis reports electronically entered into SIRENA’s file folder (Reference System in Analysis and Prevention of Occupational Accidents), information gathered by the LIs involved in the accident analysis, memos evidencing that the accident analysis report was forwarded to people outside the MLE.
By accessing the MLE computer network we checked whether the reports of accidents subject of this study were electronically inserted in the ten subfolders of SIRENA’s files.
Initially, this study accident analysis had the participation of thirteen LIs. As one of them retired and another was under sick leave, information from the other 11 was gathered through the 12 questions of the semi-structural interviews.
The "Chain Model" was useful to evaluate how much the OA analysis reports produced by LIs contributed to prevent new accidents. However, in this study only information regarding the links “dissemination of knowledge” and “prevention of new accidents” were analyzed and discussed.
To estimate how effective the accident analyses were to dissemination the lessons learned, the following are pointed out:
a) how many accident reports were sent to SIRENA’s file folder;
b) whether the report was or not discussed with the employers’ representatives, the Labour Unions and the injured workers;
c) LIs’ participation in technical meetings or formal trainings related to accidents analyzed by other LIs;
d) whether LIs had access to SIRENA’s folder or not;
e) whether the file was made available electronically so that it could be included in the above mentioned folder;
f) whether a copy of the accident analysis report was sent to people outside MLE.
Regarding prevention, we checked with SFIT if there were adjustments in the workplace during the inspection that investigated the causes of the accident, and if the companies involved were inspected again after the previous inspection was over.
The LI’s words during the interviews are shown in the text in the way they were said, i.e., without editing.

4. RESULTS

4.1. Prescribed work

After a serious or fatal OA has occurred, it is LIs’ responsibilities to investigate it through different means such as: collecting *in loco* information, producing a photographic record of the accident relevant aspects, analyzing occupational safety and health documents and, when the accident is not fatal, interviewing the victims and other witnesses of the accident. Finally inspectors must write an accident analysis report (Brasil, 2010b).
To measure LIs’ production, data of the activities, including those related to OA analysis, are included in SFIT, a computerized and codified system for monitoring LI inspections.
Besides sending data to SFIT, LIs have to produce the OA analysis report, which has to be typed according to a model established by the MLE. After it is printed it must be delivered to the

Head of Health and Safety Section. It must also be submitted electronically. The Head will be responsible for entering it in SIRENA's system electronic file which is part of the MLE computerized network (Brasil, 2010b).

4.2. Analyzed Occupational accidents

OAs analyzed by LIs at the metal-mechanic industry are presented in this topic (Table 1).

Table 1 – Occupational accidents in metal-mechanic industries, analyzed by SRTE/MG Labour Inspectors from 2011 to 2012.

Event	M.M. factor	Part of the Body hit	Injury	Observation
1	Fall of material	Chest	Death	
2	Contact with press	Head		Preparation
3	Pressurized Cilinder	Chest		
4	Lift	All body		
5	Truck	Head		
6	Fire/Welding	Legs		
7	Electric Ark	Arms		
8	Winder	Hand	Amputation	
9-11	Contact with press	Hand		Operation
12	Circular Saw	Finger		
13	Lift	Spine, knee and collarbone	Fracture	
14	Contact with press	Arm		Operation
15	Milling machine	Hand		
16	Fallen material	Leg		
17-18	Contact with press	Hand		Preparation
19	Contact with press	Hand		Operation
20	Same level fall	Shoulder		
21	Fallen material	Foot	Contusion	
22	Fallen material	Head	Contusion	
23	O_2/GLP explosion	Foot	Burn	

Source: SFIT/MLE

Note: M.M. factor - immediate factor of morbimortality; Preparation refers to operations performed at the press before its operation, such as adjustments and changing tools; O_2/GLP – Oxygen cylinders and liquefied oil gas.

Fifteen of the 23 OAs analyzed were reported to the MLE by Labour Unions. By November 2013, two accident reports sent to SFIT in July/2011 and February/2012 had not yet been received at the Head of Safety and Health Section.

4.3. Dissemination (Link 4)

After the OA analysis report is finished, the next steps are to point at the causal factors that lead to the accident and to indicate the necessary preventive measures to avoid the repetition of the event.

By consulting the folders of the companies filed in the Head of Health and Safety Section it was possible to find out that a copy of the OA analysis report was sent to stakeholders (Table 2).

Although reports of events 10 and 20 were in the companies' folders, they were not sent to any stakeholder. Reports of events 22 and 23 have not been produced. Only companies of events 1 and 6 requested MLE to send them a copy of the report.

Table 2 - Stakeholders that received the analysis reports of occupational accidents which occurred in the metal-mechanic industry, in 2011 and 2012, and which were analyzed by the SRTE/MG Labour Inspectors.

Events	Stakeholder
1	Labour Union, the injured worker family, the company
2	General Attorney's Office, Labour Court
3, 8 e 12	General Attorney's Office
4	General Attorney's Office and family of the injured worker
5,11,16,18,19	General Attorney's Office and Labour Prosecutors' Office
6	General' Attorney's Office, Labour Union, company, Labour Court
7	General Attorney's Office, Labour Union, Labour Prosecutors' Office

9	General Attorney's Office, Labour Union, injured worker, Labour Prosecutors' Office, Criminal Prosecutors' Office
13	General Attorney's Office, Labour Union, injured worker
14, 15, 17, 21	General Attorney's Office, Labour Union

Source: Company folders filed at the Safety and Health Section

The eleven interviewed LIs mentioned they usually exchange information informally with other LIs about accidents that are similar to the ones they are analyzing. This is what LI 4 said: *"We work in a very broad sphere of knowledge. So it's almost impossible to know everything. When I'm in doubt I try first to talk to someone, who has already analyzed a similar accident, or who has gone through training programs".* LI 6 comments*: "There is no formal exchange of experiences. Our institution does not stimulate this exchange of experiences".*

Ten LIs recognized that the first thing to be done in order to disseminate the lessons learned during an accident investigation process is to improve the exchange of information among LIs as LI 6 stated: *"Look ... first disseminate among ourselves in technical meetings"*. LI 8 expresses the same opinion: *"...it would be very interesting to attend lectures where other LIs would present their analysis and conclusions".*

Viewing dissemination of the learned lessons outside the MLE, seven LIs' suggested presenting the analysis at conferences and seminars. LI 7 declared: *"Seminars, conferences, files that could be consulted at the Web. Certainly, what you learn about one accident can prevent others".* LI 2 suggests: *"... organize seminars to discuss good practices regarding prevention of accidents. This exchange of ideas, the so called benchmarking…".*

Only three interviewed LIs declared that, after finishing their OA analysis results, they had communicated and/or discussed them with stakeholders such as employers, members of the companies' Occupational Safety and Health Specialized Services, the Internal Accident Prevention Commission, Labour Unions and the injured worker himself.

Six LIs said that during the analysis process or when the assessment notices, notice and/or interdiction term were sent, they tried to talk to the employer representatives about the causes of the accident, and how it could have been prevented.

The main reasons LIs gave for not discussing the report with stakeholders were their work demands, reduced staff and the inspection targets established by the MLE. These are LI 4' explanations: *"No, but I even think we should do it. We don't do it due to our job routine, to the MLE goals. We end up by missing everything that is not centered in the main focus. We end up by not having meetings due to the excessive number of tasks we are assigned"*. LI 11 completed the thought: *"We don't have enough staff, then, even if you are free to produce a deeper analysis, you try to be objective. So you end up by shortening steps that could even be more important than disseminating and discussing, however, presently we don't do this."*

By researching SIRENA's file folder in December 2013, we found that only five of the 23 OA analysis reports were inserted in it.

Only four LIs informed they usually forward an electronic copy of OA analysis report to the Head of Health and Safety Section. The other seven said they usually send only the printed report, as it is shown in LI 5's comment: *"No, I send to the Head of the Section only the printed analysis. I understand that sending it to SIRENA's file is a decision of the head of the department."* LI 6 adds: *"I have sent the reports. But our bosses don't ask us to it, there is no rule establishing LIs should send it. We had no training. I had no training on how to access it. Nobody ever told me anything about it"*.

Ten out of 11LIs reported that they do not access SIRENA's file folder to get information about an accident with similar features to the one he is analyzing. Five of them were unaware of how to access the files, as reported by LI 5: *"I'm not used to collect accident information through SIRENA as I don't know the system"*. In LI 7's opinion: *"No, I have never consulted it. I am interested in learning about it, but honestly I've never consulted it. Much more due to my lack of computer skills than anything else".*

All inspectors unanimously believe that if a MLE database including the OA reports produced by the LIs was available for the general public to consult, it would be a very important tool to disseminate the lessons learned during the analysis. LI 8 stated: *"I think it would be interesting, but I see it as almost an editorial work, catch reports and do their formatting. It would be very interesting, an indexed thing, machine type, type of situation, type of injury".* The following comment was made by LI 1: *"I think it is important that MLE allows everybody to access this database. People could go there, open it, look at it etc. It shouldn't be a bureaucratic procedure, you shouldn't have to ask formally if you wanted a copy."*

4.4. Accident prevention (Link 5)

We found that the preventive measures that companies should adopt to prevent recurrence of the events either were implemented during the accident analysis, or are being followed up by LI through other inspections (Table 3).

Table 3 –Monitoring of the metal-mechanic industries involved with occupational accidents which were analyzed by SRTE/MG Labour Inspectors in 2011 and 2012.

Events	Rectification during inspection	Occurrence of other inspection after analysis
1, 3-7, 9-13, 15, 17, 18, 20, 21	No	No
8,16 e 23	No	Yes, but no rectification
2, 14, 19, 22	Yes	---

Source: SFIT/MLE

Ten of the interviewed LIs declared that the MLE does not monitor the preventive measures prescribed to the companies. Due to the many goals set by the MLE LIs usually don't have time to think about the LA after they finish their analysis and report. LI 3stated: *"No, not usually. In this case it´s because of my work demands".* LI 5 said: *"The inspection targets to be reached are based on criteria such as the number of audited companies. This inhibits monitoring companies to check if suggested preventive measures have been adopted".*

Two LIs pointed out that the work plan does not include returning to the companies to check if the factors that caused the accident were corrected. LI 6 adds: *"In our agency there is no organization or system pointing at this direction".* Referring to planning LI 8 said: *"... planning is carried out by the heads of the department. So if I choose to return to the company to check it out, I know this will be an additional demand I will have to comply with".*

However, all LIs agreed that this follow up would be significant to check if companies really implemented the prescribed preventive measures.

All the eleven LIs also answered the following question (Table 4): "In case monitoring is included in the investigation process, do you consider it is important to have other stakeholders taking part? Which ones and why?".

Table 4 – Social actors who could monitor the implementation of preventive measures according to the Labour Inspectors.

Social Actors	Labour Inspector										
	1	2	3	4	5	6	7	8	9	10	11
Labour Union	X	X	X		X	X	X	X	X		X
Labour Prosecutors' Office		X		X	X	X	X	X			X
Criminal Prosecutors' Office				X							
Labour Court				X							
Others	X	X								X	

Source: Interviews with 11 Labour Inspectors carried out by the author.

Most LIs were in favor of the having the Unions taking part in this phase of the investigation as shown by LI 6 statement: *"Unions presence in the workplace is bigger than ours."* LI 2 agrees: *"... unions could be excellent partners in checking this for us."*

5. DISCUSSIONS

5.1. Sending of reports

Although MLE has been informed of 15 LAs, only 9 accident analysis reports were sent to the Labour Unions.

Only in two occasions a copy of the OA analysis report was sent to the companies involved in the accidents. This only happened because they had requested MLE for it. The relevant information did not reach the people who could play an important role in preventing similar accidents. If the Occupational Safety and Health Services, the Internal Commission on Accident Prevention and the employers had a copy of the OA report they could discuss it and start formulating their accident preventing strategies.

As two reports were not delivered by LIs, and two other were not forwarded to any of the interested groups, in spite of having been received and filed at the Health and Safety Section, probably no action will be taken concerning four of the 23 accidents. According to Lindberg and

Hansson (2006), after HAKO finishes an investigation, the group begins planning how the report will be distributed and who should receive it. Besides SWEA inspectors, usual recipients are other authorities, companies, workers and labour market organizations affected by the conclusions and suggestions of the reports. However, HAKO's dissemination of results and reports were criticized by the companies which had somehow been involved with the accidents. An organization that accredited a crane involved in an accident said*: "The measures taken by us did not result from the report, since we, as a company, did not receive it"* (Lindberg and Hansson, 2006).

5.2. Dissemination among Labour Inspectors

LIs' interviews showed that their strategy to gather information on accidents which have the same characteristics as the ones they are investigating is to exchange ideas with other LIs. There is no MLE action to stimulate LIs to disseminate information among themselves in a systematic way.

When Lindberg and Hansson study was conducted (2006), SWEA's central agency inspectors who did not participate in HAKO answered a questionnaire about dissemination of the information included in the accident reports. In most of the inspectors' opinion (51%) the committee had done very little to disseminate the results. Five percent said they did not know how to get hold of the reports. The interviewed district inspectors reported that more affords should be devoted to spread effectively HAKO's reports within SWEA. They thought having them simply published in the agency intranet was not enough.

In order to confirm LIs information concerning shortage of staff, we requested the Head of Safety and Health Section, Mr. Francisco Alves do Reis Junior, for the exact number of LIs professionally linked to SRTE/MG in the early 2011. We found out there were 41 inspectors able to analyze labour accidents at this time. In December 2013, only 34 of them were still engaged in their activities at the Safety and Health Section, besides carrying out inspection actions in several other places in the state of Minas Gerais.

The problem of LIs shortage has aggravated all over the country. In December 2010 there were 3.061 LIs at the MLE. By the end of 2013 the numbers went down to only 2.719[1] .

Barbosa et al. (2012), through the Technical Note No. 4, from IPEA, - the Applied Economic Research Institute presented a study showing the need to increase the number of LIs in Brazil. The study pointed out that from all states in Brazil, Minas Gerais owned the second worst average of LIs for every thousand companies in 2008/2009.

Regarding the MLE's target, another of the claims put forward by the LIs, the action goals included in the SRTE/MG project "Work Accident Analysis" were estimated. The project aimed at analyzing 280 serious or fatal accidents in Minas Gerais in 2010. This figure rose from 380 in 2011, to 386 in 2012, and reached 418 in 2013[2].

The figures reported by the MLE concerning the whole country confirmed the increased demand for Labour Inspection (Table 5). OSH inspections increased year after year, as well as the number of workers involved in these inspections, but the amount of analyzed accidents did not change. While the number of LIs decreases year after year, the goals increase, confirming LIs statements.

Table 5 – Number of OSH inspections, of workers reached and of occupational accidents (OAs) analyzed by the MLE in Brazil, from 2010 to 2012.

Year	Number of OSH inspections	Number of workers	Number of OAs analyzed
2010	135.621	17.033.658	1944
2011	138.143	17.534.078	1957
2012	154.361	18.810.932	1902

Source: <http://portal.mte.gov.br/seg_sau/resultados-da-fiscalizacao-em-seguranca-e-saude-no-trabalho-brasil-1996-a-2009.htm>.

[1] http://portal.mte.gov.br/data/files/FF8080814373793B0143D3F566471E0B/Resultados%20da%20Fiscaliza%C3%A7%C3%A3o%20-%202003%20-%202013%20atualizado%20at%C3%A9%20dezembro.pdf

[2] https://sfitweb.mte.gov.br/sfitweb/private/pages/metas_obrigatorias_consultar_resultado.jsf

We observed that there is lack of knowledge of some LI about the access to SIRENA' files folder, although they received SIRENA's e-mail address in Instruction No. 88/2010 (Brasil, 2010b). As far as SRTE/MG is concerned LIs did not receive any training on the instruction contents and how to access SIRENA's files folder.
LIs showed they were unaware on how to send their reports through the Web. They also did not know whether the OA reports should always be forwarded to the Head of Health and Safety Section or only when they were requested.
In general, LIs are not motivated to use the information kept in the reports sent to the SIRENA's file.

5.3. Dissemination outside the MLE

The LIs' interviews proved SIRENA's files could become a database available for the general public.
Jacobina et al. (2002) suggest that, health education and communication activities aimed at sharing information should be planned after LIs have finish their reports and have discussed them with stakeholders.
Producing an open database is the last of the nine steps of an accident analysis presented in a study for HSE (UK) carried out by HRA (2001).
To disseminate the lessons learned from the accident analysis, Drogaris (1993) proposes an occupational accident database network. He mentions the positive aspects of the Major Accident Reporting System - MARS, a database developed by the European Community (EC), which deals with accidents and near accidents involving chemicals. Nowadays 776 accident reports are available in the MARS for public consultation.
In the United States (US), the National Institute for Occupational Safety and Health - NIOSH, public agency linked to the Ministry of Health, has kept the FACE program - Fatality Assessment and Control Evaluation - since 1982. Currently 1010 occupational accident reports are available for consultation and download[3].
The National Transportation Safety Board (NTSB) is an independent federal agency which is in charge of investigating all civil flight accidents and significant accidents in the other means of transport in the US. Accident reports are the major products of a NTSB investigation. They provide details, analyze the evidences, conclusions and most probable causes of the accidents, as well as the related safety recommendations.
On its website HSE presents detailed OA reports of various production areas.
As we learned from those occupational accident databases, making information available is of great help for those who administrate, operate and design security systems for the most varied facilities.

5.4. Monitoring preventive measures

The interviews showed that the MLE' LIs have not monitored the preventive measures. According to them, this is due to the insufficient number of LIs involved in these actions, to the excessive goals set by the MLE and to the lack of planning regarding follow up actions.
MLE's annual plan does not set that after the investigation is over LIs have to go back to the companies in order to monitor the implementation of measures to avoid the repetition of the unwanted events. Investigations alone are not able to stop workers' injuries and deaths. Employers must adopt preventive measures and the MLE must monitor them.
In 2010 the Occupational Safety and Health Administration - OSHA, an agency of the US Labor Department, approved, the Severe Violator Enforcement Program - SVEP. This program channels resources to inspect employers who have disrespected the occupational safety and health law through intentional and repeated violations (US Department of Labor, 2010).
From Lindberg and Hansson study (2006) we can learn that the link regarding prevention is faulty. HAKO inspectors pointed out at an interview that the reports needed a better monitoring, although they had different views concerning who should be responsible for doing it. In the words of one of them: *"Someone has to be responsible for seeing that these costly HAKO's recommendations are actually put into practice".*
Most of the SWEA's district inspectors stated that monitoring results and recommendations of HAKO's reports is very important, but that this should not be the committee's job, but a task for the district inspector.

[3] http://www.cdc.gov/niosh/face/desc.html

Kjellén insists that a follow-up meeting is an important step in a thorough investigation. In his opinion the purpose of the meeting is to give people involved a chance to clarify doubts and provide further explanations. It also generates an atmosphere of trust and willingness to learn from the accident (Kjellén, 2000, quoted by Lindberg and Hansson, 2006).

5.5. Joint actions

LIs were in favor of carrying out joint actions with other public organizations such as the Labour Prosecutors' Office, to enable them to help with monitoring.

The Labour Unions, the institutions the LIs mostly remembered, can also play a key role in monitoring as they have contact with workers not only in the production sites, but also in the Internal Accident Prevention Commissions.

6. CONCLUSIONS

This paper aimed at analyzing the contribution of LI's OA investigations in preventing new accidents. It was focused in the last two links of the "Chain Model": dissemination and prevention.

Regarding dissemination, the survey findings show that information obtained through the OA analyses were not disseminated outside MLE.

Only five reports were included in SIRENA's file folder. Some LIs declared they did not access it because they had no idea they were expected to do it and because they did not know they were supposed to provide an electronic OA report and send it to the files database.

In general, LIs have not discussed the OA analysis results with stakeholders. Their job demands and the many targets set by the MLE were mentioned as the main obstacles. Their attitudes prevent information from being spread among people who could help preventing similar accidents in the future.

Accident databases such as the HSE (UK), NIOSH and NTSB (US), MARS (EC) are examples of what can be made available in the computers of the global information network concerning labour accidents and the measures to prevent them.

Our study conclusion is that the communication link is faulty and the MLE must repair it.

The prevention link structure also needs improvement. Workplace was not amended after the OA investigation analysis and companies were not monitored to check if the problems that caused the accident were solved.

In Brazil the excessive goals set to LIs plus the reduction in their numbers have lead to difficulties in investigating companies where serious and fatal accidents have occurred. However, it is MLE obligation to assume this role until the companies implement the preventive measures.

Due to all these considerations, it seems that the last two links of the "Chain Model" are weakened. Our research results are similar to the ones of Lindberg and Hansson study (2006).

Consequently we concluded that the contribution of the OA investigations carried out by LI to prevent further accidents is ineffective regarding the "Chain Model". The federal government should take actions to strengthen the dissemination and prevention links.

It is necessary to change MLE institutional position towards entrepreneurs who keep unsafe machines constantly turning workers into victims.

Before finishing we would like to say that much of what was found in this study can be extended to other units of the MLE, not only because accidents are investigated in the same way in all of them, but also because of the reduced number of LIs in activity. As there are no other studies on the subject presented in this paper, especially concerning the dissemination and prevention steps, we consider that further research is needed in order to foster debate and to complement the findings of this academic study.

7. ACKNOWLEDGMENTS

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8. REFERENCES

Almeida, I. M., 2006. Trajetória da análise de acidentes: o paradigma tradicional e os primórdios da ampliação da análise. *Interface – Comunicação, Saúde, Educação,* 9 (18), 185-202, Jan./Jun. 2006. Retrieved Jun. 14, 2013, from http://www.scielo.br/scielo.php?pid=S1414-32832006000100013&script=sci_arttext.

Barbosa, A. L. N. de H.; Corseuil, C. H. L.; Reis, M. C., 2012. *A necessidade de Auditores Fiscais do Trabalho no Brasil: uma análise contemplando o grau de descumprimento da legislação trabalhista*. Brasília: Instituto de Pesquisa Econômica Aplicada.

Brasil. Ministério da Previdência Social, 2012. AEAT Infologo: base de dados históricos de acidente de trabalho. Retrieved Jun. 14, 2013, from http://www3.dataprev.gov.br/scripts10/dardoweb.cgi.

Brasil. Ministério do Trabalho e Emprego, 2013. Cadastro Geral de Empregados e Desempregados. Retrieved Jun. 14, 2013, from http://bi.MLE.gov.br/cagedestabelecimento/pages/consulta.xhtml.
Brasil. Ministério do Trabalho e Emprego, 2010a. *Guia de análise acidentes de trabalho.* Retrieved Jan. 22, 2014, from http://portal.MLE.gov.br/data/files/FF8080812D8C0D42012D94E6D33776D7/Guia%20AT%20pdf%20para%20internet.pdf.
Brasil. Ministério do Trabalho e Emprego, 2010b. *Instrução Normativa Nº 88, de 30 de novembro de 2010.*
http://portal.MLE.gov.br/data/files/8A7C812D3066DDD701306BF8FFA527A7/in_20101130_88.pdf (Jul. 20, 2013).
Brasil. Presidência da República, 2002. *Decreto Nº 4.552, de 27 de dezembro de 2002*. Retrieved Jun. 14, 2013, from http://www.planalto.gov.br/ccivil_03/decreto/2002/d4552.htm.
Drogaris, G., 1993. Learning from major accidents involving dangerous substances. *Safety Science,* 16, 89-113.
Federação das Indústrias do Estado do Rio Grande do Sul, 2006. *Manual de segurança em prensas e similares.* Porto Alegre: Conselho de Relações do Trabalho e Previdência Social, Grupo de Gestão do Ambiente de Trabalho.
Human Reliability Associates, 2001. *Accident investigation: the drivers, methods and outcomes.* Caerphilly: HSE. Retrieved Apr. 22, 2013, from http://www.hse.gov.uk/research/crr_pdf/2001/crr01344.pdf.
Jacobina, A., Nobre, L. C. da C., Conceição, P. S. de A., 2002. Vigilância de acidentes de trabalho graves e com óbito. In: Bahia. Secretaria da Saúde. Superintendência de Vigilância e Proteção da Saúde. Manual de normas e procedimentos técnicos para a vigilância da saúde do trabalhador. Salvador: Centro de Estudos da Saúde do trabalhador, 87-115. Retrieved Nov. 25, 2013, from
http://www.segurancaetrabalho.com.br/download/vigilancia_ac_graves.pdf.
Lindberg , A.-K., Hansson, S. O., 2006. Evaluating the effectiveness of an investigation board for workplace accidents. *Police and Practice in Health and Safety*, 4, 63-79.
Lindberg, A.-K, Hansson , S. O.; Rollenhagen C., 2010. Learning from accidents: what more do we need to know? *Safety Science,* 48, 714-721.
Nobre Junior, H. B., 2009. *Os acidentes de trabalho em prensas analisados pelos Auditores-Fiscais do Trabalho do Ministério do Trabalho e Emprego no período de 2001 a 2006.* (Masters dissertation) Faculdade de Medicina de Botucatu, Universidade Estadual Paulista, Botucatu.
Park, R. M.,1998. Forging and Stamping. In: *Industries Manufacturing, Parte XIII, Vol. 3, Encyclopedia Health and Safety at Work*. Geneva, International Labour Organization. Retrieved Oct. 18, 2012, from
http://www.ilo.org/safework-bookshelf/english.
U.S. Department of Labour, 2010. *Instruction OSHA CPL 02-00-149 – Several Violator Enforcement Program, June 18, 2010.* Retrieved Dec. 12, 2013, from
https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=4503.

Zero Harm: myth or reality?

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Abstract

Background and Aims: Over the last decade, Australian industry has overwhelming embraced the concept of Zero Harm as a mantra for espousing their commitment to safety, a workplace free from injury or harm. It is suggested that the underlying principle of zero harm is based on the philosophy of zero tolerance, that is certain actions will not be tolerated under any circumstance. Zero harm is similar in some aspects of zero tolerance in that within a workplace, the concept of zero harm is creating an injury and incident free work environment were injuries are not acceptable and everything possible is undertaken to prevent them. Zero harm can also have many other derivatives including goal zero, the target is zero and vision zero. Whilst this is an admirable goal, what does zero harm mean for employees, is it achievable and does it influence workplace behaviour? What is known is that government and industry organisations have acknowledged that Australia's current safety performance is not acceptable or sustainable. With a cost of over $60 billion representing 4.8 of Australia's GDP, every year over 260 workers die and over 680,000 suffer some form of workplace injury or illness. To address this, workplace safety legislation continues to evolve to provide governance for improved safety, and organizations have invested millions into zero harm initiatives including the use of behavioural safety programs and measuring safety performance against lagging and leading indicators. Zero harm proponents postulate that there can be no other goal other than zero harm, yet opponents argue that zero harm ideology is detrimental to improved safety performance through organisations setting goals that are unachievable, unbelievable and driving a culture of under reporting of incidents to achieve set key performance indicators. As a result, the aim of this research was to undertake a quantitative examination through surveys with a large global oil and gas contracting company to evaluate the employees' perceptions of zero harm, including its' effectiveness and how the concept can be manifested and measured in the work environment. *Method*: 299 employees working in various countries (110 from Australia and 189 Asia Pacific workers) completed a battery of questionnaires that focused on obtaining perceptions regarding: (a) why there is a focus on zero harm, (b) who should promote the zero harm concept, (c) what is the meaning of zero harm and how should it be measured, and (d) whether the concept is achievable and relevant. *Results:* Analyses revealed that the largest proportion of employees believed the organisations focus on zero harm was based on the company caring for the workers safety followed by no incidents for the environment. Factor analysis of the items revealed a six factor structure with the largest factor representing the company's commitment to zero harm. Participants also reported a high level of consensus regarding workers self-efficacy to carrying out zero harm principles. Independent t-tests revealed significant differences between the genders and zero harm beliefs (e.g., males higher) as well as been employees and supervisors. *Conclusion:* Taken together, employees correctly articulated the meaning of zero harm and also believed the principles were achievable. This paper will further outline the key findings of zero harm as well as provide direction for future research.

Keywords: Zero Harm, Workplace Safety, Safety Culture, Incidents and Accidents

1. INTRODUCTION

Within Australia, industry has overwhelming embraced the concept of zero harm as a mantra for espousing their commitment to workplace health and safety. Organisations such as BHP Billiton, Shell, Rio Tinto, BP, Xstrata, Anglo American, Blue Scope, Leighton's, Tenix, Calibre, Energex, Ergon and One Steel to name a few, all use the term 'zero harm' and or other derivatives including; vision zero, goal zero, target zero, zero accidents and zero incidents as their mantra for improved safety performance. Within these organisations zero harm is an organisational goal of no accidents or injuries were all incidents are viewed as preventable and that there is no acceptable performance level other than zero harm. Whilst this is an admirable goal, empirical evidence is lacking regarding what does zero harm actually mean and is it achievable?

Believers of zero harm describe the concept as a workplace environment that is embodied by a core safety value, that no workplace death or injury is acceptable (O'Rourke, 2010). This concept is extended through a commitment that if a single day without an injury can be achieved, then 365 days without an injury is also achievable (Burnham, 2015). Workplace Health and Safety Queensland (2010) also describe zero harm as, 'no harm to anyone, anytime while at work' and postulates that zero harm is an aspirational goal not a target.

Conversely there are also sceptics of the zero harm concept who consider zero harm is neither credible or a realistic goal (Roughton & Mercurio, 2002). For example, one of these opponents, Douglas (2011), suggests that zero harm is a safety concept based purely on hope and that a false belief that all incidents are preventable may actually cause harm. Spigener (2009) and O'Rourke (2010) suggest that zero harm is a program, not a target and that zero harm focuses on exposure rather than injury and that it recognises the dangers of underreporting of incidents, as well as a focus on lost time injuries that are generally associated with target driven system. Byard (2009) and Douglas (2011), suggest that the concept of zero harm is noble but it is an unachievable goal because people don't believe that it is actually possible to achieve. As such, the zero harm goal is deemed as unrealistic or attainable and is regarded as utopic nonsense (Zwtsloot *etal*, 2013). This can negatively affect the organisation's safety culture and expose the organisation to potential under-reporting or hiding of incidents from employees, supervision and managers who may strive to avoid poor statistics (QRMC, 2011) through fear of failure or personal commitment. It is also interesting to note that opponents of zero harm have also coined the concept of binary thinking in their justification that zero harm is a workplace discourse and that one must want harm if they are not an advocate of zero harm (Long, 2012). Zero harm supporters counter this argument by reinforcing that moral condemnation of organisations would exist if they 'just accepted' incidents, especially those that may lead to fatalities or have significant environmental impact. Despite the lack of evidence-based support, organisations continue to readily embrace zero harm as a mantra for a new paradigm of workplace safety to protect their employees from occupational-related harm (O'Rourke, 2010; Young 2014,). This may continue to be problematic as there is currently limited scientific support in the field for the concept of zero harm (Zwtsloot, Aaltonen, Wybo, Saari, Kines & Beeck, 2013).

In regards to the evolution of the concept, it is proposed that zero harm evolved from a quality 'zero defects' that arose in the 1960's (Zwtsloot *etal,* 2013). This 'zero' approach then led to the concept of 'zero tolerance' which was first used in the 1980's in the United States of America in combating crime from the philosophical origins of the article 'Broken Windows' (Griffith 1999). The focus of zero tolerance has since evolved into other areas including violence at schools, bullying and drugs and alcohol (NASP, 2012). The underlying principle of zero tolerance is that certain actions will not be tolerated under any circumstance. More recently, the occupational safety movement embraced the concept. Zero harm is similar in some aspects to zero tolerance in that within a workplace, the concept of zero harm is creating an injury and incident free work environment where injuries are not acceptable and everything possible is undertaken to prevent them (Spigener, 2009). Zero harm can also have many other derivatives including goal zero, the target is zero and vision zero. Essentially, the vision is zero acceptance of injuries or fatalities (O'Rourke, 2010).

From an industry perspective, the evidence is also mixed. For example, the DuPont group are considered a global leader in safety (Zwtsloot *etal*, 2013). DuPont postulates that it is an organisation that believes all incidents and accidents are preventable, which is a core constituent of zero harm. However, DuPont recently had a chemical leak at a plant near La Porte in the US that resulted in the death of four employees (Chemistry World 2014). BHP and BP are a further two global industry examples that have a mantra of zero harm but who have recently have had significant incidents. For example, BHP Billiton recently (22 September 2012) had a contractor fatality at the Pinto Valley operation in Arizona USA (BHP Billiton, 2012), prior to this there was another BHP Billiton fatality (7 July 2011) at its port operations, Port Hedland, Western Australia (ABC News, 2011). From a global perspective, in the last decade, 45 workers died at BHP sites (Stevens, 2015). Further, BP at its Deepwater Horizon operations in 2010 had 11 fatalities and an estimated 4.9 million barrels of crude oil spill, which is the largest marine spill in history (BP Deepwater Horizon Accident Investigation report, 2010). BP has also agreed to compensate the US government and five states $24 Billion for damages stemming from this incident. This includes $5.5 Billion as a civil penalty under the US Clean Water Act (AFP, 2015). This evidence casts further doubt on the efficiency of zero harm to create lasting change in the real world.

Despite the above, the concept of zero harm has continued to evolve, and has now become not only a mantra for organisations but also a fixed identity which has become an unquestioned concept (Long, 2012; Zwtsloot *etal*, 2013). Simplistically, as inferred by Long (2012), this zero harm concept is absolute, as there is no flexibility in its concept. In fact, those that do not agree with the concept of zero harm are labeled and perceived to agree that it is acceptable that incidents and injuries will occur. This viewpoint has a fatalistic approach and subjects those that are not advocates of zero harm are powerless against incidents from happening. Taken together, there is considerable debate about the conceptual value and impact of zero harm on actual occupational safety. As a result, it may be argued that the first step is to examine workers perceptions and beliefs about zero harm, in regards to whether the concept is a viable initiative to promote and is accepted by those most at risk of workplace harm. Such research is lacking within the literature, and the current study aims to contribute to the scant endeavors that have investigated workers' perceptions regarding the meaning and value of zero harm as a workplace initiative that needs to be embraced in order to improve safety.

2. MATERIAL AND METHODS

2.1 Participants

The sample consisted of 299 workers employed in varying countries from a large global oil and gas contactor. Of the 299 participants, 77% (n = 229) were male. Participants were aged 19 to 68 (M = 38.44, SD = 10.04). The majority of participants (60%; n = 179) were classified as employees (e.g., Accountant, Operations Coordinator, Officer) and 36% of respondents (n = 108) worked in supervisory or managerial positions (e.g., Operations Manager, Supervisor, Regional Manager). Participants' experience in their current positions ranged from less than one year (.08) to 34 years. On average, participants had approximately 5 years of experience in their current roles (SD = 4.96), and 5.29 (SD = 5.30). The largest proportion of the sample worked in Australia (n = 110; 37%), followed by Singapore (n = 46; 15%), Indonesia (n = 26; 9%) and Malaysia (n = 20; 7%). Several participants reported working in more than one country (n = 9; 3%) or across the Asia Pacific region (n = 5; 2%), outlined in Table 1

Table 1 Percentage of participants by country

Countries Participated	**Total surveys received (*n*)**	**Percentage by country (%)**
Australia	110	37
Bangladesh	11	4
Brunei	17	6
Singapore	46	15
China	19	6
Indonesia	26	9
Malaysia	20	7
Thailand	19	6
Vietnam	6	2
Papua New Guinea	1	.3
Philippines	4	1
New Zealand	1	.3
Myanmar	1	.3
More than one country recorded	14	5
No country recorded	4	1

2.2 Instrument

A questionnaire was developed that required participants to rate each statement based on their own individual perception or exposure to zero harm. The development of the quantitative self-reported questionnaire included 98 items which were informed by the theoretical outcomes from a literature review and supported by various adaptations of current safety culture and safety climate questionnaires. For example, safety questionnaire's as evaluated by Diaz-Cabrera, Hernandez-Fernaud and Isla-Diaz (2007). All participants within the questionnaire were asked to express their views in regards to specific quantitative statements utilising scores on a Likert 5-point scale: 1 = strongly disagree, 2 = disagree, 3 = neutral/unsure, 4 = agree, 5 = strongly agree.

2.3 Procedure

The questionnaire was distributed by internal (organisational) mail, email, in person and/or at toolbox talks or team meetings to a cross section of the workforce that includes; management, supervision, general employees, tradespersons, and technical employees. Participants individually completed the self-reported questionnaire, which was made available either in hard copy paper format or via the Queensland University of Technology (QUT) on line 'key survey' electronic tool. Participation was confidential and anonymous. The participants were required to respond to statements based on their perceptions and experiences at their current workplace. In total, there are approximately 2700 employees within the sample organisation. Approximately 11% participated within the research project. The undertaking of the survey was conducted primarily at the workplace however, the option to complete the questionnaire outside of the work environment was also provided.

3. RESULTS AND DISCUSSION

A factor analysis was conducted on 83 items in the survey (i.e., items 11 – 31 and 36 – 98). The Kaiser–Meyer-Olkin (KMO = .92) measure confirmed that the sample was highly suitable for the analysis and, similarly, Bartlett's test of sphericity X^2 (2145) = 12056, $p < .001$ indicated that there were sufficiently large correlations between items to support this analysis. An initial principal axis analysis with varimax rotation showed that 18 items (i.e., items 24, 28, 48, 52, 53, 68, 69, 70, 71, 73, 74, 77, 82, 89, 96, 97, 98) did not load onto a factor and were therefore removed from the analysis. A second principal axis analysis with varimax rotation was carried out showing six factors that had an Eigenvalue over Kaiser's criterion of 1 as well as a minimum of 4 items making up each factor. Together, these six factors accounted for 58.42% of the variance (see Table 2 for the individual factor loadings). Fourteen items loaded highly onto Factor 1 which represented the company's commitment to Zero Harm and accounted for 37.78% of the total variance; fourteen items also loaded highly onto Factor 2 which represented worker self-efficacy to carry out Zero Harm principles and accounted for 6.69% of the total variance; four items loaded highly onto Factor 3 which represented the impact of the safety committee and accounted for 4.52% of total variance; five items loaded highly onto Factor 4 which represented negative work practices and accounted for 3.54% of the total variance; nine items loaded highly onto Factor 5 which represented prevention of incidents and accidents and accounted for 3.11% of the total variance; and ten items loaded highly onto Factor 6 which represented worker recognition and reward and accounted for 2.77% of total variance.

Table 2: Factor Structure of the Zero Harm Survey

Item	F1	F2	F3	F4	F5	F6
My company has clear safety rules that support the zero harm vision	.79					
I believe that the safety standards and rules of this company are very high and support the companies zero harm policy	.78					
The company policy and goals clearly support its commitment to safety and incident injury free workplace	.77					
The company's safety programs and actions clearly support its commitment to safety and an incident injury free workplace	.68					
This company demonstrates that it is very serious about improving its safety performance	.65					
My company has a safety management system that provides procedures and processes that will ensure the safety of its employees	.61					

My company ensures that all workers are instructed and trained on what their safety roles and responsibilities are	.60			
My Supervisors / managers regularly discuss safety	.56			
Company has safety programs to improve safety that focus on zero harm	.50			
Safety is considered first in every activity	.50			
The company provides me with the correct training to do my job safely	.48			
I have a formal performance review undertaken that includes my personal safety performance	.44			
Incident investigations are undertaken and outcomes are communicated to all employees	.43			
My supervisor will regularly ask me about safety concerns or ideas to improve safety	.42			
I always follow the highest levels of safety when I carry out my job		.78		
I always use the correct safety procedure to carry out my job		.74		
I always use the correct safety equipment to do my job		.73		
If I observe a co-worker working unsafely or at risk, I will intervene.		.69		
I always place extra effort to improve the safety within the workplace		.67		
I always follow all safety rules		.65		
I voluntarily carry out tasks or activities that will help to improve safety within the workplace		.59		
I always report all incidents and accidents that I am involved in.		.57		
I will praise a co-worker if they are doing the job safely		.56		
I make an effort to promote zero harm within the organization		.56		
I always undertake every effort to maintain or improve my personal safety		.54		
I can stop my job if the job is unsafe		.54		
My supervisor demonstrates high safety behaviours	.40	.44		
My supervisor always ensures that safety is prioritized over production		.41		
The safety committee is actively involved in promoting safety			.80	
I am kept informed of the safety committees activities			.79	
My department has a safety committee			.75	
My department has its own safety improvement plan			.46	
My supervisor sometimes encourages at risk behaviour or overlooks hazards to get the job done				-.66
My supervisor will turn a blind eye if I have to do a job unsafely if the task is critical				-.60

Our company only measures injuries or incidents				-.58		
If an employee is injured they will be blamed or punished				-.58		
When my supervisor is not present, I tend to take more risks in doing my work				-.57		
I believe that if an accident or incident does happen the worker will be blamed				-.56		
I will take short cuts in my job due to work pressures				-.55		
I believe that you will be injured at work during your working career whilst working with this company				-.45		
It is inevitable that accidents and incidents will happen in this company				-.45		
My workmates believe that all incidents and accidents are preventable					.76	
I believe that all incidents and accidents are preventable					.74	
I believe that zero harm is achievable within my company					.66	
I believe that all operating exposures can be controlled and or safeguarded					.52	
If employees follow the company's safety management system there will be no incidents or accidents					.46	
The company rewards it employees for working safely						.69
Our company recognizes and celebrates safety milestones						.65
I am praised by my manager or supervisor for working safely						.61
My work team is praised for working safely						.55
The company has a recognition program that is focused on improving safety and achieving zero harm						.42

Table 3 shows the means and standard deviations for each of the factors. Specifically, Factor 2 had the highest mean (*M* = 4.23, *SD* = 0.53), showing that, on average, participants agreed with the items regarding worker's self-efficacy to carry out Zero Harm principles. Factor 4 had the lowest mean (*M* = 2.49, *SD* = 0.74), showing that, on average, participants disagreed with the items regarding the existence of negative work practices.

Table 3: Mean Scores and Standard Deviations for the Factors

Factor		*M*	*SD*
1.	Company's commitment to Zero Harm	4.22	0.55
2.	Worker self-efficacy to carry out Zero Harm Principles	4.23	0.53
3.	Impact of safety committee	3.63	0.88
4.	Existence of negative work practices	2.49	0.74
5.	Prevention of incidents and accidents	3.96	0.73
6.	Worker recognition and reward	3.80	0.77

Note. Each of these items were measured on a 5-point scale where 1 = strongly disagree, 2 = disagree,
3 = neutral/unsure, 4 = agree, 5 = strongly agree.

Of the individual survey items, Table 4 shows the four items which participants were most likely to agree with. Specifically, participants were most likely to agree with the statement, 'I feel that it is important to maintain safety at all times' (*M* = 4.67, *SD* = 0.52) and were next most likely to agree with ‘I believe it is important to reduce the risk of accidents and incidents within the workplace (*M* = 4.66, *SD* = 0.52)

Table 4: Mean Scores and Standard Deviations for the Highest Ranked Survey Items

Item	*M*	*SD*
1. I feel that it is important to maintain safety at all times	4.67	0.52
2. I believe that it is important to reduce the risk of accidents and Incidents within the workplace	4.66	0.52
3. I believe that I have the right to challenge, or refuse to work when placed in an unsafe or at risk conditions without fear of reprisal	4.58	0.57
4. I can stop my job if the job is unsafe	4.56	0.57

Note. Each of these items were measured on a 5-point scale where 1 = strongly disagree, 2 = disagree, 3 = neutral/unsure, 4 = agree, 5 = strongly agree.

Table 5 shows means and standard deviations for core Zero Harm questions. In response to the question ‘Why do you believe your company has a focus on Zero Harm?’ participants, were most likely to agree with the response ‘My company cares about their workers safety’ (*M* = 4.49, *SD* = 0.56). For the question ‘Which of the following groups have a major role in determining the zero harm policy of your company?’ participants were most likely to agree with the response ‘Company senior management’(*M* = 4.51, *SD* = 0.62). For ‘What do you believe is the meaning of zero harm?, participants, on average, were most likely to agree with the response ‘No harm to anyone, anytime while at work (*M* = 4.73, *SD* = 0.52). For ‘In your opinion how does your company measure zero harm?’, participants, on average, were most likely to agree with two responses, that were ‘No Injuries (First aid, Medical Treatment or Lost Time)’ (*M* = 4.47, *SD* = 0.67) and ‘No Lost Time Injuries’ (*M* = 4.47, *SD* = 0.67).

Independent-samples t-tests were carried out to determine if there were any significant differences between gender and job title on each of the factors. With regard to gender, a significant difference between males and females was found for Factor 2 (i.e., worker self-efficacy to carry out zero harm principles). Specifically, males scored significantly higher (*M* = 4.31, *SD* = 0.53) than females (*M* = 4.15, *SD* = 0.50), t (276) = 2.15, p < .05 (two-tailed). For job position, a significant difference between employees and supervisors/management for Factor 4 (i.e., existence of negative work practices). Specifically, employees scored significantly higher (*M* = 2.62, *SD* = 0.73) than supervisors/management (*M* = 2.26, *SD* = 0.71), t (274) = 3.93, p < .001.

Table 5: Means and Standard Deviations of the Zero Harm Questions

Question	*M* (*SD*)
Why do you believe your company has a focus on Zero Harm?	
My company cares about their workers safety	4.49 (0.56)
My company does not want to be prosecuted	4.30 (0.85)
Community expectations	4.08 (0.74)
Company promotion	4.08 (0.78)
Shareholder expectation	4.08 (0.79)
Union pressure	3.24 (1.08)
Which of the following groups have a major role in determining the zero harm policy of your company?	
Legislators	3.98 (0.81)
The community	3.72 (0.94)
Share Holders	3.83(0.91)
Company senior management	4.51 (0.62)
Union organisations	3.39(1.05)
What do you believe is the meaning of zero harm?	
No harm to anyone, anytime while at work	4.73 (0.52)
No Incidents (Environmental impacts)	4.49 (0.75)
No Lost Time Injuries	4.55 (0.67)
No Injuries or incidents	4.57 (0.64)
I do not know	1.71 (0.94)

In your opinion how does your company measure zero harm?	
No Injuries (First aid, Medical Treatment or Lost Time)	4.47(0.67)
No Incidents (Environmental impacts)	4.35 (0.75)
No Lost Time Injuries	4.47 (0.67)
No Injuries or incidents	4.46 (0.63)
I do not know	1.77 (0.95)

Note. Each of these items were measured on a 5-point scale where 1 = strongly disagree, 2 = disagree,3 = neutral/unsure, 4 = agree, 5 = strongly agree.

4. CONCLUSION

Organisations seeking a paradigm shift in their safety performance have adopted the mantra of zero harm as a methodology to eliminate workplace accidents, a philosophy and belief that all accidents are preventable (Zwtsloot *etal.*, 2013). This study has reviewed this concept by undertaking an exploration from an employees' perspective, to examine the perceptions and exposure to zero harm from a workers' view point. A central aim of the study was to examine the perceived meaning of zero harm. The majority of the participants agreed that it was no harm to anyone, anytime while at work. This provides support for the assertion that zero harm is instrumental in arguing against common fatalism (Zwtsloot *etal.*, 2013). In contrast, workers were less likely to believe the concept emerges from union pressure or shareholder expectations.

As demonstrated within the factor analysis, the highest agreement among the participants was the company's commitment to zero harm and this commitment is based on the foundation that the company cares about their workers safety. As one would expect, senior management was seen as the driving role in determining the zero harm approach for workplace safety within the organisation. Interestingly, in regards to how the company measures zero harm, there was an equal opinion of 'no injuries including first aid, medical treatments or lost time injuries' and 'no lost time injuries'. The latter, demonstrates the importance of reducing lost time injuries from the perception of the respondents but may suggest that zero harm can still be achieved if other types of injuries that do not include lost time injuries still exist (i.e., first aid or medical treatment injuries). It is well established that the reporting of lost time injuries (LTI's) is problematic through misrepresentation and or underreporting (Oleinick 1993; Probst 2008 & Young 2013).

It is also noteworthy that, on average, most participants reported high self-efficacy levels to carry out zero harm principles which suggest they are empowered to take responsibility for their own safe behaviours. Correspondingly there was a high level of disagreement in relation to negative safe work practices suggesting that whilst they may occur, they are not proportionally at the same level as workers undertaking safe behaviours. It is also interesting to note that male respondents indicated significantly high levels of self-efficacy to carry out zero harm principles than females. Further research is required to determine the origins of such possible gender differences. As one would expect, employees due to their exposure scored significantly higher than supervisors and managers on their perceptions of the existence of negative work practices.

There is a lack of scientific evidence to suggest that zero harm is an achievable end state, if a concentrated effort on zero harm will lead to an improvement of workplace safety or if employees even believe in the concept. Zero harm organisations have demonstrated significant improvements in their lagging indicators especially the lost time injury frequency rate (LTIFR) however, underreporting and manipulation of incidents are major obstacles to verifying their accuracy. This research paper has moved from an organisational perspective to an employee perspective to gain a workers perspective on zero harm. This has demonstrated that within this organisation, there is a strong support for the zero harm and its application within the company. Although, there is still significant research to be undertaken to see if zero harm can truly be understood and achieved. This paper provides a platform for future research and in particular the direction for scientific research into the manifestation of zero harm within an organisation including its constructs and strategies. Further research is also warranted on the impact of zero harm discourse on workers, supervisors and managers.

5. REFERENCES

ABC News (2011) retrieved June 2015 from http://www.abc.net.au/news/2011-07-07/worker-killed-at-bhp-port-hedland-site/2785436).

AFP (2015) Retrieved July 2015 from http://finance.ninemsn.com.au/newsbusiness/9004090/bp-to-pay-record-24-billion-over-gulf-of-mexico-oil-spill

BHP Billiton (2011) Retrieved from http://www.bhpbilliton.com/home/investors/news/Pages/Articles/Fatality-At-Pinto-Valley-Operation.aspx

BP Deepwater Horizon Accident Investigation report (2010) Retrieved from http://www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/incident_response/STAGING/local_assets/downloads_pdfs/Deepwater_Horizon_Accident_Investigation_Report.pdf

Burnham. M. (2015). *Targeting Zero Eight Questions to Ask Before Using Zero as a Safety Target.* Professional Safety. April 2015

Byard. P. (2009). 'Could Zero Harm be killing our people?'. *Australian Journal of Mining*. Retrieved September 2012 from http://www.theajmonline.com.au/mining_news/news/2009/october/october-22-09/other-top-stories/could-2018zero-harm2019-be-killing-our-people

CCH Australia (2003). *Australian Master OHS& Environment Guide*. CCH Australia Limited.

Chemistry World (2014) retrieved June 2015 from http://www.rsc.org/chemistryworld/2014/11/methyl-mercaptan-leak-kills-four-workers

Diaz-Cabrera,D.; Hernandez-Fernaud. E. & Isla-Diaz.R. (2007) An evaluation of a new instrument to measure organisational safety culture values and practices. Accident Analysis and Prevention 39 (2007) 1202-1211

Douglas.A. (2011). 'Zero Harm – a slogan created for the CEO'. Retrieved July 2012 from http://www.safetysolutions.net.au/articles/46377-Zero-harm-a-slogan-created-for-the-CEO.

Elvik,R. & Amundsen, A.H.(2000). *Improving road safety in Sweden. Main Report. Report 490*, Oslo, Institute of Transport Economics. Retrieved October 11 2011 from https://www.toi.no/category.php?search=true&fd=1&fm=1&td=31&tm=12&sort=relevance&categoryID=29&fy=2000&author=Elvik&query=&x=35&y=9

Griffith,G.(1999). *Zero Tolerance Policing: Briefing Paper No 14/99*. NSW Parliamentary Library Research Service. Retrieved December 19 2011 from http://www.parliament.nsw.gov.au/prod/parlment/publications.nsf/0/796C90ABE8349FDFCA256ECF0008CE11/$File/14-99.pdf

Long. R. (2012). 'The Zero Aspiration, the maintenance of a dangerous idea'. Retrieved January 2012 from http://www.safetyrisk.com.au/the-zero-aspiration-the-maintenance-of-a-dangerous-idea/

Long, R. and Long, J. (2012). Risk Makes Sense: Human judgement and Risk.2nd Edition. Scotoma Press, Kambah ACT.

NASP (2012). Zero Tolerance and Alternative Strategies: A Fact Sheet for Educators and Policymakers. Retrieved July 2012 from http://www.nasponline.org/resources/factsheets/zt_fs.aspx

O'Connor,P.; Buttrey, S.E.; O'Dea, A & Kennedy, Q. (2011) Identifying and addressing the limitation of safety climate surveys. *Journal of Safety Research* 42 (2011) 259-265

Oleinick. A. (1993). Current methods of estimating severity for occupational injuries and illnesses: data from the 1986 Michigan comprehensive compensable injury and illness database. Am. J. Ind. Med. 23 (2), 231-252

O'Rourke, V. (2010). When can you claim to have a zero harm workplace?, *National Safety Magazine, National Safety Council of Australia*, 02 March 2010, p42-43.

Probst. T.M (2008) Organisational injury rate underreporting: the moderating effect of organizational safety climate. J. Appli. Psychol. 93 (5), 1147-1154

QRMC (2011). Zero Harm: an objective review. *QRMC Risk Management newsletter*, July 2011, Issue 17. Retrieved November 2014 from http://www.qrmc.com.au/category/newsletters/

Roughton. J.E. & Mercurio. J.J. (2002). *Developing an Effective Safety Culture: A Leadership Approach*. Butterworth – Heinemann, Woburn, MA.

Spigener, J. (2009). The Zero Harm organisation: The false security of low injury rates, *Industrial Safety and Hygiene News*, Vol.43, Iss.5.

Stevens. M. (2015). Retrieved July 2015 from http://www.afr.com/business/mining/australias-workers-are-safer-but-still-not-safe-enough-20150717-gietcl

Tingvall.C. & Haworth.N. (1999) 'Vision Zero – An ethical approach to safety and mobility'. Paper presented to the 6th ITE International Conference Road Safety & Traffic Enforcement: Beyond 2000, Melbourne, 6-7 September 1999.

Workplace Health and Safety Queensland (2010).*Zero Harm at Work Leadership Program: 2010 Program Members Reporting Evaluation Report.* Queensland Government, Department of Employment and Industrial Relations. Retrieved December 19, 2011 from http://www.deir.qld.gov.au/workplace/resources/pdfs/zeroharm-evalreport-2010.pdf

Young. S. (2013). From zero to hero. A case study of industrial injury reduction: New Zealand Aluminium Smelters Limited. *Safety Science* 64 (2014) 99-108

Zwetsloot, G.I.J.M.; Aaltonen, M.; Wybo, J.; Saari, J.; Kines, P. & Beeck, R.O.D. (2013) The case for research into Zero Accident Vision. *Safety Science*, 2013, 58, 41-48

Computer-aided advanced technique for the analysis of occupational accidents

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Abstract

Notwithstanding the Italian strong commitment of recent years, the number of occupational fatalities is still impressive, at least in terms of frequency rate; moreover, the recent crisis and large-scale job reductions made the data analysis somehow more complex.

The statistical databases, even if based on the questionable Heinrich assumptions, can be a precious instrument for the prevention of work related accidents. Some databases evolved to include information on the violations of the safety standards, which play a pivotal role for an exhaustive Risk Assessment (in absence of this datum only Attention Indexes can be inferred).

Anyhow, an unbiased understanding of the embedded causes (Root Causes) of the work-related accidents is certainly necessary, to integrate and complete the information from databases, and attain an effective occupational risk prevention. A limited comprehension of the Root Causes laying at the very base of the events chain leading to the accident can in fact involve slapdash remedies, occasional audits, and inspections clearly inadequate to highlight and control the criticalities of complex activities.

Since some years, our research team developed the original CCCP (Computer-aided Cause Consequence for Prevention) technique, based on extensive investigation on the different approaches to the work-related accident analysis. The CCCP technique focuses on the in-depth examination of each accident, and its two-way approach makes possible both a clear understanding of the Chain of Intermediate Events up to the Root Causes, and to verify and compare the expectable effectiveness of possible preventive measures.

The research group tested the CCCP technique and software on a number of work related accidents, analyzed to support Prosecutor Investigations in different ATECO sectors, gaining interesting results, in an analysis environment complete, user friendly and, thanks to its System Approach, immune from errors due to subjective judgments or hasty evaluations. The last pages summarize and discuss the results of the analysis of some accidents.

Keywords: Occupational Safety and Health, Accident computer-aided analysis for Prevention,

1. FOREWORD

The use of the statistical data on work related accidents is derived from the Heinrich (1931) approach, which suggests that prevention can be implemented based on information on the frequency of deviations from a correct working situation: this led to the development of very large databases on injuries and fatalities in many industrialized countries. The Heinrich model is however based on a “Person Approach” (the misconduct of victims or colleagues is the main cause of deviation, in spite of the obvious consideration that they and they only are in direct contact with the Hazard Factor): the resulting accident analysis is often incorrect, and useless for improvements of the safety system. Therefore, the Heinrich model is not free from criticism, both in itself (Reason,2000), and in terms of representativeness of the input data (Manuele,2011), and hence at least obsolete for the modern safety science.

Even so, accident databases can still be of help for prevention: the Attention Index - A.I., focusing the inspector’s attention towards the more common direct causes of the event makes possible effective inspections.

However, some common errors and misuses leading to a biased forecasting of expectable accident rates, and thus to important distortions in the prevention action should be avoided, the most common being:

1. reduced statistical basis (at regional or even smaller scale, without consideration of the local industrial situation),
2. poor analysis of boundary data (e.g. economical and occupational situation),
3. wrong range of time for the aggregation of the accident data, so that exceptional events may come as a surprise. Worst, the lack of information on the violations of Safety

Standards, the consequent impossibility of a direct calculation of the accident Probability of Occurrence, and the misinterpretation of A.I. as a Risk Index lead directly to an incorrect Risk Assessment.

The introduction of a well tested Guideline for an effective and exhaustive Hazard Identification and Occupational Risk Assessment and Management (originally discussed in Faina et al, 1996-97, recently reproposed in Borchiellini et al, 2015) made possible to bypass the problem. The general approach of the Guideline, based on the Expected Frequency of Occurrence Level -which formalizes the concept that only fulfilling up to date OS&H technical standards and regulations can grant a zeroed or minimized risk- is summarized in Figure 1.

A - from the usual definition:

RISK = predictable damage due to the event M × expected frequency of occurrence P

since in the industrial activities not covered by the EC 2012/18/UE Directive, such as in our case, we can write:

$$M = PD \cdot FC$$

where:

PD = seriousness of the possible damage (death, injuries and health impairments, etc..);

FC = interference (or contact factor) is function of the percentile exposure time to potentially hazardous operations or situations compared to the working cycle;

then:

$$RISK = PD \cdot FC \cdot P$$

B - a numerical risk evaluation unbiased by subjective estimation can then be reached, where:

- PD is expressed e.g. in terms of lost days according to Italian standard UNI 7249/2007 (work related accident statistics – injury frequency/severity rates) and Italian law D.M.12/07/2000 (dispositions for worker's disability insurance);
- FC can be estimated in terms of % of the work shift involving the exposure to Hazard Factor;
- P, i.e. the possibility of deviation from the correct work organization/development, can be numerically evaluated in a simplified way (according to the UE suggested approach see Doc.5196/94/PA – Official Journal European Communities – 05/07/94):
  - ✓ the minimum probability of occurrence of hazardous events obviously corresponding to a situation coherent with the progress of the technical safety standards; a simplified and effective approach to the evaluation of P can be based on the use of the *expected frequency of occurrence level*, written as:

$$PR = \frac{\text{expected frequency of occurrence of the event (present situation)}}{\text{minimum expected frequency of occurrence in compliance to up to date safety standards}} \quad \begin{array}{l} \leq 1 \text{ correct situation;} \\ \geq 1 \text{ unacceptable situation} \end{array}$$

  - ✓ the approach provides an adequate evaluation of the possible severity of event's consequences, since in a situation accomplishing to the regulatory requirements there won't be any worsening in consequences due to other flaws (for example in terms of communication, organization of first aid, etc..).

C - to identify the Hazard factors (potentially involving a OH&S Hazard) the following approach is recommended:

⇒ *preliminary general risk analysis and control of site characteristics in terms of intended use, fittings, general support service (fire and accident management, emergency organization, ...), e.g. by means of a Preliminary Hazard Analysis;* ⇒ *identification and management of interferences (e.g. PERT & Functional Volumes Analysis);*	⇒ *safety analysis and control of every working activity (for example through the use of a Job Safety Analysis);* ⇒ *failure analysis and control by means of Hazard Evaluation Techniques (e.g. HazOp, FMEA for one failure or FTA, ETA for multiple failures (Guidelines for hazard evaluation procedures, Center for Chemical Process Safety, American Inst. of Chem. Eng., 2008)*

Figure 1 – Guidelines for Risk Analysis and Management approved by the SCHMOEI EC Commission (1996), extensively and successfully tested in a number of activities of different ATECO sectors.

ü Such an approach presents however some limitations:

ü an apodictic faith in the updated technical safety standards, TLVs, etc. is necessary, the general principles –such as the Commandment thou shalt not kill - being of no technical help;

ü conditions not covered by detailed technical standards cannot be directly treated: this is taken into account in the aforesaid Guidelines, and some analysis techniques are suggested, e.g. in terms of Occupational Volumes techniques to manage the interferences;

ü the management of Residual Risks requires further special analysis covering new materials and substances, technical and organization progress, etc.

On the other hand, the availability of statistical accident databases stimulated attempts of data mining and interpretation, covering different aspects and making possible different results.

Data in general (and work related accident data in our case) consist in fact in the information collected along the investigation process. They are pieces of information either written, spoken, stored or symbolized, that can be used as a basis for making references or inferences, for an in-depth understanding of the chain of causes leading to each event, the final

target being to correctly identify the preventive measures to implement in similar situations.
Data may be numerical or non-numerical:

ü numerical data (e.g. age of the worker involved, years of experience, number of lost days, etc.) consist of values that can be numerically quantified. Data retrieval is then possible in a number of ways (see Figure 2), computers being since many years the simplest means.

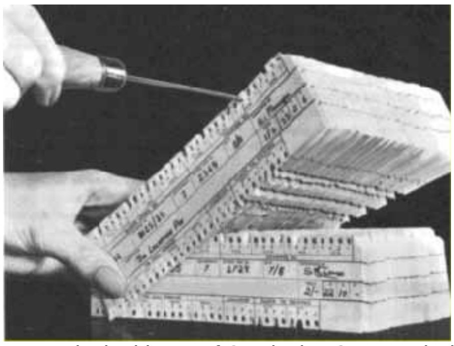


Figure 2 – A step in the history of Cataloging Systems (Jolley,1968).

ü the non-numerical data cannot be directly quantified, the problem being that, while some of the non-numerical data can be easily associated to numerical codes (e.g. sex, damaged body part, etc.), and then treated as numerical data, this is not the case of the Accident Investigation Summaries. Since the reports of investigation contain a large amount of information in the form of textual description, a series of attempts researchers tried to develop retrieval techniques, sometimes with odd results (e.g. from of unchecked use of automatic multiple word search programs). Obviously, the use of keywords can simplify the problem, each of them being subsequently associated to a numerical code, but a large quantity of information is inevitably lost: the full report can be available only in written lines/pages annexed to each form, but not automatically analyzed).

Nowadays, common approaches are based on advanced data mining and processing techniques, and methodologies commonly based on Root Causes Analysis In our experience Root Causes Analysis is effective where well-established working context and procedures are available (e.g. in surgery operating rooms), but often misleading in ordinary industrial situations, since the organizational and technical flaws can be almost completely overlooked.
A research work care of CS&P (Research Center for Culture of Safety and Prevention) of Politecnico di Torino, produced interesting results based on analysis with clustering algorithms, fuzzy logic or statistical learning algorithms inspired by biological neural networks (e.g. Demichela et al, 2007). Thanks to the substantial evolution of some databases (e.g. US DOL OSHA Agency), including information on the violations of the safety standards, in some cases a careful analysis of technological modifications can make available useful correlations (Camisassi et al., 2004, 2006). In this area, the CCCP (Computer-aided Cause Consequence for Prevention) technique, an original evolution from CCA
- Cause-Consequence Analysis (itself a combination of FTA - Fault Tree Analysis & ETA – Event Tree Analysis), represents a result of particular relevance. The CCCP technique is special for the in-depth examination of each single accident and countermeasures identification, and free from problems due to data availability and quality,
In the final release (Table 1,right), after evolution and tests (see e.g. Demichela et al, 2011- Luzzi et al, 2015), the CCCP approach can effectively support the discussed Guideline. It can in fact contribute to correctly understand the preconditions leading to the very Root Causes of work-related accidents -a demanding task in complex situations where the most serious criticalities may be concealed, the Iceberg analogy common to clarify this concept- and in the definition of the preventive countermeasures.
The software structure is of valuable aid, leaving however the analyst always free to make independent decisions, since reduces the possibility of errors due to subjective judgment or hasty evaluation, and the too easy conclusion involving some victim's misbehavior.

2. THE CCCP APPROACH

The CCCP technique focuses on the Root Causes of work related accidents, the target of the analysis being a thorough investigation of the chain of indirect causes, which, in logically connected steps from the Top Event to the Root Causes, produced the accident.

Prevention countermeasures are then sought not only for each cause, but also for combinations of intermediate causes, so that a number of links can be developed correlating the possible indirect causes of the event to the corrective measures. A net of corrective measures is then created, among which it is possible to select some of the cause- intervention connections, to ensure the safety of the whole system.
The Root Causes adopted for the model grant the development of the analysis according to a System Approach.
The peculiarity of the technique is the capacity of modeling the system both in backward sense following a chain of Intermediate Events in order to identify the Root Causes of a Top Event, and in forward sense, starting from the Root Causes, and discussing the most suitable prevention measures. Table 1(right) shows a graphical demonstration: the two arrows depict the backward path of event causes investigation and the forward path of prevention. The construction of the tree is not a linear process, but may imply a number of iterations before reaching a final configuration that adapts to the specific case.
The integrate software environment *Infortuni sul lavoro (Work related accidents)* & *Root Causes* translates the theoretical model into a useful computer guide. All the occurrences are strictly codified to make the analysis objective and free from ambiguity.

- *Infortuni sul lavoro* is structured in 11 sections, covering a large number of different aspects of the context. The order of filling is dynamic and there is always the possibility to add or correct the information previously typed. In addition, the selection of some options can condition the filling and determine the request of a more specific description on the topic;
- *Root Causes,* structured in 8 sections, two of them able to automatically suggest optimized solutions, however modifiable by the analyst, is much more rigid, and the order to fill out the sections is pre-defined. Moreover, the analyst can make choices only among controlled options. These restrictions ensure the total absence of subjectivity, and provide a valuable help to go in deep in the analysis, posing a number of questions and stressing the links between different events.

The codification of options respects as far as possible the ESAW protocol (see Table 2, and Figure 3) and drop down menus are extensively used to avoid the possibility that a single parameter, defined with different descriptors, could not be univocally recognized.
An application on a real case follows, complete with the most clarifying forms, as a demonstration of the compilation process and the output of the model.

Table1 – home screen of the CCCP software (left) and flow chart of the accidents analysis two-way approach (right).

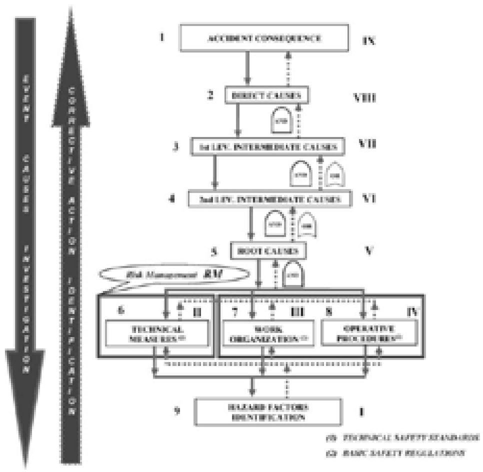


Table 2 – Categories of codification.

Category of events	erences at the origin of elaborated lists	Number of possible associations
Direct Cause	ESAW	1
I level Intermediate Causes	ESAW	More than one
II level Intermediate Causes	Original elaboration	More than one
Root Causes	Original elaboration (Figure 3)	More than one
Macro-categories of Causes	Principles of Risk Assessment & Management	2, also simultaneous

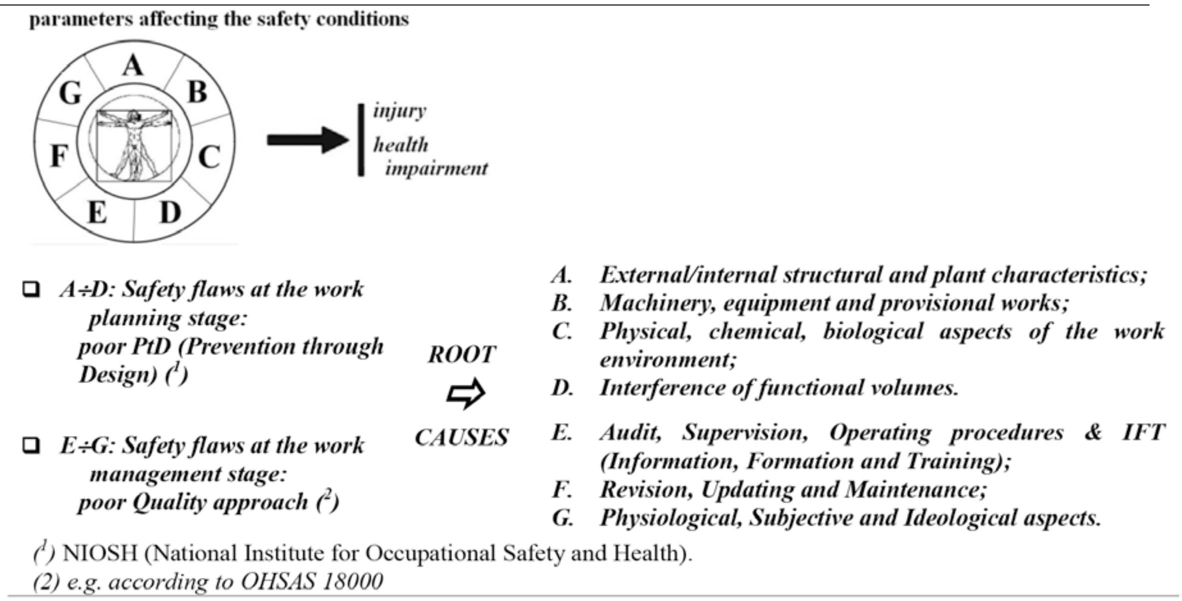


Figure 3 – the classification adopted for the Root Causes.

3. EXTENDED EXAMPLE OF THE CCCP BASED ANALYSIS

3.1. The accident

The accident selected for the extended example occurred during the realization of a tunnel for an hydro plant. During the shotcrete-multiple layers lining phase, a portion of cement detached from the high side of the vault struck the operator causing fatal injuries (see Figure 4).

The analysis made possible both to clarify the circumstances related to the operating situation, and to understand in- deep the chain of causes leading to the event: inadequate techniques and technologies selection, poor work organization and lacking supervision.

In detail, the existing document of Risk Assessment appears to be the result of a precompiled general form, certainty not special for the operation under exam, so that the Hazard Identification Technique used is likely a general-purpose checklist. The evaluation of both Severity of Damage (ED) and Probability of Occurrence (P) are the result of a subjective risk matrix, which neglects the Contact Factor (FC). A window of the CCCP-Infortuni sul lavoro software (see Figure 5) underlines that the evaluation of the risk is **subjective**. Furthermore, the Exposure Model of workers is absent from the Risk Evaluation Document, and the solutions for management of risks cover just a few of processes.

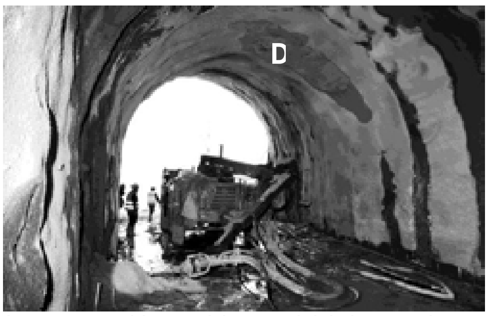


Figure 4 – The area of event: the shotcrete machine and (D, top-right) the area interested by the cement fall.

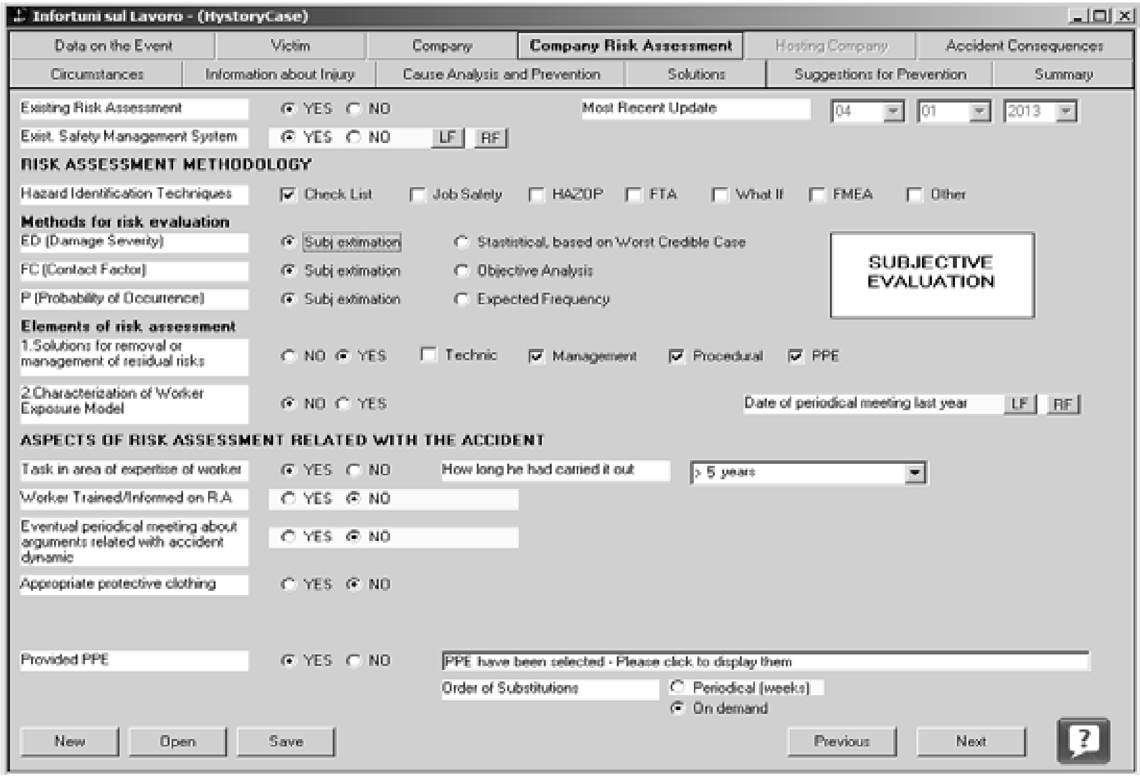


Figure 5 – Risk Analysis window from the CCCP-Infortuni sul Lavoro software. Note: a) in the top lines the 11 sections covering different aspects of the context, and the command Cause Analysis and Prevention, activating the RootCauses subroutine; b) the presence of the LF (load file) and RF (read file) commands, to upload/download extended documents in .pdf format, and make comprehensive information available.

3.2. The accident causes

The compilation of CCCP-Root Causes permits the creation of a cause network, capable to represent complex cases, with multiple correlations. Table 3 summarizes the identified causes:

Table 3 – Causes of the accident

For the falling of the cement block	*For the presence of the worker in the area of impact*
General structural aspects; Machine; Supervision of working operations; Procedures for machine operators.	General systems for environmental conditions control; Machine (again); Functional volumes; Procedures for workers.

In the screen reproduced in Figure 6, the letters represent the existence of AND-Gates or OR-Gates connecting the accident causes (the different condition derive from the input data introduced). The check indications define if the causes ARE or ARE NOT necessary to the occurrence of the event (this leading to the identification of the Minimal Cut Set). This distinction is essential to understand the difference between the possible/essential prevention measures.

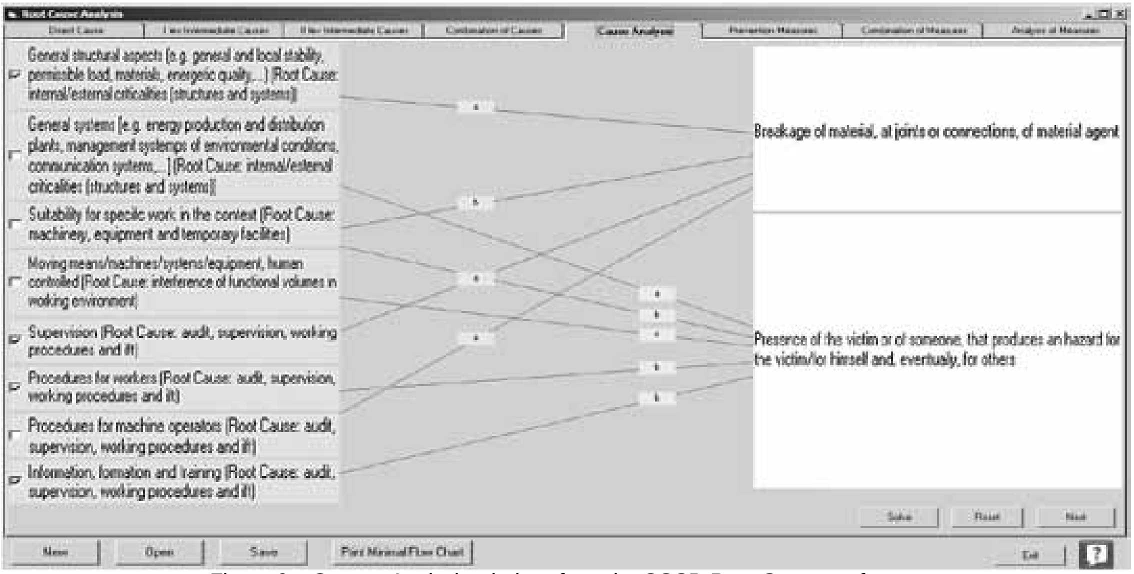


Figure 6 – Causes Analysis window, form the CCCP-Root Causes software.

3.3. Suggestions on the prevention countermeasures

As shown in Figure 7, the CCCP-Root Causes presents the possible prevention solutions in a general form, in line with which the analyst must define, for each case, the implementation issues. These decisions are stored in the software, and with the increase in the number of analyzed cases, consequently increases the number of examples to which to refer.

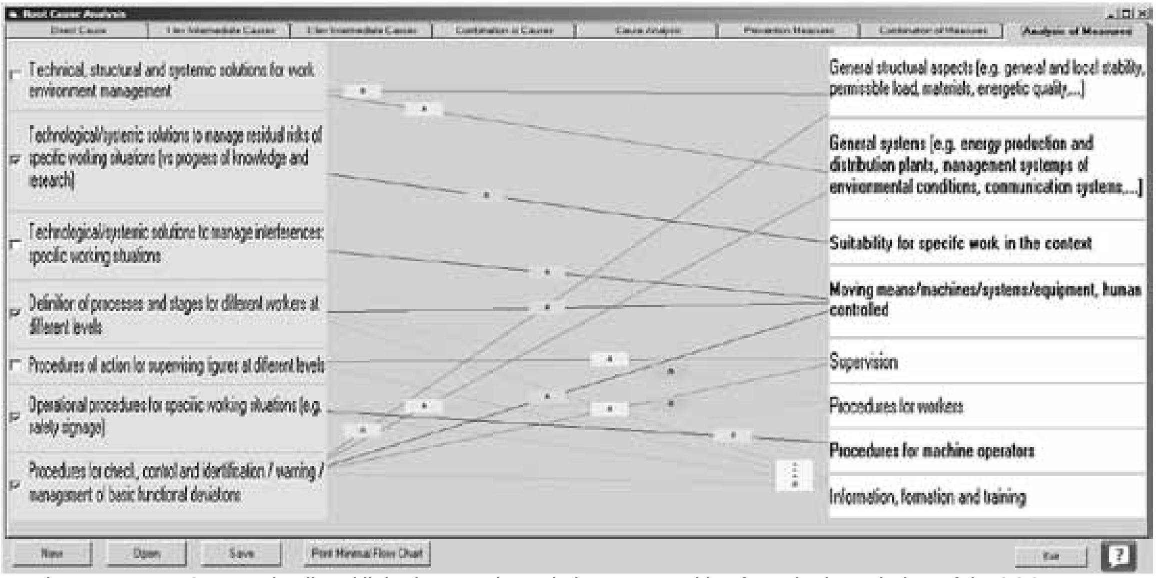


Figure 7 – Root Causes detail and linked preventive solutions, as resulting from the last window of the CCCP-Root Causes software.

The model proposes two different solutions, not mutually exclusive but complementary (see Table 4): on one hand, the minimal cut set is enhanced, and the user can select the minimal solution set suitable to break the chain of events that generated the special accident under exam. In addition, other possible accident causes solved with the same set of measures are enhanced, to underline the convenience in realizing such measures. On the other hand, since the software highlighted all the other Root Causes in the scenario under consideration, it is important not to neglect any of them and to solve them all to make safe the whole system and realize a more complete prevention.

Table 4 – Minimal (left), and Complete (right) Solution Charts.

ACCIDENT CONSEQUENCES *Internal injuries Multiple injuries* ↓ ***DIRECT CAUSE*** *Stucking, trapping, crushing under* ↓ ***I LEVEL INTERMEDIATE CAUSE*** *-Breakage of material, at joints or connection, of material agent* *-Presence of the victim that produces an hazard for himself* ↓ ***MINIMAL SET OF II LEVEL INTERMEDIATE CAUSES*** *-General systems* *-Suitability for specific work in the context* *-Moving means/machines/systems/equipment, human controlled* *-Procedures for machine operators* ***MINIMAL SET OF PREVENTION MEASURES*** *-Technical, structural and systemic solutions for work environment management* *-Technological/systemic solution to manage residual risks of specific working situations* *-Technological/systemic solution to manage interferences: specific working situations* *-Operational procedures for specific working situations* ***FURTHER CAUSES SOLVED BY THE MINIMAL SET OF PREVENTION MEASURES*** *-General structural aspects* *-Procedures for workers* *-Information, formation and training*	***ACCIDENT CONSEQUENCES*** *Internal injuries Multiple injuries* ↓ ***DIRECT CAUSE*** *Stucking, trapping, crushing under* ↓ ***I LEVEL INTERMEDIATE CAUSE*** *-Breakage of material, at joints or connection, of material agent* *-Presence of the victim that produces an hazard for himself* ↓ ***II LEVEL INTERMEDIATE CAUSES*** *-General structural aspects* *-General systems* *-Suitability for specific work in the context* *-Moving means/machines/systems/equipment, human controlled* *-Supervision* *-Procedures for workers* *-Procedures for machine operators* *-Information, formation and training* ***PREVENTION MEASURES*** *-Technological/systemic solution to manage residual risks of specific working situations* *-Definition of processes and stages for different workers at different levels* *-Operational procedures for specific working situations* *-Procedures for check, control and identification/warning/management of basic functional deviations*

4. COMPENDIUM FORMS ON SOME ACCIDENTS ANALYZED WITH THE CCCP TECHNIQUE

Accident # 1

ACTIVITY SECTOR: F43 Construction - Specialized CONSEQUENCE ☐Non Fatal > 30 ld	NOTES: operation carried out with a rented MEWP

gutter collapse

results of the MEPW collapse

The MEWP lost stability due to incorrect operation exceeding the maximum lateral manual force.
The MEWP basis - positioned without preliminary analysis- skidded on cobblestones and got stuck against the building wall.
A progressive deformation of the column on the opposite brick fence reduced the falling velocity of the platform and the operator survived by clinging to an orange tree.

	Accident causes chain		Possible corrective actions	
1		Operator injuries	*Correct use of the safety belt*	IX
2		Platform falling trajectory	*n.a.*	VIII
3		MEWP lose stability and fall beginning, stabilizers stuck against a wall, started the structure deformation	*n.a.*	VII
4		Sudden failure of an element of the gutter	*See I & RM*	VI
5		Incorrect operator behavior, involving lateral forces exceeding the machine stability limits	*Monitoring the effectiveness of the training courses (ex Italian OS&H law DLgs 81/08 art 73 c 5)*	V
RM		Poor risk management	*Resulting from II, III & IV*	RM
	6	Incomplete on board signs - manual not clear and exhaustive	*Careful evaluation of the machine stabilizers positioning vs pavement*	IV
	7	stabilizers Improvised organization: no 2nd operator, no supervision	*Responsibilities definition and supervising*	III
	8	Incorrect work procedures – carelesspositioning of the MEWP	*Revision of the MEWP safety (possible incorrect EC labelling is under*	II
9		Non exhaustive hazard identification leading to poor risk assessment (PR > 1)	*Even if not officially required by the Italian OS&H law, some Risk Analysis and Management of yards involving the MEWPs*	I

Accident # 2	
ACTIVITY SECTOR: C24.10-Steel Production CONSEQUENCE □Fatal - Burns	the overhead traveling crane velocity was increased from 3.5 m/s to 5.2 m/s. NO updated IFT of the operator

tilted ladle area of the spill

effects of the heat wave

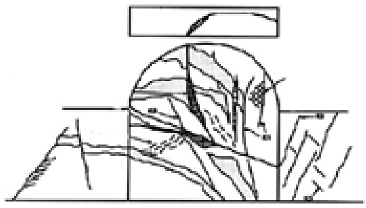
in a steel mill, a modification was introduced to improve the performances of a overhead traveling crane used for the 160 t ladles handling;
the IFT of the crane operator was not updated including the new crane performances;
due to the excessive descent velocity, the ladle interfered with an obstacle, tipped and spilled approx..100 tons of molten steel;
the consequent thermal wave and steel droplets explosion caused impressive consequences and fatal burns to a worker operating in the area.

	Accident causes chain	Possible corrective actions	
1	Fatal burns	*n.a.*	IX
2	Victim reached by the thermal wave from approx. 100 t of spilled steel	*n.a.*	VIII
3	Ladle tilt and molten steel spillage	*n.a.*	VII
4	Excessive velocity in the ladle handling	*n.a.*	VI
5	Modification of the operating parameters of the overhead traveling crane Procedures/organization of work, Operators IFT	*see III*	V
RM	Poor risk management	*Resulting from II, III & IV*	RM
6	Absence of plant tests after the changes	*Revision of the modified plant conformity to the safety standards*	IV
7	Absence of supervision and IFT	*Supervising and IFT even for occasional*	III
8	Operation not analyzed after changes. Absence of communication between operators	*Updated technologies for higher and safer crane performances and ladle handling. Performance and Safety tests on the plant*	II
9	No revision of the Risk Assessment and Management after the crane operating parameters modification	*Devoted Risk Assessment and Management applied to a plant modification proposal*	I

Accident # 3	
ACTIVITY SECTOR: F42-13 Civil Engineering CONSEQUENCE □Fatal - Crushed	NOTES: incompatible contemporary operations

area of the accident

D



rock fracture systems in the area accident area

The worker was manually removing debris at the basis of the right side of the face, and cleaning the lifters with C.A.. The jumbo was still drilling the last holes of the round in the left side of the face. A □1 m^2 rock (D) fell off from the top-right part of the face and stroke him.

	Accident causes chain	Possible corrective actions	
1	intrathoracic injury	*n.a.*	IX
2	struck by falling objects	*n.a.*	VIII
3	falling rock from the tunnel face	*see II*	VII
4	general instability of the face	*systematic inspections of the geologicalcharacteristics at the*	VI
5	Interference of functional volumes. Audit, Supervision, Operating procedures & IFT	*IFT (responsible included!)*	V
RM	poor Risk Management	*Resulting from III & IV*	RM
6	no face reinforcement to improve the local stability	*functional volumes analysis and work scheduling*	IV
7	Careless work organization & inspection	*organization and supervising*	III
8	incorrect procedures, man at work in proximity of the drilling machine	*adoption of face reinforcement techniques*	II
9	Poor Risk Assessment & Management (the local variability of the rock neglected)	*Hazard Identification, with particular reference to the geological conditions, and interference risk*	I

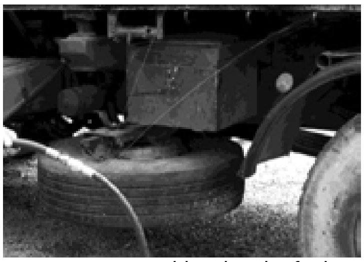
Accident # 4

ACTIVITY SECTOR: 1234-33 Maintenance

CONSEQUENCE Fatal - Head injury

NOTES: The victim worked under temporary contract.

the machine involved into the event



pressure test evidencing the fault in the hydraulic hose of the bucket cylinder

A hose of the hydraulic circuit feeding the bucket jacks started leaking. The operator tried to intervene, and loosened the connection without preliminarily securing the bucket in the higher position. The bucket fell and struck him. No supervisor was present; no instructions handbook on board and the prop provided by the manufacturer had been removed.

Accident causes chain			Possible corrective actions	
1		fatal (head injury)	*n.a.*	IX
2		struck by the falling bucket	*see III, IV*	VIII
3		loosening of the hose connection	*See IV*	VII
4		leakage of the hydraulic hose (machine in very poor general conditions)	*See II*	VI
5		audit, supervision, operating procedures & IFT. revision, updating and maintenance;	*See III, IV*	V
RM		risk management	*resulting from II, III & IV*	RM
	6	poor machine general condition, no instructions handbook on board and the prop provided by the manufacturer had been	*detailed procedures and operator IFT*	IV
	7	no supervision and lack of General Support Services (in particular communication)	*general work organization*	III
	8	work procedures not exhaustive, no specific IFT	*machine maintenance program and records*	II
9		poor Risk Assessment & Management	*Risk Assessment and Management including the equipment conditions and* General Support Services	I

Accident # 5

ACTIVITY SECTOR: 08-12 Sand and Gravel Quarry

CONSEQUENCE Fatal - Drowning

NOTES: poor general maintenance

the truck recovery operations

the couple of collapsed leaf springs

One of the rear right axle leaf springs of the truck got broken in the past, and the problem was not detected. The accident was caused by the collapse of the 2nd leaf in the maximum load condition during the dumping phase. The truck balance was then compromised and the breaking action not sufficient, due to the worn treads of the tires of the 2nd axle. No protection was installed in the dumping area.

Accident causes chain			Possible corrective actions	
1		fatal (drowning)	*n.a.*	IX
2		fall of the truck into a quarry lake	*see II*	VIII
3		collapse of a leaf spring, insufficient breaking action	*see V, VI*	VII
4		undetected broken spring. No protection installed in the dumping area	*truck maintenance program and records*	VI
5		external/internal structural and plant characteristics; machinery, equipment and provisional works;	*do*	V
RM		Risk Management	*Resulting from II, III & IV*	RM
	6	no protection installed in the dumping area	*procedures for dumping operation*	IV
	7	no supervision and lack of General Support Services (in particular communication: researches started with huge delay)	*general coordination and supervision*	III
	8	lacking procedures for the dumping operations poor general IFT	*best: a dozer used for the final dumping minimum: barriers in the dumping area*	II
9		poor Risk Assessment & Management (PR > 1)	*Risk Assessment and Management including the equipment conditions. Employers*	I

5. CONCLUSION

The CCCP approach for in depth analysis of work-related accidents, and prevention countermeasures definition – an original evolution from CCA - Cause-Consequence Analysis (itself a combination of FTA - Fault Tree Analysis & ETA – Event Tree Analysis)- is discussed, together with the related computer assisted system, with the support also of some practical examples.

As demonstrated, the technique can be a valid guide for the analyst, and keep him far from common errors due to subjective judgments or hasty evaluations. However, the Authors heavily stress that the integrate software which translates the theoretical model into a computer guide is not intended as a substitute of the analyst in the decision making .

The software is intuitive and user friendly, thanks to the presence of a number of pre-defined selection options (drawn, where possible, from widely used databases) for many of the involved parameters, and, asides from some input data necessary to run the root causes subroutine, there is large flexibility in the completion of the information to be recorded in the various forms,

Moreover, the user can select the minimal solution set suitable to break the chain of events that generated the special accident under exam, or enlarge the risk management to the whole system, since also other scenario faults then the ones directly leading to the investigated event are brought into evidence.

Finally, the detailed prevention solutions adopted by the analyst for each event are stored, so that with the increase in the number of analyzed cases, consequently increases the number of examples to which to refer.

6. ACKNOWLEDGMENTS

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7. REFERENCES Published papers

Borchiellini, R., Maida, L., Patrucco, M., Pira, E. (2015). Occupational S&H in the case of large public facilities: a specially designed and well tested approach. *Chemical Engineering Transactions*, 43, 2155-2160. doi:10.3303/CET1543360.

Camisassi, A., Cigna, C., Patrucco, M. (2004). Safety at the construction sites: risk analysis and operating conditions of the machineries and lifting equipment (in Italian). *GEAM - Geoingegneria ambientale e mineraria*, XLI, 19-32.

Camisassi, A., Cigna, C., Nava, S., Patrucco, M., Savoca D. (2006). Proceedings from Mine Planning and Equipment Selection (MPES 2006): *Load and haulage machinery: an evaluation of the hazard involved as a basis for an effective risk evaluation*. Torino, IT.

Demichela, M., Murè, S., Piccinini, N. (2006). Assessment of the risk of occupational accidents using a FUZZY approach, *Cognition Technology & Work*, 8, 103-112.

Demichela, M., Monai, L., Patrucco, M. (2011). La analisi approfondita degli eventi infortunistici quale essenziale strumento di prevenzione: un protocollo di indagine post-evento messo a punto a supporto dell'attività degli analisti. In Flaccovio Editor, *Ingegneria forense : metodologie, protocolli, casi studio / N. Augenti, B.M. Chiaia (cur.)* (231-246). Palermo, Italy.

Faina, L., Patrucco, M., Savoca, D. (1996). Proceedings from S.H.C.M.O.E.I. 2006: *Guidelines for risk assessment in Italian mines*, Luxembourg.

Heinrich, H.W. (1931). *Industrial accident prevention*. McGrawHill (Ed.), New York, USA.

Luzzi, R., Passannanti, S., Patrucco, M., (2015). Advanced Technique for the In-Depth Analysis of Occupational Accidents. *Chemical Engineering Transactions,* 43, 1219-1224. doi: 10.3303/CET1543204.

Manuele, F.A. (2011). Dislodging two myths from the practice of safety. *Professional Safety*, 52-61.

Occupational Safety & Health Administration. (2015). *Accident Investigation Search and Reports*. Retrieved from http://www.osha.gov/pls/imis/accidentsearch.html

Reason, J. (2000). *Human error: models and management*. BMJ, 320, 768-770. Jolley, J.L. (1968). *Data Study*. Alberto Mondadori (Ed.), Milan, Italy.

Websites

ESAW. (2013). Retrieved from http://ec.europa.eu/eurostat/documents/3859598/5926181/KS-RA-12-102-EN.PDF. Inail. (2015). Retrieved from http://www.inail.it/internet_web/appmanager/internet/home.

NIOSH. (2015). Retrieved from http://www.cdc.gov/niosh/topics/ptd/.

OHSAS. (2015). Retrieved from http://www.ohsas-18001-occupational-health-and-safety.com/index.htm. OSHA. (2015). Retrieved from https://www.osha.gov/oshstats/index.html.

Occupational Risk Assessment and Management at the highway maintenance yards: suggestions drawn from some experience in Italy

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Abstract

The peculiarity of highway maintenance yards can introduce important OS&H (Occupational Safety and Health) criticalities. Therefore, lacks in Risk Assessment and Management produce a high number of work related accidents, as shown in the national and international accident databases. The Risks minimization requires both a through Risk Assessment and Management, and an efficient Safety inspection activity. Such problems are particularly relevant in Italy, since a number of peculiar parameters makes the Italian highway system subject to frequent and important maintenance interventions often in complex scenarios. The present paper summarizes the results of a systematic research work leading to an original approach to the Risk reduction, based both on innovative prevention solutions, and on the optimization of the Safety inspection activities.

Keywords: Occupational Safety and Health, Highway maintenance yards, Risk Assessment and Management

1. FOREWORD

The Italian Highway System covers more than 6000 km, with 1800 km of tunnels, bridges and viaducts, in continuous increase. This involves the necessity of systematic maintenance and special interventions, in a particularly relevant number of kilometres due to the highly variable Italian climatic conditions, imposing additional wear to structures and materials of large part of the highway net. Additional deterioration factors affect some highways stretches, among them mean altitude a.s.l., and traffic load.

A large number of kilometres of Italian highways are located in mountain areas, where the atmospheric agent actions become relevant, and cause additional stresses on structures and materials.

Moreover, the predominance of freight transportation by motorways and the presence of crucial nodes in the Italian highway network, produce high and intense load of heavy vehicles on the involved stretches with similar consequences. To evaluate the traffic load on the Italian highway system, the Authors gathered information from the Aiscat (Italian Association of Highway and Tunnel Companies) database. The Aiscat data show that in a large part of the Italian highway net circulate hundreds of millions of vehicles per km, most of which heavy vehicles.

Table 1 summarizes the "*total*" and "*heavy vehicles*" traffic rates (number of vehicles per km).

Table1 – Italian highway system Traffic rate (n° of vehicles per km), from the Aiscat 2015 database.

Cumulative data January-March 2015 (millions of vehicles per km)					
Italian highway Stretches (companies)	Total	Heavy vehicles	n highway stretches (companies)	Total	Heavy traffic
Autostrade per l'Italia,	9340.1	2307.4	Centro Padane	215.2	74.5
Traforo Monte Bianco	2.43	0.85	Brescia-Padova	1134	321.2
Traforo S.Bernardo	1.54	0.15	C.A.V.	369.3	95.6
R.A.V.	24.2	6.6	Brennero	959.8	284.2
S.I.T.A.F.	78.3	21.1	Autovie venete	521.3	169.1
S.A.V.	78.8	17.3	Autostrada dei fiori	240.7	63.2
A.TI.VA.	113.2	19.4	Aut.le della Cisa	136.3	41
Asti-Cuneo	29.6	7.1	S.A.L.T.	352.2	79.7
S.A.T.A.P. A 4	511	128.2	S.A.T.	38.7	8.5
S.A.T.A.P. A 21	426	147.7	Strada dei parchi	459.1	63.5
Torino-Savona	177.9	130.9	Tang.le di Napoli	221	18.3
Milano Serravalle-MI.Tang.li	320.9	65.7	Aut. Meridionali	353.3	32.8
Società di progetto BREBEMI	51.9	12.2	Consorzio Aut. Siciliane	330.4	52
Tang.le Esterna di Milano	4.5	1.0	Total	16491.6	4074.2

2. OS&H - OCCUPATIONAL SAFETY AND HEALTH DATA FOR HIGHWAY MAINTENANCE ACTIVITIES

In the highway maintenance operations limited spaces, high power complex and peculiar equipment, haste to complete the work, and some misconducts of the users lead to a significant number of accidents, often characterized by dramatic Severity Rates. The multitude of work-related accidents recorded in the Official Italian database of Inail (National Institute for Work Injury Insurance) confirms the high criticality of this kind of yards. The Inail database made possible the characterization of the most frequent causing deviations.

The following graphs summarize the data on events occurred in Italian highway maintenance yards during six years, from January 2008 until May 2013: information are codified according to the ESAW (European Statistics and Accidents at Work) methodology, and consider the main characteristics of each event, the involved people, and the causes and circumstances.

In the Italian highway maintenance yards occurred, in the considered time span, 5562 non-fatal accidents and 87 fatal accidents (the 1.5% of the total). It is noteworthy that 86% of the fatal accidents are officially classified as "in itinere" (during trips to and from the yard) due to vehicle loss of control, and causing neck, spine, vertebrae traumas; the remaining 14 % is bound with the specific yards activities (Figure 1).

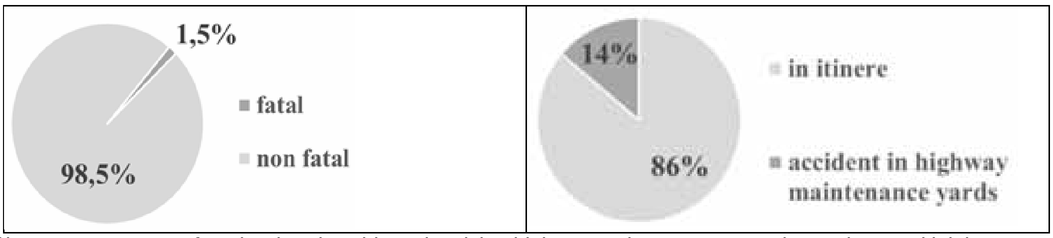


Figure 1 (left) – consequences of work-related accidents involving highway maintenance operations; Figure 1 (right) – relevance of the fatal "in itinere" events.

Figure 2 summarizes the main causes, and some details of non-fatal accidents in the highway maintenance yards.

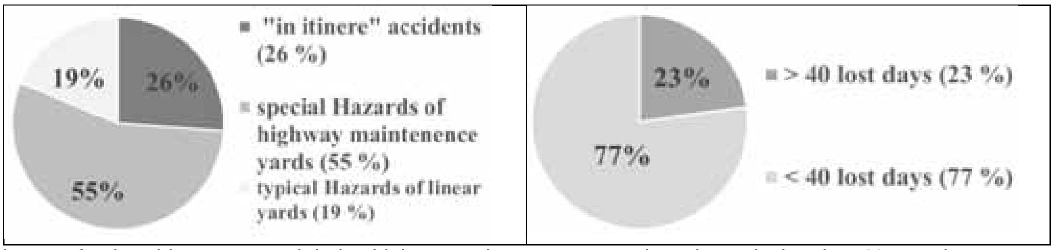


Figure 2 (left) – non-fatal accidents occurred during highway maintenance operations: in particular, the 19% are due to causes typical of similar temporary or mobile construction sites (slipping, tripping, materials and equipment, etc.), whilst the 55% are partly due to the special criticalities of highway yards (limited spaces, high power complex and peculiar equipment, etc.);
Figure 2 (right) – seriousness of non-fatal accidents due to the special criticalities of highway yards.

A comparison between Italian and USA data from 2003 to 2007 (sources OSHA (Occupational Safety and Health Administration), CFOI (Census of Fatal Occupational Injuries)), confirmed the similarity in terms of hazard factors and criticalities of highway maintenance yards: limited spaces, high power complex and peculiar equipment, haste to complete the intervention, etc., even if the USA highway network and maintenance technologies are remarkably different.
According to the OSHA data, workers run over causes 50 % of the fatal accidents in the highway maintenance yards, and it is ascribable to equipment and vehicles belonging directly to the construction firm managing the site (54%), or to other companies involved in the work (46%) (Pegula, 2010).
The Inail database contains no information on the accidents caused by interference between traffic and maintenance sites; according to the OSHA database the run over of maintenance workers due to traffic amounts to approximately 30% of the total.
Due to the importance of this aspect, the Authors also investigated the ISTAT (National Statistical Institute) and ACI (Italian Automobile Association) data, to deepen the violations of the Traffic Laws. The result was impressive: the total number of sanctioned violations in 2013 amounted to more than 900.000 (560.000 due to excessive speed, 35.000 due in general to reckless driving). Even if no direct correlation is at present possible, countermeasures are certainly necessary.

3. RISK ASSESSMENT AND MANAGEMENT IN HIGHWAY MAINTENANCE YARDS

Table 2 summarizes the basic definitions in OS&H (Borchiellini et al., 2015).

Table 2 – basic OS&H definitions

Risk can be defined as the potential of losing something of value: life, health, property or environment can be compromised by a given action, activity or inaction involving a Hazard Factor which can cause the Unwanted Event, and expressed according to the following relationship:

*RISK = M * P (predictable damage M due to the Unwanted Event × expected frequency of occurrence P)*

where:
*M = ED *FC * n*
ED = seriousness of the possible consequence (death, injuries and health impairments, etc...);
FC = interference (Contact Factor): a function of the percentile exposure time to potentially hazardous operations or situations vs the working cycle (common reference 8h/d);
n = number of exposed workers

*RISK = ED * FC * P * n*

Risk Assessment: the evaluation -pivotal to define a correct prioritization of Risk Management- of the levels of risk involved in a situation, due to the associated hazards. Hazard Factors Identification and Exposure Models Definition are therefore of utmost importance.
Risk Management: all the activities which give rise to the elimination or minimization of risks, through *prevention* (i.e. technical, organizational or procedural steps to reduce -and possibly set to zero- the expected frequency of occurrence or the contact factor), or *protection* (general or personal), to mitigate the severity of the possible damage.

An accurate and effective Risk Assessment in complex situations, among them the one under exam, requires a systematic approach, based on a rigorous schematization of the various contexts, scenarios and types of maintenance and improvement yards, to bring into evidence the problems which may be added to those typical of similar temporary or mobile construction sites.
Table 3, drawn for the more common yard typologies, and resulting from a throughout analysis of the Italian highway network, summarizes the main parameters which can directly or indirectly affect and condition the characteristics, the design and the safety of both workers and third parties.

Table 3 – highway maintenance yards classified on the basis of the main parameters which can affect their characteristics, design and safety (in addition to those typical of a similar temporary or mobile construction site)

parameter	typical criticalities	examples
Type and characteristics of the yard	level of urgency, importance, extension, and duration of the activities;	emergency repairs or activities which can planned with no special haste; radical renovations and modifications;
	frequency of occurrence: exceptional / occasional / systematic;	parts maintenance due to accidents; pavement repair/renovation, etc.;
	position and evolution in space: stationary / mobile yards;	localized embankment maintenance; painting of lane markings;
	special yards;	organized to make possible activities not directly related to the normal use of the highway;
“internal” parameters:	unique features of each situation;	in case of emergency repairs, the seasonal conditions can require quite different design approaches even for the same activity;
	available areas and special constraints, possible interference of contemporary activities;	the limited areas usually available can be further reduced, e.g. by overbridges, and interference problems rise in presence of other yards, e.g. for the construction of a junction;
	additional problems;	poor design in terms of maintainability, typical of the less recent stretches; equipment, materials and parts supplying, emergencies management, etc...
“external” parameters	orographic & geomorphological characteristics, mean weather conditions, traffic load in general, and light / heavy traffic "seasonal" changes,..;	different traffic load, steeper stretches, straights and bend radii, windy conditions can introduce criticalities due to both the mean vehicle velocities, and the difference in speed between light and heavy vehicles, and modify both the importance and frequency of the maintenance interventions, and the risk of interference with the yard;
	peculiar site characteristics, such as tunnels, viaducts, etc..	interventions in tunnels can require special ventilation and fittings, criticalities from old linings, etc..

Table 3 brings into clear evidence that every maintenance yard situation, if properly and thoroughly analyzed, presents unique features and safety criticalities, and requires a special PtD (Prevention through Design) approach for an effective Risk Management aimed to the elimination or minimization of the associated risks as suggested by NIOSH (National Institute for Occupational Safety and Health).

The proposed schematization, together with an in deep investigation of the intermediate and Root causes of the occurred accidents, can effectively support the Risk Management phase, and contribute to identify the most suitable design for each special situation. Even if nowadays the analysis of occurred accidents is limited to a general statistical approach, some innovative investigation techniques are available, of some help also in the discussion of the best control measures to interrupt the chain of causes of the event. Table 4 summarizes the results of the analysis of an accident, resulting from the use of the CCCP - (Computer-aided Cause Consequence for Prevention) technique (Luzzi et al., 2015):

Table 4 – Example: accident occurred in 2001, analyzed with the CCCP technique

ACTIVITY SECTOR F42 Construction – Highways, etc.			NOTES: data resulting from Prosecutor Investigation		
CONSEQUENCE → 3 workers involved					
A vehicle run into a maintenance yard where the replacement of a guardrail segment was ongoing (the guardrail was originally damaged due to a collision caused by poor pavement conditions). The event occurred in a rainy day.					
Accident causes chain			Possible corrective measures		
1		*1 fatality and 2 injured workers*	*n.a.*		*IX*
2		*struck by a vehicle out of control*	*see III & IV*		*VIII*
3		*loss of control of the involved vehicle, excessive velocity*	*do*		*VII*
4		*slippery wet pavement in heavy rain*	*see II*		*VI*
5		*poor pavement conditions*	*maintenance and renovation*		*V*
RM		*poor risk management*	*resulting from II, III & IV*		*RM*
	6	*poor pavement conditions, and no special draining materials*	safety lanes, traffic detour, speed limits, yard signage, etc.;	*IV*	
	7	*no* barriers, Truck Mounted Attenuators, etc.	*temporary* collective protection systems,	*III*	
	8	*inadequate signage positioning*	*improvement of the pavement characteristics*	*II*	
9		*non exhaustive hazard identification leading to poor Risk Assessment (PR > 1, according to Regione Piemonte 10303/2007 recommendations)*	*adoption of a Prevention through Approach special for the yard*		*I*

Table 5 summarizes some possible Risk Management actions on the factors that can increase, in the case of highway maintenance yards, the Risk typical of similar temporary or mobile construction sites.

Table 5 – possible Risk Management actions to minimize the peculiar risks of highway maintenance yards

	factor	technical measures	other (organization & procedures)
Internal Risks	ED	emergency solutions special for the context;	special emergency procedures;
	FC	due to the limited areas often available, throughout analysis of the risk of interference and introduction of physical/non physical safety barriers;	introduction of strict work procedures; interruption of work in case of difficult environmental conditions (e.g. poor visibility);
	P	PtD approach special for the operation, including techniques, technologies and equipment selection, etc.;	special inspection and maintenance of equipment and fittings, special supervision and IFT (Information, Formation and Training);
	n	reduction to a minimum of the number of exposed workers, through a mechanization level as high as technically possible;	do;
External Risks	ED	collective protection systems (barriers, Truck Mounted Attenuators,…);	speed limits;
	FC	scheduling of the highway maintenance activities to minimize the need of interventions in critical traffic or weather conditions;	special organization of activities, shifts and trips to and from the yard;
	P	minimization of the number of highway maintenance interventions, through improved design choices and adoption of innovative materials and techniques;	safety lanes, traffic detour, speed limits, yard signage coherent with the general provisions of D.I. 04/03/2013, etc.;
	n	as suggested for the internal risk management;	as suggested for the internal risk management.

4. SOME RESULTS OF THE RESEARCH WORK

Two main topics may condition the safety of both workers and third parties, in general and more so in the case of particularly risky and complex activities:

a) The adoption of a PtD approach, which should consider both Safe Work Organization, and the Maximum Safety Technologically Achievable criteria, in coherence with the provisions of law (89/391 EEC Directive, enforced in Italy by D.Lgs.81/08), where we can read: "*Art.6. General Obligations on employers, c.2. The employer shall implement the measures referred to in the first subparagraph of paragraph 1 (necessary for the safety and health protection of workers, including prevention of occupational risks and provision of information and training, as well as provision of the necessary organization and means) on the basis of the following general principles of prevention: … (e) adapting to technical progress*". The 92/57/EEC Directive special for Temporary or mobile construction sites, also included in the Italian Dlgs.81/08, reiterates and details these concepts, and sets this task to the 'Coordinator for safety and health matters at the project preparations stage'). These criteria should then be applied both to operations developed in the maintenance yard, and, from a more general point of view, to the context in which the maintenance site is located. Asides from the well known guidelines and good practices for the "normal" linear yard safety, and taken into account the contents of Table 5, the following pages will discuss some examples of possible technological improvements on the safety of the stretch and of the yard, which already proved effective abroad and are finding growing use also in the Italian highways (EU Commission under the transport RTD programme, 1998).

b) The minimized Risk level achieved for the system should be preserved and improved along the time, nowadays in accordance to quality principia (e.g. according to OHSAS 18000). The aforementioned 92/57/EEC Directive sets this task to the 'Coordinator for safety and health matters at the project execution stage'. In our case, because of the number and complexity of the various different maintenance sites, the task of the Coordinator becomes very challenging, since he should deal with both the aspects that require high expertise and capacity of judgment, and those of mere routine.
We will discuss below an original and well-tested approach for Safety Analysis, periodic audits and inspections, aimed to optimize the work of the expert evaluator, and to increase the safety of workers and third parties.

4.1 Examples of new technologies to support the safety of highway and of the maintenance yard workers

4.1.1. Innovative materials and laying technologies for the highway pavement

A number of innovative materials and laying technologies for the highway pavements are nowadays available, this being a promising theme for study and applied research and development on bituminous binders, aggregates, additives and related products. The main targets are technical and economic efficiency, pavement duration, and environmental issues (Nösler, 2008).

Fiber or steel-net reinforced pavements, flexible and high resistance pavements in Polymermodified Binders, and other solutions can in some cases already provide important benefits in terms of resistance to stresses induced by heavy vehicles, cracking and cracks propagation, together with excellent surface characteristics, improved adherence, reduced aquaplaning or splash & spray phenomena and degradation by deicing, and good soundproofing.

The use of such materials and technologies for new highway stretches, or to replace the currently existing ones, can enhance the system availability, and then directly reduce the number of necessary repair/renovation interventions, i.e. the need of maintenance yards. Hence, the FC value decreases, thanks to the increase of
M.T.B.F. (Mean Time Between failures), the latter being the result of the sum of M.T.T.F. (Mean Time To Failure) + M.T.T.R. (Mean Time To Repair).

Obviously, a preliminary risk analysis is essential, to define the expectable M.T.T.R. value, and make sure not to have introduced new hazard factors for the maintenance yard workers.

4.1.2. Technical improvements for the management of possible distributed traffic □yard interferences

In case of mobile linear yards, the usual segregation of the working areas from the traffic, based on Jersey barriers, involves that the progressive modification of the yard area makes also necessary the modification of the barriers layout.

The traditional procedure (Figure 3 left) implies that the yard workers manually unfasten each module of the barrier, lift it up and move it to the new position by means of a crane; finally, it is necessary to reconnect the module to the already moved barrier. Workers and equipment operate in immediate proximity of the regular traffic; as sole safety means, signs, flagman and light signals are introduced to draw the attention of the highway users.

Hence, this operation is one of the most critical for the safety of the highway maintenance yards.

The adoption of the mechanized "Barrier Zipper" technique for Jersey barrier transfer (Rathbone, 2000). makes possible a significant Risk reduction for both workers and users, see Figure 3 right, and Table 6 which summarizes the results of a PHA (Preliminary Hazard Analysis) applied to the traditional and "Barrier Zipper" transfer techniques.

Figure 3 (left) – barrier transfer: traditional procedure; Figure 3 (right) – mechanized "Barrier Zipper" technique.

Table 6 – Extract of a Preliminary Hazard Analysis on barrier movement activity

Hazard	Cause (1)	Risk reduction achieved with the "Barrier Zipper" technique	Note
workers and flagmen run over by vehicles unrelated to the yard;	regular traffic in proximity of the working areas;	limited exposure of the workers;	during the barrier tranfer with the "Barrier Zipper" technique, no workers operate in unprotected areas;
yard equipment struck by vehicles unrelated to the yard;	unprotected yard equipment and vehicles during the barrier tranfer;	minimization of unprotected yard equipment and vehicles;	the Barrier Transfer Machine is the sole machine necessary, and operates safeguarded by the barrier already tranferred;
crushing;	handling of heavy loads;	hightly mechanized activity carried out from cabin and safe areas;	the "Barrier Zipper" technique does not imply manual operations such as unfastening/fastening of each module;
……	…………	…………	………….

(1) some parameters typical of the Italian highway scenarios can further increase the Risk for both yard workers and users.

The Risk reduction possible through the adoption of the described solution results from:

- the reduction of P, thanks to the continuous barrier covering the whole length of the yard. The safety of drivers is also increased, thanks to the clarity of the situation;
- the reduction of F, since the yard workers operate exclusively from the safe side of the barrier;
- the reduction of n, thanks to the mechanization of the system.

4.1.3. Technical improvements for the management of possible localized traffic yard interferences

In case of stationary maintenance yards of limited extension and duration, where no Jersey barriers are present, the protection of the yard from the hazard of vehicles irruption is possible by the positioning of obstacles of adequate size and mass (usually some heavy equipment or trucks). Obviously, such an improvised approach, even if somehow effective to the purpose, can dramatically worsen the seriousness of the consequences for the driver of the impacting vehicle.

Some Truck Mounted Attenuator (TMA) devices are presently available, specially designed to improve the yard protection and reduce the collateral damages. Figure 4 shows the basic idea: to increase progressively the resistance to the impacting vehicle momentum, and to handle as well as possible the direction of impact, preventing rebounds or uncontrolled deviations.

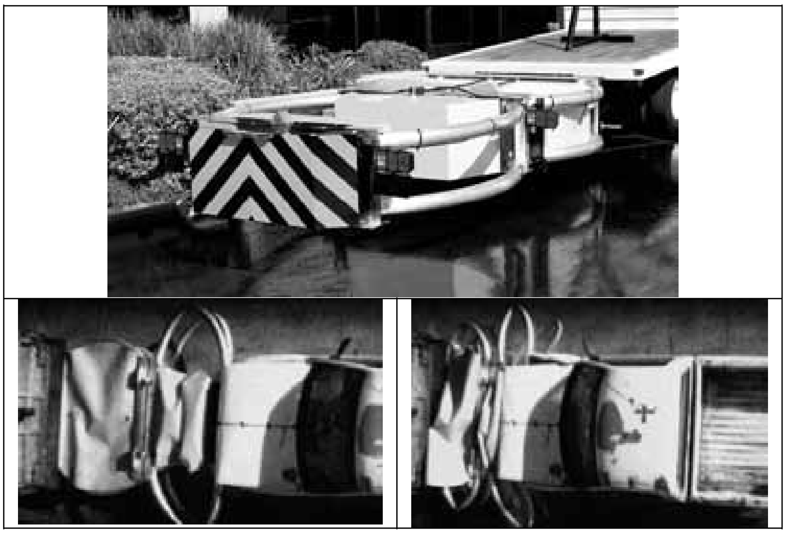


Figure 4 – Truck mounted attenuator, and crash test results.

Granted that, in this case also, the discussed measures signaling the yard are necessary, the Risk reduction possible through the adoption of the described solution results from the reduction of F, since the possibility of irruption of vehicles out of control into the working area is limited; asides, the safety of drivers is somehow increased.

4.2. Original approach to system organization, proposed to support the activity of the ‘Coordinator for safety and health matters at the project execution stage’

According to the aforementioned EEC Directives, the minimized Risk level achieved for the system should be preserved, and improved along the time.

In particular, the ‘Coordinator for safety and health matters at the project execution stage’ is charged of the tasks listed below (92/57/EEC Directive, Article 6), the main reference for his activity being the Safety and Health Plan (drawn by the 'Coordinator for safety and health matters at the project preparations stage').

Project execution stage: duties of coordinators

The coordinator(s) for safety and health matters during the project execution stage appointed in accordance with Article 3 (1) shall:

(a) coordinate implementation of the general principles of prevention and safety:
- *when technical and/or organizational aspects are being decided, in order to plan the various items or stages of work which are to take place simultaneously or in succession,*
- *when estimating the period required for completing such work or work stages;*

(b) coordinate implementation of the relevant provisions in order to ensure that employers and, if necessary for the protection of workers, self-employed persons:
- *apply the principles referred to in Article 8 in a consistent manner,*
- *where required, follow the safety and health plan referred to in Article 5 (b);*

(c) make, or cause to be made, any adjustments required to the safety and health plan referred to in Article 5 (b) and the file referred to in Article 5 (c) to take account of the progress of the work and any changes which have occurred;

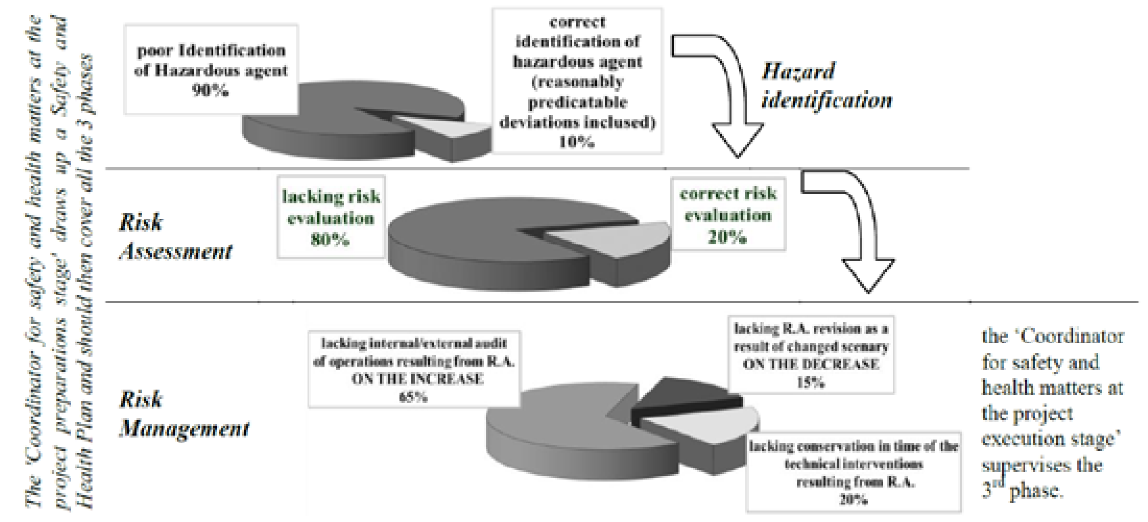
(d) organize cooperation between employers, including successive employers on the same site, coordination of their activities with a view to protecting workers and preventing accidents and occupational health hazards and reciprocal information as provided for in Article 6 (4) of Directive 89/391/EEC, ensuring that self-employed persons are brought into this process where necessary;

(e) coordinate arrangements to check that the working procedures are being implemented correclty;

(f) take the steps necessary to ensure that only authorized person are allowed onto the construction site.

Taken into account the typical situation of a large number of construction activities summarized in Table 7 (Patrucco, 2008), the ‘coordinator for safety and health matters at the project execution stage’ should devote special care in the supervising of the 3rd phase (Risk Management).

Table 7 – safety experts and their demanding tasks. The linked pie charts summarize the errors in the Risk Assessment and Management process causing accidents (as resulting from Prosecutor investigations).



In particular, the 'Coordinator for safety and health matters at the project execution stage' should evaluate the Safety documentation drawn by the employers and, if necessary, ask for amendments (the responsibility of the employers remains in any case unaffected, as provided for in Directive 89/391/EEC).

This also is somehow frustrating, since, as shown in Figure 5, only in a limited number of cases the situation results directly acceptable.

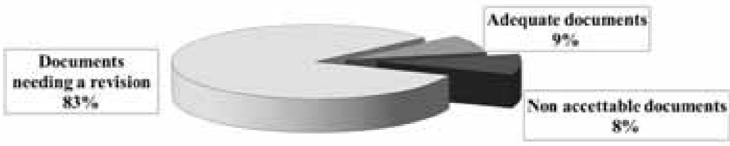


Figure 5 – Results from a statistical analysis on the congruence between the Safety and Health Plan and the Safety documentation drawn by the employers, in a number of real cases.

Where we consider the tasks of the 'Coordinator for safety and health matters at the project execution stage' in terms of supervising the activities at the yard -an essential step to grant real OS&H- it is usually possible to make a distinction between:

ü an at depth level supervision, involving an accurate and critical appraisal of the general yard layout and organization, safety solutions for normal operating conditions and emergency situations, cooperation between employers if necessary, equipment selection and their safety characteristics included, crew composition and adequacy, etc. essential to investigate and control the hidden criticalities, if any;

ü an elementary level supervision, aimed to verify the evidences in terms of compliance of the site, equipment and fittings characteristics, and workers behavior with both the dictates of the law, and the provisions of the Safety and Health Plan. It should be emphasized that, apart their intrinsic importance, the evident criticalities can be symptomatic of not immediately identifiable OS&H problems.

  In our case, because of the number and complexity of the various different highway maintenance sites, the task of the Coordinator becomes very challenging, as he should deal with the aspects that require both high expertise and competent judgment, and those of mere routine.Moreover, practical experience confirms that the elementary level inspections must be frequent, to promote the attention to OS&H of personnel with various qualifications working in the yard, while at depth inspections can be sparser, but thoroughly cover the critical operations.

  The original and well-tested approach for Safety analysis, periodic audits and inspections, aimed to optimize the work of the Coordinator (the expert evaluator), and to increase the safety of workers and third parties, expects that the expert evaluator:

ü carries out personally the in-depth preliminary analysis, and the on-site inspections when necessary, and organizes, coordinates and discusses the activities of Fellow evaluators, who access the yard frequently, as shown in the following Table 8;

Table 8 – tasks and typology of evaluators

Fellow evaluator

ü *verifies the bureaucratic aspects of contractual regularity and safety;*
ü *can tell and annotate the evident non-conformities to the OS&H regulations and good practices.*

Expert evaluator

ü *examines and verifies the congruence between the Safety and Health Plan and the Safety Documentation drawn by the employers;*
ü *makes, or causes to be made, any adjustments required to the Safety and Health Plan;*
ü *supervises to activities particularly critical for OS&H.*

ü makes available -to support the work of the Fellow evaluators- adequate data collection forms, and evaluation indexes for "weighing" situations and behaviors complying/not complying with the basic OS&H regulations and good practices (see Figure 6)

Yard data (address, ...)			Date and time of the inspection		
EXTERNAL CRITICALITIES MANAGEMENT	CORRECT	TOT	INCORRECT	TOT	Safety Index (%)
Working habits		10		2	83
PPE		9		1	90
Signage		8		1	89
Protection from regular traffic		7		0	100
Tidiness and waste elimination		5		1	83
INTERNAL CRITICALITIES MANAGEMENT	CORRECT	TOT	INCORRECT	TOT	Safety Index (%)
Working habits		11		1	92
PPE		8		0	100
Signage		9		2	82
Protection against falls from a height		8		6	57
Machinery and equipment		6		1	86
Working area protection		7		2	78
Tidiness and waste elimination		3		0	100
TOTAL OBSERVATIONS	CORRECT	100	INCORRECT	18	Yard Safety Index (%)
SAFETY INDEX	$\frac{\text{correct observations}}{\text{correct observations} + \text{incorrect observations}} \times 100$				85

Figure 6 – example of Safety Index Datasheet, completed by a Fellow evaluator.

The Safety Index adopted is an evolution of what suggested by Laitinen (Laitinen H. et al, 1998, 2002) and it is expressed as follows:

$$Safety\ Index = \frac{\#\ observed\ compliances}{\#\ observed\ compliances\ +\ \#\ observed\ NON\ compliances} * 100$$

The Safety Index can be directly calculated as a weighted average of the results of all the observations made in the yard in relation to the different deviation scenarios under observation, or, as we also tested, subject to corrective coefficients ascribed to the various deviation scenarios, as a function of the statistical frequency and / or the severity of the consequences;

ü completes the evaluation of all the gathered information, so that an exhaustive and structured rating on the OS&H of the yard remains to acts, for the adoption of possible improvements of OS&H, and, if it is the case, to support the client on measures to be taken against the employers (Figure 7);

DATE:	TIME:	
EVALUATOR		
YARD ADDRESS		
DIRECT OBSERVATIONS		
CONFIRM OF THE WORKING PHASE AT THE INSPECTION DATE		
CONFIRM OF THE LIST OF THE COMPANY INVOLVED		
CONFIRM OF THE PROFESSIONALS INVOLVED		
CONFIRM OF THE LIST OF THE MACHINERY INVOLVED		
CONFIRM OF THE PRESENT FIGURES WITH OS&H TASKS		
EXPERT EVALUATOR COHERENCE BETWEEN THE ACTIVITIES AND THE OSP DISPOSALS	YES/NO (Evaluation on the yard management in the enclosed)	
FELLOW EVALUATOR SAFETY INDEX	TOTAL OF THE CORRECT OBSERVATIONS	
	TOTAL OF THE INCORRECT OBSERVATIONS	
	SAFETY INDEX $\frac{correct\ observations}{correct\ observations+incorrect\ observations} \times 100$	

Figure 7 – Compendium sheet completed by the expert evaluator, containing his direct observations, and the results of the activities of the Fellow evaluators.

The suggested approach represents then an effective tool for:
ü through inspections of OS&H at highway maintenance yards;
ü improving the general yard OS&H conditions;
ü widespread dissemination of the safety culture at all levels, Fellow evaluators included;
ü the OS&H management in a sound quality approach.

Thanks to its simple structure, and to the interlinked card logical sequence, the proposed approach can be supported by Computer Assisted techniques. A test software proved to be of good help for the completeness of the data and observation sheets, the calculation of the Safety Index, and for both the creation of an OS&H database for each maintenance yard, and for the different yard typologies as previously classified.

5. CONCLUSION

The peculiarity of the highway maintenance yards requires a special Risk Assessment and Management, and efficient Safety inspection activity, particularly relevant in the case of Italian scenarios, whose peculiar characteristics somehow increase the common yard Risks.

The research work made available some interesting results:

a) a through categorization of the different maintenance yards, of pivotal importance to define the different scenarios and identify the most suitable safety measures to be adopted in each situation;
b) a critical review and some practical examples of innovative techniques and technologies currently available, and of their possible effects on the total system efficiency (safety included);
c) the discussion on an original and well-tested approach for Safety analysis, periodic audits and inspections, aimed to optimize the results of the work of the ‘Coordinator for safety and health matters at the project execution stage’.

More generally, the research work confirmed that at least in complex situations, among them the highway maintenance yards, the Risk Assessment and Management must be absolutely specific, each situation requiring special Prevention through Design and Quality Management approaches. Moreover, the dissemination of the "Culture of Safety" can play a key role in the reduction of risks of workers and third parties.

6. REFERENCES

Published papers

Borchiellini, R., Maida, L., Patrucco, M., Pira, E. (2015). Occupational S&H in the case of large public facilities: a specially designed and well tested approach. *Chemical Engineering Transactions*, 43, 2155-2160. doi:10.3303/CET1543360.

Laitinen, H., Kiurula, M., (2002). *TR Safety supervision on the building site, Finnish Institute of Occupational Health*. Finnish Institute of Occupational Health.

Laitinen, H., Marjamaky, M., Paivarinta, K., (1998). The validity of the TR safety observation method on building construction. *Accident Analysis & Prevention,* 31, 463-472. doi: 10.1016/S0001-4575(98)00084-0.

Luzzi, R., Passannanti, S., Patrucco, M., (2015). Advanced Technique for the In-Depth Analysis of Occupational Accidents. *Chemical Engineering Transactions,* 43, 1219-1224. doi: 10.3303/CET1543204.

Patrucco, M., (2008) Report of research activity on OS&H. TEMPUS Project - JEP 41045 – 2006 “Training for Occupational Safety and Health Improvement (TOSHI)”, 09 October 2008, Ministry of Industry, Belgrade, Serbia. Nösler, I., (2008). Modifizierte Spezialbitumen für leistungsoptimierte Asphaltbeläge: *Internationale Verkehrstage*

Modifizierte Bindemittel/Asphalte. Wuppertal. DE.

Pegula, S., (2010). Fatal occupational injuries at road construction sites, 2003–07. *Workplace Safety and Health*.

Retrieved from http://www.bls.gov/opub/mlr/2010/11/art3full.pdf.

Rathbone, D.B., (2000). Movable barriers for high-traffic work: safety on the highway. *Public Work magazines*, 131(2), 28-30.

Websites

ACI. (2015). Retrieved from http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche.html.

Aiscat. (2015). Retrieved from http://www.aiscat.it/pubblicazioni.htm?ck=1&nome=pubblicazioni&idl=4. CFOI. (2015). Retrieved from http://www.bls.gov/iif/oshcfoi1.htm.

ESAW. (2013). Retrieved from http://ec.europa.eu/eurostat/documents/3859598/5926181/KS-RA-12-102-EN.PDF. Inail. (2015). Retrieved from http://www.inail.it/internet_web/appmanager/internet/home.

ISTAT. (2015). Retrieved from http://www.istat.it/it/archivio/137546. NIOSH. (2014). Retrieved from http://www.cdc.gov/niosh/topics/ptd/.

OHSAS. (2015). Retrieved from http://www.ohsas-18001-occupational-health-and-safety.com/index.htm. OSHA. (2015). Retrieved from https://www.osha.gov/oshstats/index.html.

Quoted European and Italian regulations

Council Directive 89/391/EEC. (1989). *"Framework Directive" on the introduction of measures to encourage improvements in the safety and health of workers at work* (Official Journal of the European Communities, L 391 December 89).

Council Directive 92/57/EEC. (1992*). Implementation of minimum safety and health requirements at temporary or mobile construction sites* (Official Journal of the European Communities, L, 245, August 1992).

D.Lgs. 81/08. (2008). *Testo unico sulla salute e sicurezza sul lavoro* (G.Uff. n.101, 30 aprile 2008 - S.O.n.108).

D.I. 4 Marzo 2013. (2013). *Segnaletica stradale per attività lavorative svolte in presenza di traffico veicolare* (G.Uff. n.67, 20 marzo 2013).

What we talk about when we talk about HSE culture – Turtles all the way down

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Abstract

This paper is an extensive review of 235 journal papers addressing HSE culture published between 1992 until 2014. The review was conducted in order to analyse the historical development of the concept of HSE culture. The research is related to our previous work regarding the use of the concept of "culture" in accident investigations, and is focusing on the spread of the term "HSE culture" and its coresponding meaning within the community of safety research.

The review of the journal papers has been supported by a statistical analysis of data obtained by a structured and systematic registration of information from the 235 journal articles in order to analyse the development in the distribution of term "culture" in texts addressing "HSE" within the community of HSE researchers, and the function and meaning of the term "culture".

The analysis has been twofold. Firstly, we have analysed the spread of the term "HSE culture". Then we have looked at the variation in what the term signifies, i.e. how the term is defined and used in the articles. The methods used in the statistical analysis has been frequency, table and correspondence analysis. The use of correspondence analysis makes it possible to "correlate" categorical data. The result of the statistical analysis were then interpreted. In the interpretation, we have applied a semiotic perspective, focusing on the distinction between signs (form) and the signified (meaning).

Among our findings is that there is a correspondence between the profession of the writers and how "culture" is defined and/or used in the texts. Psychologist and engineers tend to treat culture as one factor among others, which influence human behaviour, whereas anthropologist tends to use culture as a metaphor to signify the holism of an organisation.

More than 70 % of the articles using the term "HSE culture" are only addressing safety. Further, almost 30 % of the articles are reviews of other articles, and 23 % of the papers use survey data. Almost half of the most cited papers (more than 100 citations) are reviews of other papers.

Keywords: culture; HSE; diffusion of terms; communication; learning

1. INTRODUCTION

The history of the concept of culture, or more precisely the concept of "safety culture" have been told and retold in several publications addressing "safety culture" or "HSE culture" within the community of safety researchers. Common traits in these stories seems to be that (a) safety culture is a concept that can be traced back to the accident investigation performed by the International Atomic Energy Agency in the aftermath of the Chernobyl accident, that there (b) is a lot of confusions and disagreement regarding how the concept should be defined, and that (c) further research on safety culture has to be conducted.

In order to map the articles, we have answered the following research questions:

Theme 1:
The development in the distribution of term "culture" in text addressing "HSE" within the community of HSE researchers.

1. Who writes about HSE and culture? (professions , nationalities, industries)
2. Has the popularity of culture changed over time within the community of HSE research? [time]
3. What is the most quoted core references?
4. Who are the most quoted core references in the papers that are most frequent used as core references?

5. Which methods have been used in studying “HSE culture”?
o What is the extent of empirical studies on “HSE culture”?
6. Is there any correspondence between branch of industries and the year of publication?
7. Is there any correspondence between core references and professions?
8. Is there any correspondence between core references and industries?

Theme 2:
The function and meaning of culture
1. Are the texts addressing health, safety and/or environment?
2. Are the texts normative or descriptive?
3. Are there any coherence between normative or descriptive texts and the distribution of text addressing culture?
4. What does “culture” denote? [type of definitions]
5. Is there any coherence [eller association] between the definitions of culture and the distribution of text addressing culture?
a. Is there any correspondence between the profession of the writers and the definition/use of HSE culture?
b. Is there any correspondence between the branch of industry addressed and the definition/use of HSE culture?
6. Is there any correspondence between the nationality of the writers and the definition/use of HSE culture?

The ambition of this research is to scrutinize the history of the use of “culture” within the community of H, S and E researchers. This has been done in order to discuss the function of “culture” within the community of HSE researchers, and to discuss the validity of the concept in order to understand and explain phenomena relevant for HSE issues. Due to limitations in paper length combined with the comprehensive amount of data, this paper first and foremost presents some descriptive results findings and core characteristics of the dataset in addition to central questions derrived from these findings. These are the basis of which further analysis on the discourse of the H, S and E research community is based.

Therefore, the paper is structured as follows: section 2 presents research methods, sections 3, descriptive data results, and section 4 conclusions.

2. MATERIALS AND METHOD

2.1. Materials and Methods
We have applied a semiotic approach in this study. This implies that we try to elucidate the difference between sign, reference and meaning, relying on the theoretical assumption that the relation between the sign (form) and the signified (meaning) is arbitrary Saussure (1974), following techniques presented by Bernard (2011). We started out by analysing the actual use of the sign “culture” in text written by and for researchers working on health, safety and environment. This means that we have identified academic publications where the sign “culture” have been used with “HSE” in recognized journals, which then has been collected, analysed and categorized against a refined codebook.

2.2. Sampling/Corpus of texts
The sample of journal papers have been obtained by using the search engines Science Direct, Google scholar, and the combination of the signs “culture” and “HSE” as keyword. In other words, we have identified only those papers that use both the sign “culture” and “HSE”. We have excluded some of the more obscure and obviously irrelevant results, but as we have been interested in what kinds of arguments and kinds of discussions that are allowed and are flowing within the discourse of HSE culture, we have retained most articles in the corpus of texts.

2.3. Coding information into variables
A set of variables was defined and constructed in order to obtain coded information from the articles, making it possible to conduct statistical analysis. The majority of the variables were categorical, but some were string variables that could be transformed into categorical variables after the information had been obtained. A few variables, such the year since publication and times used as reference, were interval variables.

Some of the information was rather easy to code into variables, such as, e.g. name of the journal, nationality and profession of the authors, methods used and the industry studied. Coding information regarding how the term “culture” was used in the text was more challenging. Several variables based on different taxonomies of culture were applied in this coding process.

The coding of the journal articles was conducted by a team of researchers. A test coding was performed in order to ensure consistency in coding and as high accuracy as possible, between different researchers. The reliability of the data regarding variables i.e. name of authors, year of publication, journal, author discipline, nationality of the authors, number of references, branch of industries, region of the world, methods applied and the formal definition of “culture” are considered as high. The reliability of the data related to the variables regarding the meaning of the term “HSE culture” is weaker due to the lack of accuracy between different researchers .

2.4. Statistical analysis

2.4.1. Descriptive statistics

Descriptive statistics represented as frequency and contingency tables has been developed in order to inspect the distribution of the data. These analyses gave us information about the authors of the text concerning e.g. their profession, nationality, geographic area of the research, number of references, definitions of culture etc.

2.4.2. Correspondence analysis

Factor analysis of simple correspondence analysis was conducted in order to identify possible relations between categories of two discrete variables. The advantage with a correspondence analysis is that is especially suited for analysis of large contingency tables with many categories (Clausen 1998). Checking for relationship can be done by performing e.g. test of Chi-square, which in fact is the first step in correspondence analysis. In addition, the correspondence analysis provided additional information to what degree the different values of the variables contribute to the relationship. This means that we can use the method to reveal if there is an association between e.g. specific professions and the use of specific main references, the time period when the paper was published, and geographical area of the study etc.

3. RESULTS AND DISCUSSION

3.1. Descriptive data

As this paper presents descriptive data, results are organized as follows; 1) author origin, 2) development in the usage of the concepts of culture and HSE between 1993.2013, 3) Referencing, 4) methods used, 5) understandings of HSE, 6) understandings of culture, and finally 7) understandings of HSE culture.

3.1.1. Author origins

One obviously important factor in the different ways authors understand and use the concepts of culture and HSE, is the originated contexts they write on the basis of. The fields of HSE (and especially the that of the S) are multidisciplinary and as we show in Bye, Rosness and Røyrvik (2015), the concept of culture can have different referents, and holds different accentuation in the various contexts. Thus it is of interest to describe the origin of the authors both in terms of geographical, professional and industrial contexts.

The largest category of the authors (33 %) are technologist, holding different engineering degrees (chemical engineers, construction engineers etc.). It is reasonable to assume that a portion of risk analysis and management specialist (8 %), and the safety advisors (6 %), also have a technological background. Psychologist counts for 22 % of the papers. About 10 % of the papers have different types of social scientist as corresponding author. This numbers does not take into account that the majority of the papers involves several authors, probably with different professional backgrounds.

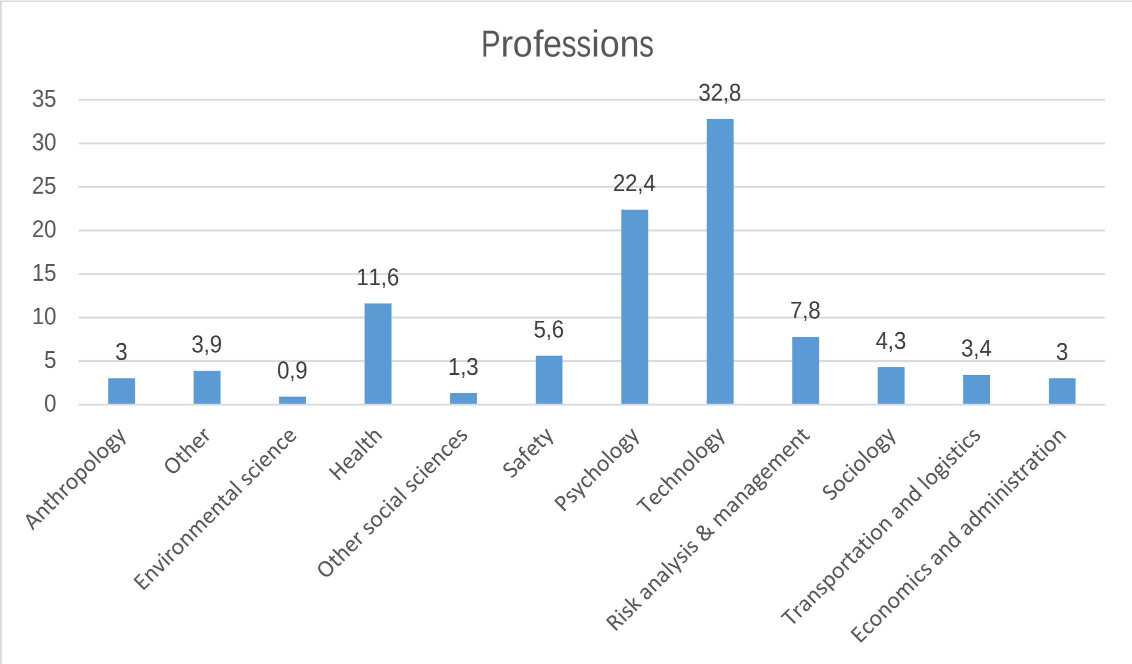


Figure 1 – Author profession

More than 40% of the journal articles originates from Europe, and excluding not specified and transnational articles, European authors constitutes about 64%. This indicated a centralization of discussions, isolation of discussions on the basis of geographical delimination.

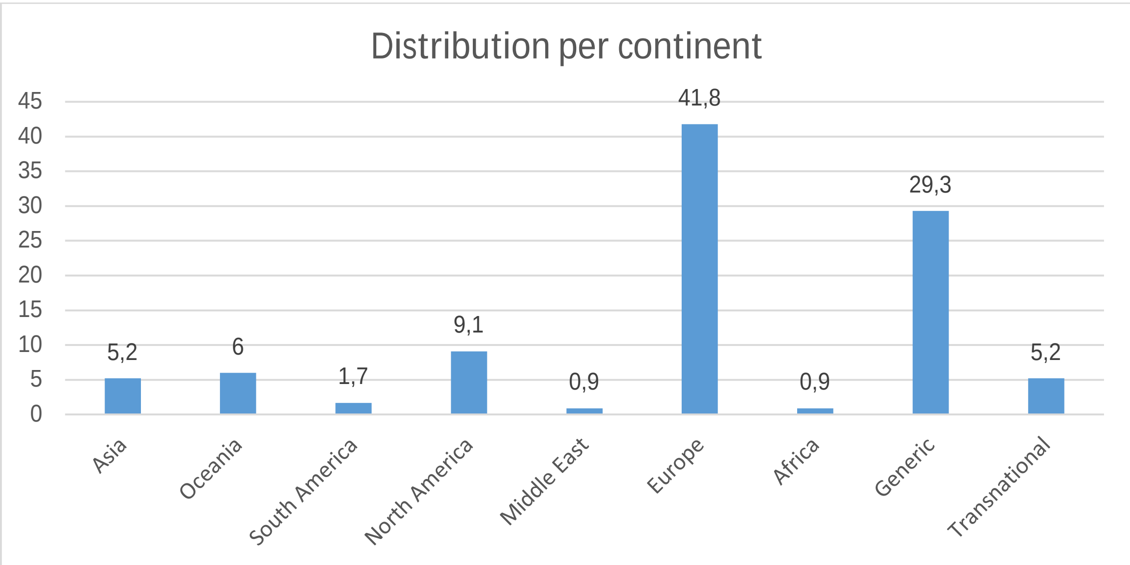


Figure 2 – Origin by continent

Broken down to nation-states it is clear that some few nations dominate the picture. US/Canada and UK provides the most articles, while relative to the population Norway account for a perhaps surprisingly large part of the articles. Based on this picture it is obvious that HSE culture is treated academically in a few regions. And as countries such as Norway dominates (relatively speaking) in these debates, it points to the relationship those academic debates has to the respective countries industry (e.g. oil) and HSE regulations.

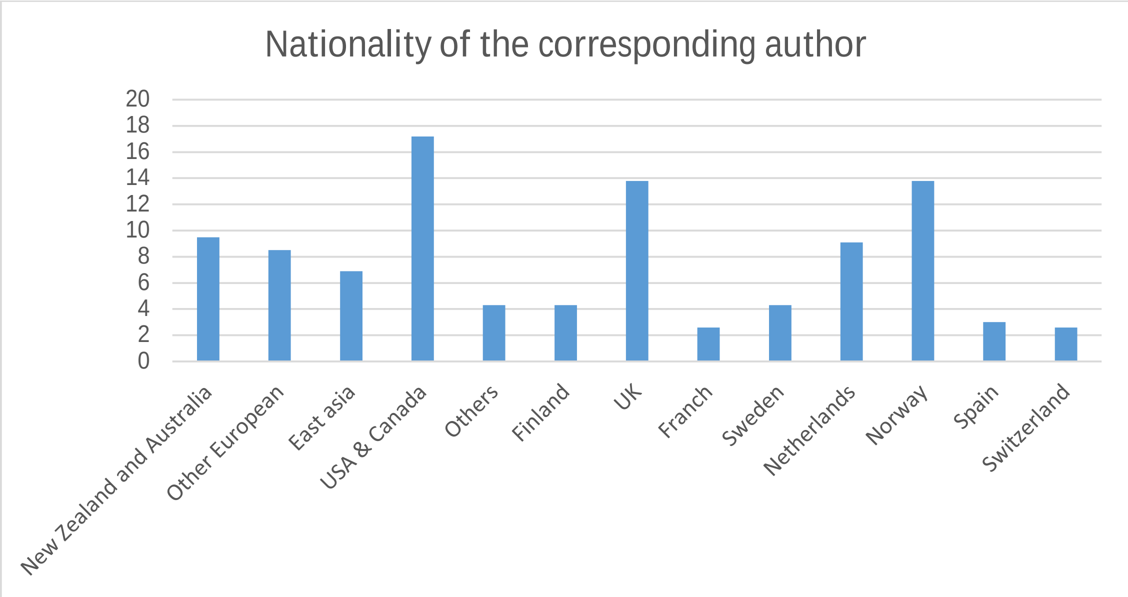


Figure 3 – Origin by Nation-State

Figure 4 shows that ¼ of the papers are focusing on different sectors of transportation systems (Aviation, Railroad, Shipping, Road transportation). Almost ¼ of the sample consist papers using the oil and gas industry as the area of research. Almost 14 % of the paper does not address any specific industry at all. This paper are discussing and/or presenting theories that are not contextualized to any specific activity or industry. Nuclear industry represent the context of 7.8 % of the papers. This seems rather astonishing taking into the consideration that the nuclear industry often I considered as the “mother of safety culture”.

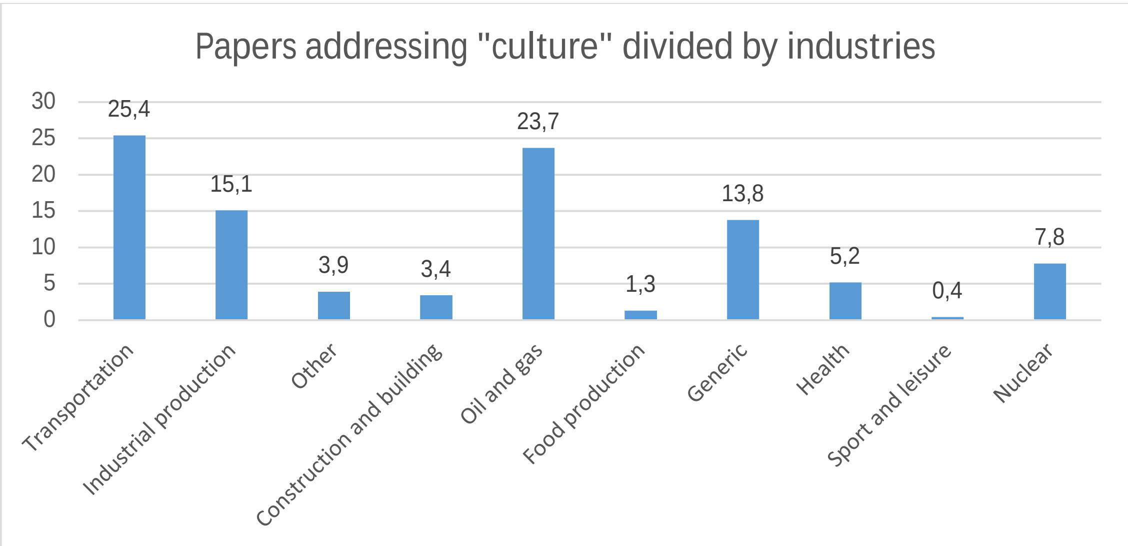


Figure 4 – Origin by industry

3.1.2. Popularity of HSE culture

Our sample of papers addressing “HSE” and “culture” have been published in the period 1993 to 2013. The heyday of “culture”, measured in number of publications, seems to be between 2006 - 2012 (Figure 5). Figure 6 shows that the heyday of culture especially has been discussed in relation to Oil and gas, transportation and industrial production (which includes several industries – but addresses types of production). Figure 7 shows that this more than anything activated discussions within the technological professions as well as psychology. Finally, figure 8 shows that it was in Europe that these discussions was activated. All of the tables shows relative stability within the other categories.

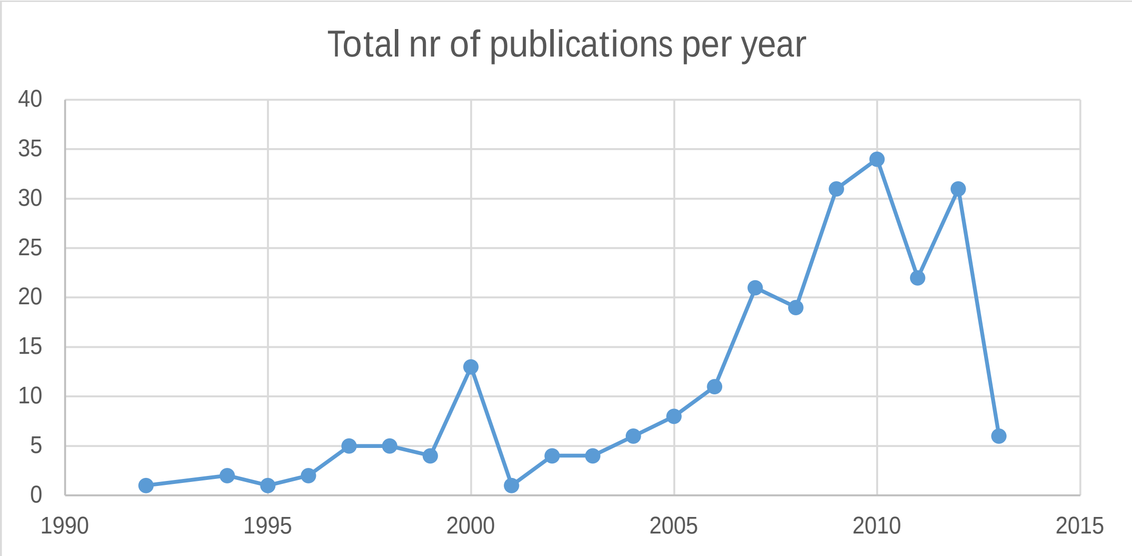


Figure 5 – Total publications per year

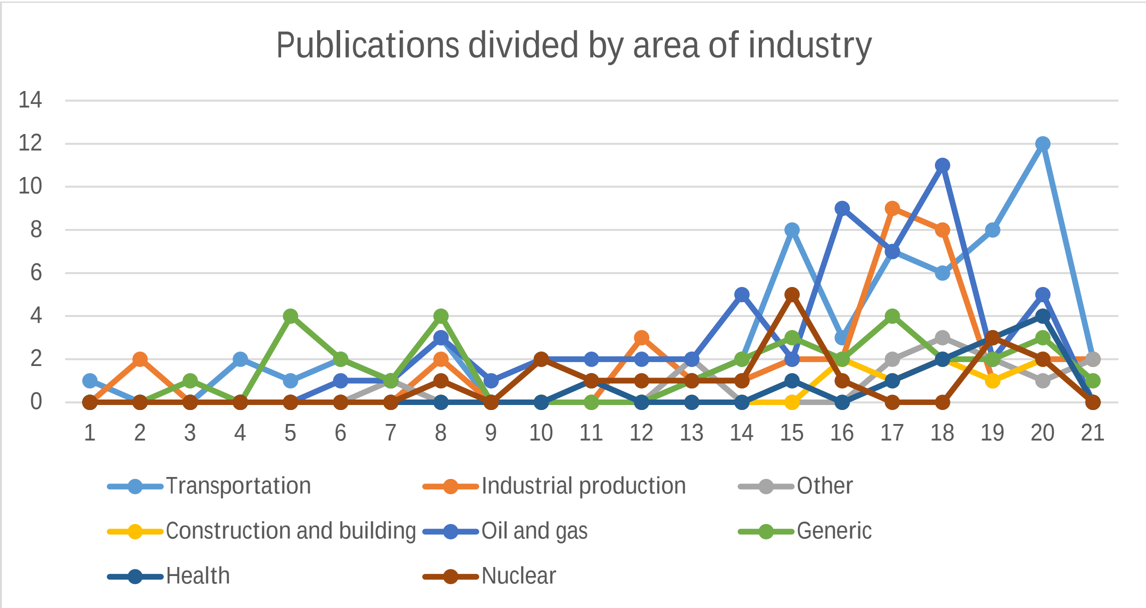


Figure 6 – Total publications per year

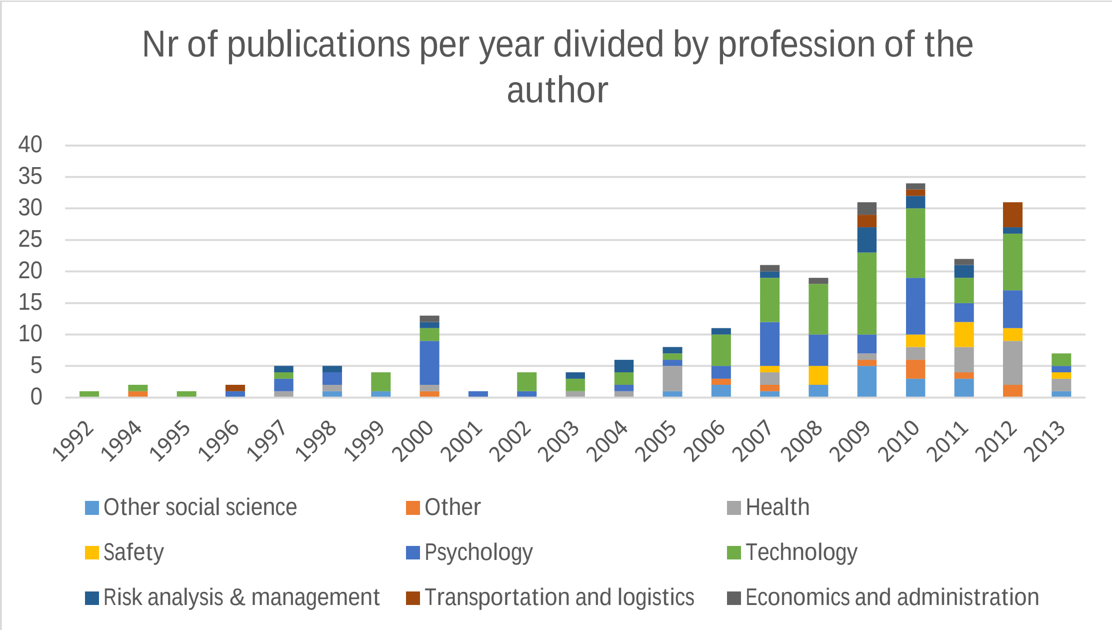


Figure 7 – Professions discussing HSE culture

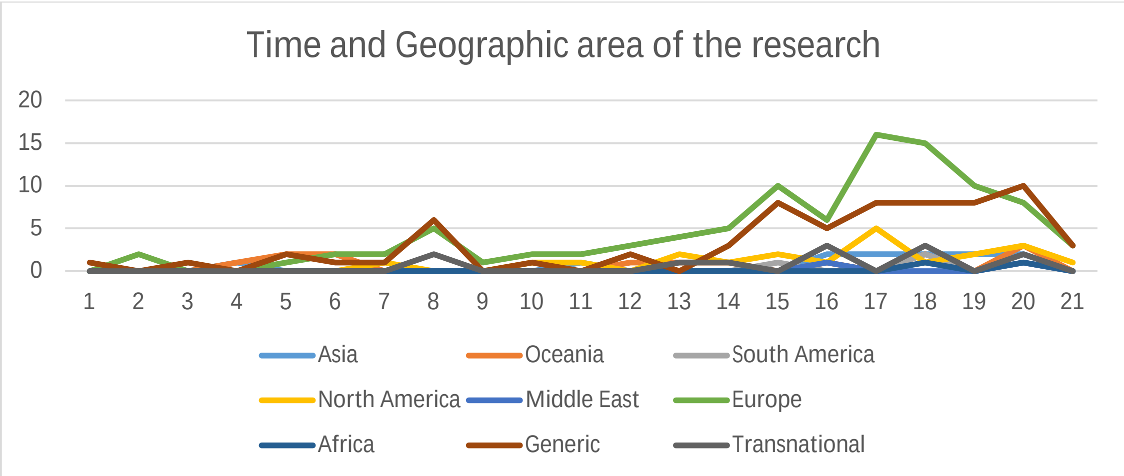


Figure 8 – Geographic development 1993-2013

3.1.3. Referencing

21 % of the papers do not use any references linked to the use of the term “culture”. This is rather astonishing taking into consideration that “culture” is a term that signifies an abstract concept. Further, we observe that there is a large variation in the use of core references when addressing “culture”. In 32 % of the papers, the core reference is an author that has not been used in more than one other paper in this sample. The most frequently used core references when addressing “culture” is Reason , Schein and Hofstede (years excluded here).

3.1.4. Methods used

The most striking in figure 9 is the number of articles that lack empirical data. Counting only the 20 most cited articles, more than 50% lacks data. Counting the 116 (N=232) most cited articles, 43% does not present any data. These findings indicates that a large portion of the debates regarding HSE culture are self-referential thus leading us to question their substance (hence the subtitle turtles al the way down).

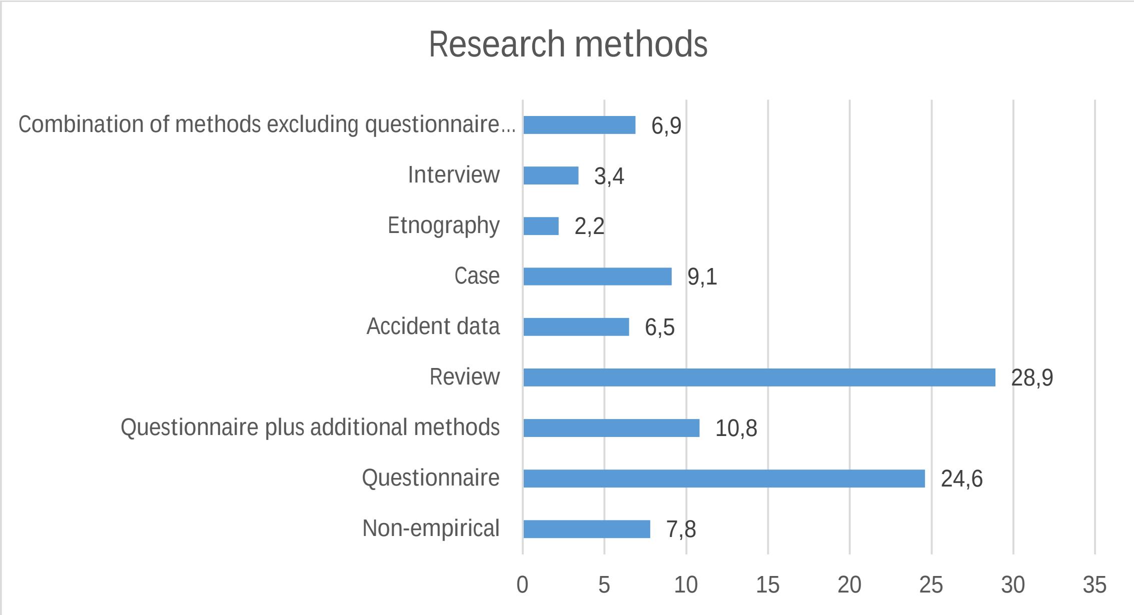


Figure 9 – The different research methods

3.2.1 HSE

One of the clearest results (Figure 10) is that articles labelled as debating HSE first and foremost talks about safety.

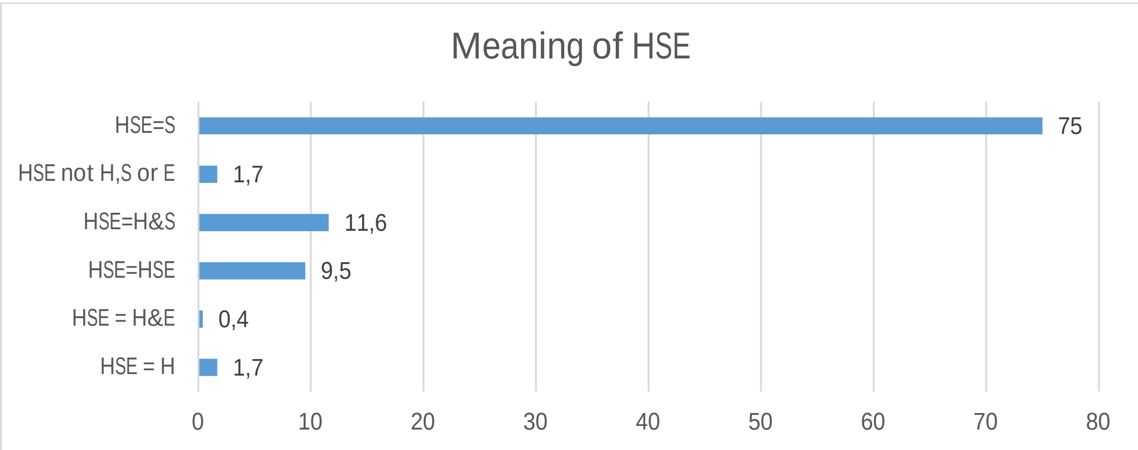


Figure 10 – HSE denotes safety

Figure 11 shows the different referents of HSE – sometimes it denotes practice and sometimes a system. Interestingly, as many as 38,8% refer to HSE both as practice and a system.

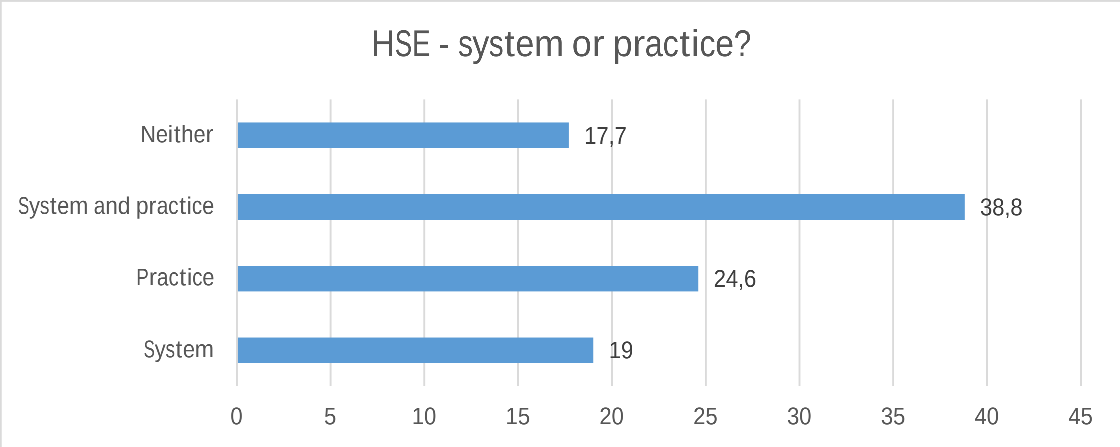


Figure 11 – the referent of HSE

3.2.2. Culture perspectives

Figure 12, 13 and 14 shows the different and dominating understandings of culture. Psychology and engineering (often overlapping) views, understanding culture as a factor located in the mind dominates the picture.

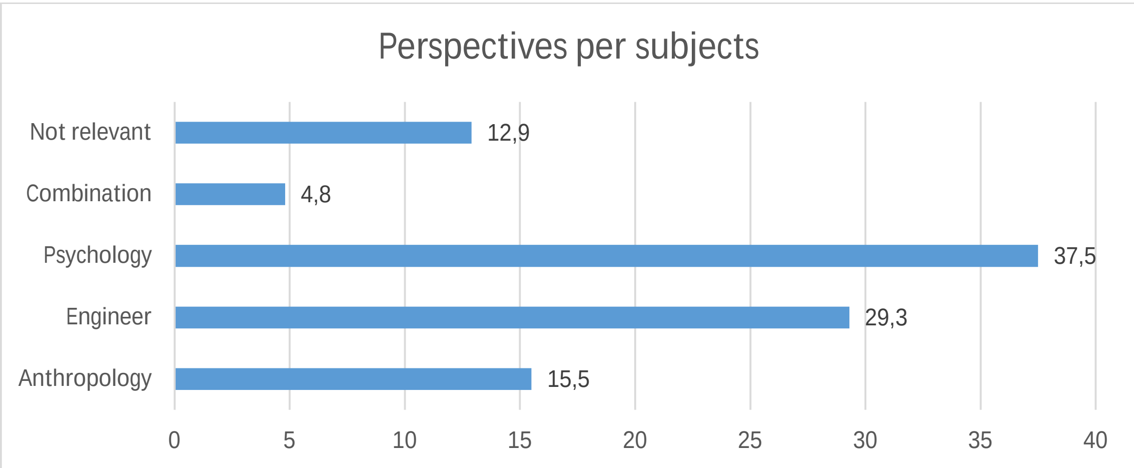


Figure 12 – Culture understood as discourse of psychology, engineering or anthropology

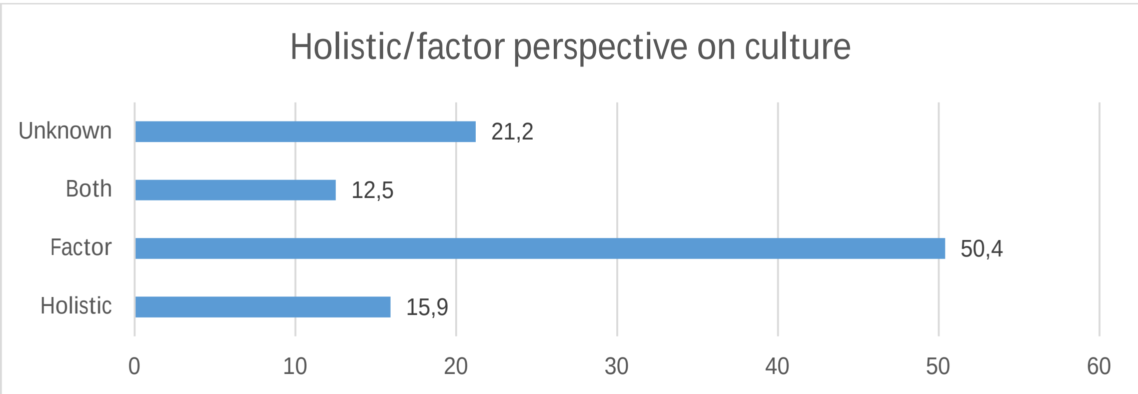


Figure 13 – Holistic or factor perspectives on culture

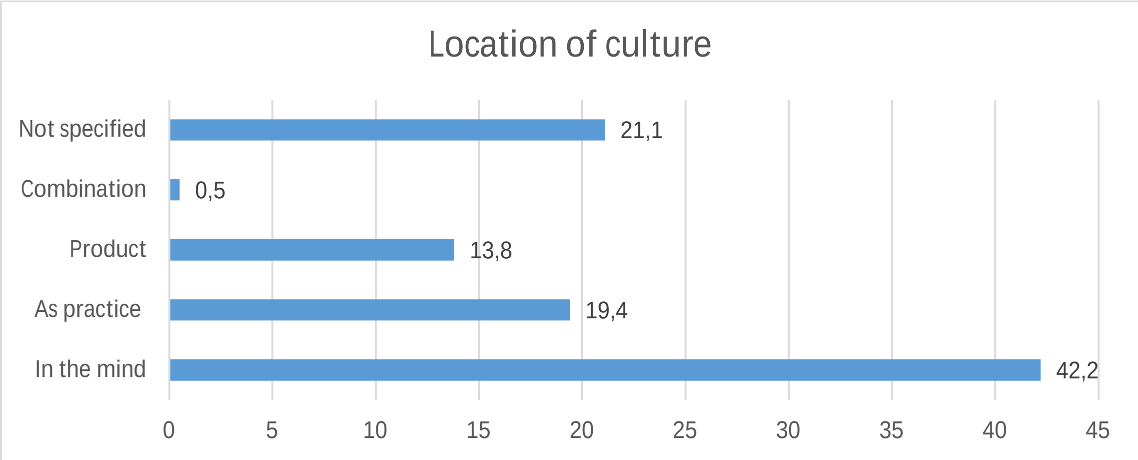
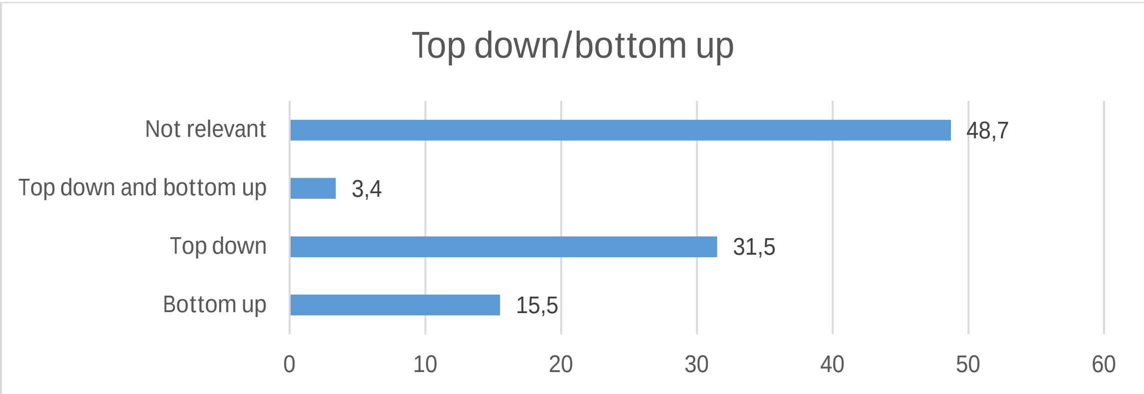
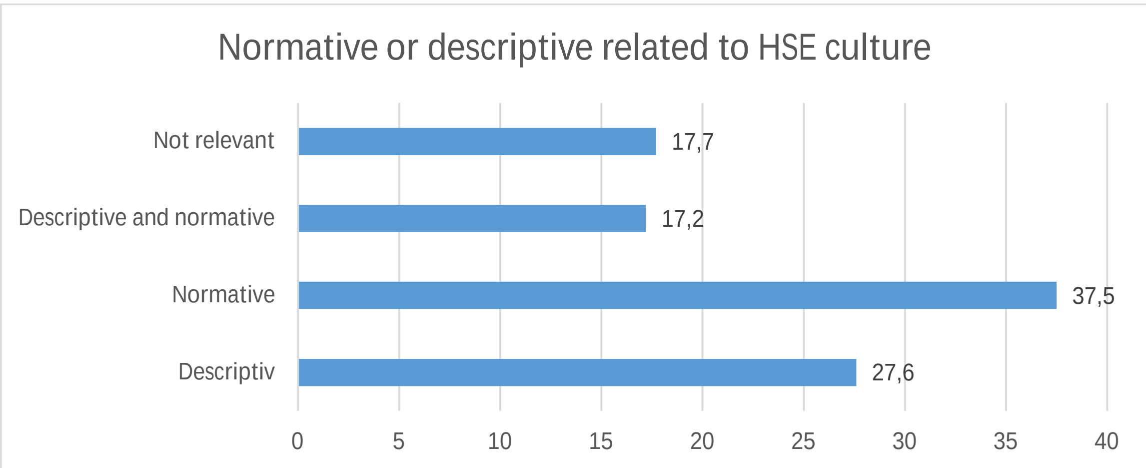


Figure 14 – The location of culture

3.2.3. HSE culture

As figures 15 and 16 show, many articles are irrelevant when they are to be categorized by views on HSE culture, as they are tags as concerning HSEculture but does not discuss it. But as figure 15 show, those discussing HSE culture see it as something that *could* and (figure 16) *should* be improved by management or facilitation.





4. CONCLUSIONS

This paper prioritizes presenting descriptive data, and as such the implications and arguments are not developed explicitly throughout the paper. Still the results provide an interesting picture of a research community with a surprising degree of self-referential rendering. We have also found a vast diversity in types of discussions and referents held by the same concepts. But also we found clear tendencies such as HSE really denoting safety, and centralization in terms of contexts debating and references used in these debates.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Bye, R. J., Rosness, R. and Røyrvik, J.O.D. (2015) "‘Culture’ as a tool and stumbling block for learning: The function of ‘culture’ in communications from regulatory authorities in the Norwegian petroleum sector." Safety Science.

Bernard, H. R, (2011). Research methods in anthropology. Qualitative and quantitative approaches. AltaMira Press, Plymouth.

Clausen, J. A. (1998) Life reviews and life stories. In: J. Z. Giele & G. H. Elder (eds) *Methods of life Course Research: Qualitative and Quantitative approaches* (pp 189-212). Thousand Oaks, CA: Sage

Røyrvik, J., (2012). Værvinduet, en teknologisk artikulert entitet I oljeindustriens erobring av natur (PhD thesis)., NTNU Department of Anthropology, Trondheim.

Saussure, F., (1974). Course in general linguistics. Owen, London.

Professional competence, air and seamanship and safety

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Abstract
In this paper we discuss airmanship and seamanship, and how these valued qualities are transformed or challenged by developments in technology and more detailed governance of work and safety. We base our discussion on early data from participatory observation of work on ships and planes. We describe some of the changes in the regulation and control of work and discuss how this affects key professionals (pilots and ship officers, primarily). We also discuss how new technologies relate to and influence airmanship and seamanship. A key contribution of this paper is outline a relational and processual understanding of professional competence, one in which regulation of work and new technologies aren't regarded as dichotomies to professional competence, rather something with which it is connected and integrated and also in co-development with.

Keywords: Professional Competence; Seamanship, Airmanship, Regulation, Skill.

1. INTRODUCTION
In discussions with practitioners and researchers alike the importance of specific kinds of professional competence for safety is often a matter of concern. While new technologies as well as regulation and control measures are introduced these discussions often take the form of lamenting a loss. Good seamanship, a captain will tell you, isn't only book knowledge. It is a practical competence, involving attitudes and skills, including bodily and tacit components. It is something you are. And it can't be replaced by rules, checklists and new technologies.

An ongoing research project (PROCOM) takes this interest in professional competence as a point of departure. We are studying professional practice on different kinds of ships, airplanes and will also include helicopters. We seek to disentangle the phenomenon of professional competence from the ever-present discourse of something invisible, almost mythical being lost, in the era of de-skilling, technological development and proceduralization, and learn more about what it is in itself and also how it is in transformation *with* the changes in technology and regulation of work.

2. METHODS AND MATERIALS
The paper presents data from an ongoing study. We have conducted field work (participant observation and interviews) on anchor handling vessels, supply boats, and on regular passenger planes. We will also conduct interviews in small independent helicopter services (we have some preliminary basis from other projects. See Bye et al, 2013). In combination, these data provides us with a sample of cases in which the nature of the tasks (the complexity of work), the degree of regulation and external control and the level of automation is highly variable. Still they are all cases where the discussions of seamanship and airmanship are highly relevant.

- Anchor handling vessels are immensely strong specialized tug-boats used to move floating drilling rigs. The balancing of forces of weather, current, heavy anchors and chains in these operations is a demanding and dangerous task both for captains and sailors. In the petroleum industry ships are recognized as one of the most demanding type of ships to be on.
- Offshore supply boats. The supply boats also work for the oil rigs and platforms. However, their tasks are more routinized and normally less demanding for the crew. These ships, too, are impressive, as they are built to endure all sorts of weather and

have advanced positioning technologies and strong engines. Their main task is to transport necessary goods and equipment to and from the installations.

- Passenger flights. We have studied regular, national and regional flights with modern Boeing 737s. These are highly automatized, with several automatic systems. They operate in tightly regulated airspace and are subject to increasing external control in terms of environmental monitoring etc. The pilots are still recognized and respected as professionals that are important for safety. Increasing international competition from low cost airlines has led to some controversy, also regarding the status of the pilots.
- Independent helicopter services. In Norway these are small independent companies. They perform unscheduled flights, transporting people and goods, sometimes lifting heavy loads, managing unfamiliar terrain and unpredictable weather, and at least to compare to scheduled passenger flights, the formal safety management systems to support them are slender.

Combined these cases give us examples of different situations where airmanship and seamanship are regarded as important, but where the technologies involved, the organization of work, the nature of the tasks to be performed are different, and where the professional competence is in transition.

3. THEORETICAL OUTLINE

Airmanship, seamanship and professional competence.

This paper is based on early findings from the project “Professional Competence, Standardization and Safety in Aviation and the Maritime Industry”, funded by the Norwegian Research Council. The project started out after a series of projects on maritime safety in which discussions of *good seamanship* had been an ever present topic in interviews and discussions among seamen and regulators. We wanted to address this phenomenon explicitly and included airmanship as a comparative case. Though the term professional competence can have other meanings in other contexts, in this paper we mean good seamanship and good airmanship unless something else is stated. The discourses of good sea/airmanship are well established in the fields we have studied.

'Competence' is a term with many academic and common-sense connotations. There is no single, canonical definition or interpretation of competence, and it is understood differently in different disciplines such as management research, psychological, sociological and educational research (Håland and Tjora, 2006). Competence is often linked to qualifications, knowledge, skills and practice (Høyrup and Pedersen, 2002). Jensen and Prahl (2000) see competence as an intersubjective phenomenon, suggesting that it is related to dynamic interaction between individuals not only an individual capacity. Professional competence includes formal training and strictly regulated task execution but it also involves *skills* of a more experience based and embodied nature.[1]

As work is routinized and tasks replaced by new technology, theoreticians on modernity have discussed different modalities of *deskilling*[2] (Marx 2005, Braverman 1974) as consequences. This doesn’t only refer to the effect that the individual worker loses competence because his tasks are simpler, but also to a more general reorganization of work in which skill and craftsmanship is less important and control is centralized.

A relational and processual approach.

We understand professional competence as a relational and processual concept. As a consequence, we regard competence not as a static asset held by individuals, but see that it can be influenced by (or *situated* in) different conditions, e.g. technological developments, regulations, safety management systems, economic conditions/demands for efficiency etc. The relational approach means that we see how practice is interwoven with technology. (See Haavik, 2014 for a discussion of relational approaches in safety research.) Several independent research strands, in which we do not need to delve in for this paper, has inspired our view on

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[1] See for example Palsson’s discussion of enskilment at sea (1994) and more generally Ingold’s (1993, 2000) discussions of skill and its relation to different technologies.

[2] Manifestations of deskilling are 1) Decline in craftsmen, 2) Increasing separation of mental and physical labor, 3) Decline in levels of training, and 4) Increase in the interchangeability of labor. See Braverman, 1974 or Røyrvik, 2012.

the inter-relations between human practice and competence and technology and representational artifacts on the other hand. The research strand on distributed cognition (Hutchins, 1995), Ingold's (1993) discussions of technologies and skilled practice, Latour's (e.g. 1995) actor-network theory also stresses these interrelations. More recently the socio-material theory forwarded by Orlikowski and Scott (2008) and Suchman (2007), also stresses the "constitutive entanglement" of technology and practice. In sum these provide inspiration to inspect the dynamics in the interrelationships between procedures, technologies and work, to see how they are entangled, rather than searching for deterministic or social constructivist accounts of these relations. Technology and regulation change, and so does professional competence. These are the inter-relations we seek to understand.

Regulative and technological change.
Both in the air and on sea developments of a technical and organizational/regulative nature change the framework conditions in which the professionals conduct their work. To some extent key skills are rendered unnecessary by new technologies and procedures.
Also the role of some professions is losing some of its status as technology and/or standardization. Almklov et al (2014) discuss how a convergence ~~of~~ trends internationalization, standardization, self-regulation, and a growing consultancy business~~–~~ leave the practitioners' perspectives on what safe work practice is less influential. These developments lead to an increased weight on the general over the particular and experience based in the safety field. This, in turn, gives stronger discursive power to generic models of safety vis-à-vis perspectives grounded in practical experience in specific industries. At the same time, competence beyond what is described in formal documentation is found to be a key resource for resilience, the dynamic situational adjustments performed by professionals in practice (see e.g. Rasmussen, 1997; Hollnagel et al 2006; Roe and Schulman, 2008; Haavik, 2013). Almklov and Antonsen (2014) argue that key competencies in this respect are often situational dependent and "invisible" to formal systems. Efforts to improve safety through rules, standardization and regimes of accountability, may threaten the leverage for professionals to develop, perfect and utilize skill.

Procedures and systems that regulate work can (and should) be seen as technologies or tools. As Suchman (2007) reminds us, the procedures or plans aren't just representations, but they are resources employed by people in concrete situations. Barley and Kunda (2001:76) observe that "digital technologies seem to be eliminating some types of work, creating others, and transforming a significant portion of what remains". Much of the regulation of work (checklists, reporting systems, procedures etc) is inscribed in technical systems, making the boundary between procedures and technologies even more blurred.[3] A particular class of technologies that are relevant for the discussion of good seamanship and airmanship are systems that automate parts of the work of our informants, like dynamic positioning systems and autopilots.

3. SOME EARLY RESULTS
While proceduralization, standardization and control measures from the organization outside the plane/boat on one hand may challenge the autonomy of captains and pilots, automation may replace them (for some tasks) and transform their work. Though sweeping deterministic accounts about deskilling may be tempting[4] we will seek to disentangle these changes based on our empirical observations and interviews. In this, the variation between the nature of work, and organization of work, in our cases are resources for discussion. In our presentation we compare the professions by the dimensions of 1) task complexity and 2) extent of rules governing work practice, as illustrated in Figure 1.

[3] The difference between a digital procedure/checklist and a paper based one is interesting in itself. The digital systems are often designed to have agency beyond what the paper based list has: The drop-down menu leaves you with a finite number of choices. In some cases checklists are inscribed in systems in a way that you cannot proceed with your primary work before the "paperwork" is done. This difference in performativity between ICT based administrative systems may be elusive and subtle, but important.
[4] For example, on how automation and proceduralization erodes seamanship and disempowers seamen, an entirely plausible and arguable account.

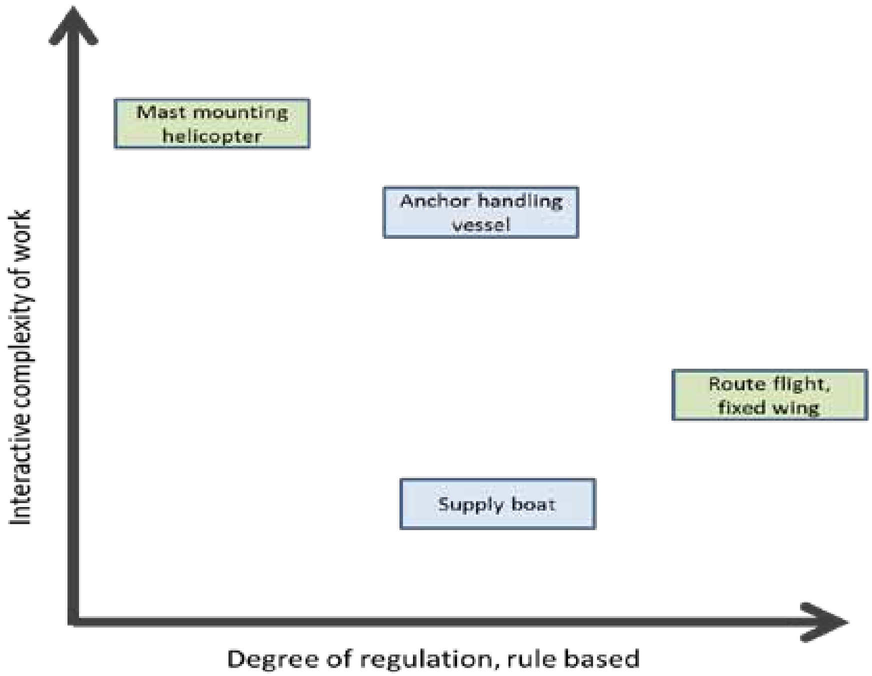

Figure 1 – Tentative placement of cases along the degree of rule based regulation, and the degrees of complexity (and (un)predictability) of tasks.

Note that both the axes and the placement of the cases are highly tentative and simplified. The figure still serves to illustrate some of the task differences that we will discuss in the following pages. Note that by interactive complexity we also imply a certain amount of uncertainty or uncontrollability of the work.

In our maritime cases, the observation was clear: Both onboard anchor handling vessels and the supply boats our informant agreed that the need for (what they regard as) good seamanship was most important on AHVs. The job on these ships was more unpredictable and complex. The forces involved are immense. The ships we studied[5] belonged to the same company and was contracted to the same oil company. Their work was heavily regulated through procedures, formal meetings, documentation, safety programs, reporting etc, and our informants noted a marked transformation in this respect both on AHVs and supply boats. In normal operations the advanced technology also alleviated much of the need for the intervention of people. On both ships, it was commented by our informants that normal sailing was simple, and not something that required all that much skill. They did a lot of paperwork on the bridge, ticking off checklists, emailing the head office, calculating fuel usage etc. The marked difference occurred when the AHV was using its enormous winches to lift anchors, move chains and tow rigs.[6] When doing this the external forces exerted on the ship are dangerous both for the ship itself (it may capsize) and in particular for the sailors on deck handling wires and chains there.

Several serious accidents have occurred in relation to these activities during the last two decades, also involving several fatalities. In these operations one of the chief officers on the ship (captain or first officer) and his second in command on the shift sit turned backwards in adjacent seats, one operating the engine, rudder and thrusters and the other the winch system. They also have the sailors on deck, the rig and other boats involved in the operation on radio. In these situations external forces are literally pulling the vessel. Everyone onboard feels the boat moving about and hears the noise from winches and chains. The officers are conducting a joint balancing act, one determining the positioning of the ship, the other the pull and release of the winch. Both, of course, influenced by weather and currents, the weight of the load lifted, the

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[5] The project group also has an extensive experience with supply boats and AHVs from other projects. One participant has his PhD based on field work on an AHV (Røyrvik, 2012).

[6] This change is also observed by Røyrvik et al (2015) that distinguishes between two modes of operation aboard AHVs. Their paper also describes the anchor operations in some more detail.

situation on deck and orders and advice received on the radio from the rig or other AHVs involved in the operation. They also have to know the capacity of the ships own systems. For example, pulling the winch too hard with the ship angled incorrectly can be dangerous.[7] Interestingly, few procedures or checklists are used in this kind of work. It deviated from the "normal" situation in this respect. It seemed to us, and the informants concurred, that this required extraordinary skills.

That kind of skill can only be achieved by experience. Interestingly, the formal requirements for promotion (in terms of experience) are overrun by informal organization (a control mechanism first reported by W. Lloyd Warner in the famous Hawthorne experiments)[8] among the shipping companies, officers and officers to be. Our informants state that the formal required nr of runs to be qualified for promotion are way too low to be safe and even taken serious by peers and sailors. Thus, no candidates will seek promotion before they have experience enough to be accepted and respected by AHV crews as competent.

A few things can be learned from this. While much of the regular work on an AHV is predictable and controllable, thus possible to regulate or even automate, the balancing of forces (and coordination with other parties) real time during operations required skills way beyond the procedural. The need for experience and seamanship was also explicitly recognized with respect to these operations. The regulatory regimes for AHVs and supply boats are almost identical. It seemed to us that the anchor operation was too complex to regulate in the same way as their normal work. Some causes for this can be proposed: 1. The complexity of the work. Several uncontrollable external influences affect the situation (the load, weather, situation on deck and in the engine room, the rig, other ships etc) in a dynamic manner. 2) Temporality: Action must often be taken in a split second. The understanding of the operation and the ability to stay ahead of possible problems, the prospective sensemaking (Rosness et al, 2015), is crucial to handling this.

New technologies are enrolled in this work. The workstations for the officers are highly instrumented, and they will sometimes use automatic or semi-automatic positioning, depending on their preferences and the specific situation. Also, it is interesting to note that the two officers running the operation need to have a very holistic understanding of the operation at hand, but also of technical issues (on deck and in the engine) and of the surrounding organization.

Figure 2 The sailors on deck have connected a chain. Seen from the bridge. As the winch starts to pull, the ship must be positioned correctly to balance the forces from the heavy load, weather and currents.

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[7] The Bourbon Dolphin accident in 2007 cost eight lives. The vessel was turned over by the weight of the anchors and chains. Part of the reason was that the ship was too small to handle the operation safely.

[8] Too read more about the informal organization of Hawthorne workers, see Schwartzmann 1993, about Warners role see Baba 2009 and Røyrvik 2012.

This brings us to the developments in the cockpit of airplanes. In a similar manner, the work of pilots is increasingly subject to both increasing regulation and increasing automation. Autopilots and improved support systems at most airfields make “hand-flying” and local knowledge less neccesary. In contrast to the maritime industry, airlines and airports have been heavily regulated and standardized for several decades. Though individual planes may have their minor idiosyncrasies, and airfields certainly have some local variety, the extensive standardization basically provides for an interchangeability of pilots. The contextual variability of their work is reduced to a minimum.

The company in our case has recently renewed the fleet, so that most of the older aircrafts (737-300) has been replaced by newer (737-800). A new electronic system for flight planning has replaced more time and space (paper) consuming manual calculations. This has reduced the workload for the pilots substantially, particularly before take-off. At the same time, less time needed has resulted in the companies tightening the schedules, so the time margins have not necessarily increased.

The accomplishment of flights is highly influenced by weather conditions. For example, sight, temperature, wind, thunderclouds and runway conditions are conditions that make every flight a unique experience that must be dealt with uniquely. Some of these conditions are entered in a standardized manner into equations that are managed by the flight management computer (FMC), and hence are included into the envelope of standard operation, for example in the calculation of take-off and landing. Other times the conditions require human interpretation and needs to be manipulated before entered into the FMC, or to be discretionary assessed and dealt with, for example when changing the descent due to thunderclouds.
The tight scheduling of flights introduces time pressure as a factor affecting the flights. In case of delays, pilots may choose to alter the flights in order to gain time. For example, the chosen descends may deviate from the one suggested by the FMC.

While check lists and procedures to a large extent seemed little relevant on the AHVs and supply boats, some are an intrinsic part of the pilot’s profession. Both for pilots and captains automation (autopilots, dynamic positioning systems) have eased some of their work. Also both professions have been to a larger extent been involved in “external” initiatives. For example, both sea captains and pilots are now subject to regulation seeking to reduce fuel consumption. Thus, an airline pilot includes this in his decision making. Maybe trying to catch up with a delay will increase fuel consumption. Similarly, the captain on our AHV had to notify the management on land that he wanted to cruise above the recommended speed from the harbor to the rig. Talking to the other captains, and based on his experience, he had some concerns that there might arise some delays in the rig move operation. By arriving a bit earlier, he hoped to be able to give some slack to the operation. This evaluation, as the pilot’s inclusion of environmental factors in their flying patterns may indicate that airmanship and seamanship to a greater extent includes interaction with the external organization and organizational goals beyond just operating the vessel or airplane.

We have not yet conducted the last case in our study, individual helicopter services. Based on interaction with the industry in previous research we know that they conduct several complex tasks, e.g. when lifting poles for electricity grids, and that the small businesses (quite understandably) have only cursory safety management systems. We thus regard this to be a case where the complexity and unpredictability of work can be high whereas the formal control systems are few. This case is placed as having high interactive complexity/uncertainty due to the unpredictability when lifting heavy loads in different terrains. In many ways somewhat similar to the AHVs.

5. CONCLUSION

Airmanship and seamanship is changing. In this paper we have inspected how these qualities relate to technological and organizational/regulatory changes.
We have suggested that airmanship and seamanship is about handling complexity and variability. Our case in anchor handling[9] showed situations where such dynamic management

[9] Similar skill based operations are also expected to be prevalent in many independent helicopter operations, like services on electricity grids.

still exists, though changing with technology. However, we also note increasing bureaucratization of work and external control. This may lead to changes in professional identity and loss of status and autonomy. In particular the recent decades of deregulation and increased competition has reduced the status of pilots. Handling this external influence, embedding it in operational decisions, exemplified with our discussion of environmental considerations, also shows that airmanship and seamanship relates to an organizational field, including procedures and reporting systems, not only as oppositions, but as something with which it co-operates. The cockpit and bridge are more connected to the rest of the organization, and new skills in handling these connections are developing. Like the pilots have done for decades, seamen today to a greater extent define (some) of the rules and regulations, some paperwork, as parts of their skill. In a similar manner, automation and positioning technologies definitely changes the required skills involved in seamanship and airmanship. Our informants, both on sea and in the air, develop a competence in how and when to use it, its limitations and strengths.

6. ACKNOWLEDGMENTS

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7. REFERENCES

Almklov, P. G., & Antonsen, S. (2014). Making work invisible: New public management and operational work in critical infrastructure sectors. *Public Administration*, *92*(2), 477-492.

Almklov, PG, Rosness, R., Størkersen K. (2014). When safety science meets the practitioners: Does safety science contribute to marginalization of practical knowledge? Special issue of *Safety Science* on the Foundations of Safety Science.

Baba, M. (2009). W. Lloyd Warner and the Anthropology of Institutions: An Approach to the Study of Work in Late Capitalism. In Anthropology of Work Review, XXX(2), s.29-49.

Barley, S. R., & Kunda, G. (2001). Bringing Work Back In. Organization Science, 12(1), 76-95.

Braverman, Harry (1974). Labor and monopoly capital. New York: Monthly Review

Bye, R.J. , J. Slejelid, B. Heide, G.Lillehammer. B. Aasprang, S. Antonsen, J.E. Vinnem & B.Bø (2013) Safety study land-based helicopters. [Sikkerhetsstudie innlandshelikopter.] Hovedrapport. Dokumentnr. ST-04215-2. Safetec. Trondheim.

Hollnagel, E., Woods, D.D., Leveson, N. (2006). Resilience Engineering: Concepts and precepts. Ashgate, Aldershot, UK.

Hutchins, E. (1995). *Cognition in the Wild*. MIT press.

Haavik, T. K. (2011). On components and relations in sociotechnical systems. *Journal of Contingencies and Crisis Management*, *19*(2), 99-109.

Håland, E., Tjora, A., (2006). Between asset and process: Developing competence by implementing a learning management system. Human Relations 59(7), 993-1016.

Ingold, Tim (1993) 'Epilogue: "Technology, Language, Intelligence"', in T.G. Ingold & Kathleen R. Gibson (eds), Tools, Language and Cognition in Human Evolution (Cambridge: Cambridge University Press): 447–72.

Ingold, T. (2000). *The perception of the environment: essays on livelihood, dwelling and skill*. Psychology Press.

Latour, Bruno (1987) *Science in Action: How to Follow Scientists and Engineers Through Society* (Milton Keynes, Buckinghamshire: Open University Press).

Marx, K. (2005). Første bok: Kapitalens produksjonsprosess. Del 3. I K. Marx Kapitalen Oslo: Forlaget Oktober AS

Orlikowski, W. J., & Scott, S. V. (2008). Sociomateriality: challenging the separation of technology, work and organization. *The academy of management annals*, *2*(1), 433-474.

Palsson, G. (1994). Enskilment at sea. *Man*, 901-927

Rosness, R., Evjemo. TE, Haavik, TK & Wærø I (forthcomng) Prospective sensemaking in the operating theatre. *Cognition, Technology & Work*.

Røyrvik, Jens (2012): "Værvinduet – en teknologisk artikulert entitet i oljeindustriens erobring av natur." Thesis submitted for PhD in social anthropology, Trondheim: NTNU. - See more at: http://www.cultureunbound.ep.liu.se/article.asp?DOI=10.3384/cu.2000.1525.124617#sthash.U2o7qqDw.dpuf

Røyrvik, J., Skarholt, K., Lamvik, G. M., & Jonassen, J. R. (2015). Risk management in anchor-handling operations: The balance between control and autonomy. I: Safety and Reliability: Methodology and Applications: Proceedings of the European safety and reliability Conference, ESREL 2014, Poland, 14-18 september 2014. Taylor & Francis 2015 ISBN 978-1-138-02681-0. s. 685-693

Suchman, L. (2007). *Human-machine reconfigurations: Plans and situated actions.* Cambridge University Press.

Schwartzman, H. B. (1993). Ethnography in Organizations. Newbury Park, CA: Sage Publications.

Case study: analysis and verification of the requirements of security of the thirty-six regulatory standard in the fridge enterprise located in the midwest of minas gerais

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Abstract

Nowadays, the security aspects are very important to enterprises, because the number of the labor accidents increased, bringing losses to the organizations and damaging the health and the life quality of the employees. The advantages acquired for the organizations that worry about this subject are motivation employees, to know that they work in a secure environment and to know that they have good situation to work with tranquility. Avoiding damage to their health and generating greater confidence for the same, increased of productivity and the improvement of the company image, which has strengthened with all its partners and society. Therefore, the regulatory standard has the objective of standardize and help the enterprises with the security procedures, with the objective of conserve the health and the life quality of the employees and protect them of possible accidents of work. The finality of this report is exhibit the secure measures that are used of the organization located in the Midwest of Minas Gerais that works only with slaughter and storage of pigs in the cold chamber. It perform a search literature that covers all involved topics of this report. Furth more, are used, with analysis procedure the direct observation to identify all the risks that the work environment cause to their employees. With the purpose of providing information about the working conditions of the employees, were realized interviews conducted with employees about the risks according to their perception, they are exposed. The conformity of the enterprise with the thirty-six regulatory, which deals with safety and health at work of slaughter and processing of meat and meat products companies, standard are checked and the nonconformity, are checked too. Based on the items of this standard were analyzed all conformities and non-conformities of each of these items according to what was envisaged by standard and which can be seen in company. According to the articles of the thirty-six regulatory standard, there are twenty-nine conformities and seventy-two nonconformities, of the one hundred and one. The articles that are comply according to the thirty-six regulatory standard, are very important, like and in relation to platforms, walkways and platforms the company follows all the requirements thereof, thus offering greater security for workers to carry out the fridge activities. Already, the non-conformities, the enterprise does not practice most of the requirements of the thirty-six regulatory standard, like with machinery and temporal organization of work, which do not have any item that was conformity. It is possible realize that the enterprise has more non-conformities than conformities, even now adopting various requirements compatible with the standard. It causes risks to the health and secure of the employees. The problem is that violation of the thirty-six regulatory standard increases the chances of the employees of that company to be victims of accidents and there is the possibility of the employees of they have diseases because of work. This enterprise should have a program to health at work to prevention of accidents.

Keywords: Risks; accidents, slaughter.

1. INTRODUCTION

The work more than a way to ensure financial stability is the expression of useful of the people for business and for society. Besides people spend most of their adult life in the workplace, exercising their functions, receiving interference from other persons, the interference of factors related to working environment and the imposed rules and regulations according to the criteria defined by the organization where they operate.

According to all these precepts related to work, it is critical that companies understand the complexity that all these factors result in the realization of the work and provide a safe environment, and is a facilitator of health and well-being of their employees.

The benefits obtained by the organizations concerned and work are numerous and range from satisfaction and motivation that the employee has to know that working in a safe environment and it has all the support to carry out their activities in the best possible way. Avoiding damage caused to their health and generating greater confidence for the same, until the issue of increasing worker productivity and the company's image has strengthened against all its partners and society. Thus, to assist Brazilian companies to obtain these results there are the regulatory standards that provide information on what are the appropriate procedures related to medicine and work safety according to the type of company where employees work and activities that they play.
Among these regulatory standards NR is located (Regulatory Standard) - 36 (2003) which deals with the safety and health of workers at work in slaughter and processing companies of meat and meat products. The existence of this rule is extremely important, because the work of these organizations exposes employees to various risks due to the work environment in which they live, as well as the requirements emanating from the functions performed by them.
This article aims to analyze if the work done by the nine employees of the slaughter area of a refrigerator located in the Midwest region of Minas Gerais, it has conformities and nonconformities according to NR 36 (2003).
The fridge in question works with the slaughter of pigs, which occurs about two to three times a week according to the demand. The company carries out its activities from fertilization swine, maternity, nursery and fattening to slaughter process that is the focus of study of this work.

2. MATERIALS AND METHOD

As an analytical procedure was used direct observation with the purpose of providing information about the working conditions that which employees are exposed and the interview with the workers about the risks that according to their perception, they are exposed.
The method used to carry out these analyses was the case study. According to Yin (2005) case study as research, strategy comprises a method that encompasses everything - dealing with the planning logic, data collection techniques and approaches specific to their analysis. In this sense, the case study is neither a tactic to data collection nor merely a feature of planning itself, but a comprehensive research strategy.
The materials used were a camera to record the working conditions to which employees during the execution of their activities and a computer to store the information obtained.

3. RESULTS AND DISCUSSION

For the study became subject to comparison with standard regulatory 36 (2003) it was necessary prior knowledge of the process that is performed by the company, where the focus for the verification of the requirements was the slaughter of pigs.
The process begins with forwarding the pig to the scale where it done weighing the animal so that it is determined whether it is fit for slaughter, if it has the minimum weight required by the company that is 150 kg. Whereas if the animal is not fit it is forwarded to the pens for fattening being slaughtered in later processes.
After the pig, weighing he is sent to a location where a clerk causes an unconscious state in the animal, through an electronic device that is positioned below the ear, in the head region, that is five to eight seconds for total faintness animal.
In order to cause the death of the animal, an employee inserts a knife in the pig artery, so that all the blood of the animal drain.
Later the official position the feet of the animal in a hook for transporting the same to the place where the first part of the cleaning process will be will happen, by washing with a water hose.
The animal goes to the tank containing water at a temperature ranging between 68 and 72 degrees, where it is for one minute, until all the pig hair disappear.
During the next process, the employee removes the nails and the rectum of the animal and he passing the torch around the animal's body. To finish this step, the employee cleans the animal carcass.
Finally the animal is opened, have their organs removed and is routed to the cold room, where he remained for twelve hours before being transported to the truck for shipment of all its parts, and the housing and the liver goes to the butchers and a bellyful for further manufacturing poultry feed.
After studying the whole process, both the physical and organizational, has made the comparison of the activities that being carried out in the fridge with the regulatory requirements of the standard 36 (2003), which established that the company adopts various security requirements. They are

extremely important to the quality of life of workers. However many requirements are in non-compliance with the standard.
The first approach to standard regulatory 36 (2003) to be analysed is on the furniture and jobs. The company complies with most of the items related to this topic, but also has some non-conformities.
The company adopts requirements as work surface height and features compatible with the type of activity to perform by employees, dimensional characteristics of jobs that allow the placement and movement of body segments properly and work area within the manual range area, in order to avoid the adoption of inappropriate postures and excessive range of motion.
The company also offers to workers who perform their activities exclusively on foot, enough legroom and feet at the base of the work plan in order to allow for maximum approximation thereof to the operating points, avoiding the adoption of extreme positions.
The jobs are also suitable, because they have floors with non-slip characteristics, constant cleaning and environmental hygiene, and provide flow of water and waste system.
Finally, still according to the conformity of the standard 36 (2003), the company has devices that enable the opening of the doors from the chamber through the interior without much effort and alarm which can be activated in case of emergency, ensuring the reduction of risk of accidents to workers that location.
Regarding the non-compliance of securities and jobs, the standard defines the benches, treadmills, Norias, tables or machines must have no sharp edges. There are sharp edges on all sides and equipment, generating constant risk of accidents, injuries, injuries, infections and illnesses to workers.
Also according to the furniture item and jobs, it found that the refrigerator does not have seats or benches near the workplace to the allowed breaks, which provided, since all activities in the refrigerator made exclusively standing. Disagreement with this item of the rule can bring serious damage to the worker, since it can result in serious injury due to static posture of the lower limbs. It also found that the areas of work and movement sized to allow the safe movement of people and materials needed to perform the service.
Due to bad environmental design, employees often have to pass beneath pallets and platforms to perform transportation of materials and tools necessary craft appropriate to them, which generates a very high risk of accidents and submit the employee adoption of postures, damaging your health and your well-being.
Anyway, according to this topic from the norm, jobs must have weather protection when activities occur in the outer area, which does not occur, since, especially in the unloading of animals, the place has no signage. The company does not offer collective protection equipment and no employee has personal protective equipment, leaving them at the mercy of possible accidents that caused by animal handling still alive.
The next topic in the standard regulatory 36 (2003) concerns the platforms, walkways and platforms. The same shows only conform to the norm, since the company uses suitable pallets will then work plan with dimensions, depth, width and height to allow safe handling and platforms with height, positioning and sizing to ensure safety worker.
The fourth item of NR 36 (2003) points out the specifications for the handling of products, and establishes specifications and dimensions for transport systems, in order to avoid the adoption of excessive and sustained postures of the upper limbs and neck.
The standard also stipulates the implementation of control measures to refrain workers from prolonged exposure to vibration and immersion or constant contact of the hands of the same with water.
The company adopts both points discussed above in order to ensure comfort and safety to employees who carry out activities directly related to the handling of products.
Nonconformities this topic are inherent in the implementation of control measures in order to prevent effete workers continuously and repetitively sudden movements and overuse of muscle strength. However, what the norm provides contradicts what done in the refrigerator, where employees need to resort to using excessive force to perform the animal carcass transportation to the cargo truck, and the same activity requires movement's sudden and high impact on the shoulders, neck and back due to the large load to transport.
The standard also mentions measures adopted for the lifting and transportation of goods and cargo, in this regard, the company has a greater number of non-compliances than compliances, and the only line is on the floors and walkways, which hosts withdrawals, transport and loading weight, which are in perfect condition.
Regarding non-conformities, the first of this topic deals with the technical and organizational measures that the employer must undertake to provide the means to reduce the need for constant

manual loading of products and loads of great weight. However, we realize that this requirement does not apply because the fridge does not have a measure or means to reduce the effort made by the worker, especially in the clean animal transportation for cargo trucks.
The second non-compliance refers to those activities, in accordance with the standard; they performed so that the employee's physical effort is consistent with their strength capacity, safe and healthy way. This does not observe, since the load, transported on-site service is much greater than the individual capacity, since the physical effort is visible through the facial expression and body behaviour of workers to perform the activity.
Already as a third point, there is the ergonomic analysis of the work, which aims to assess the compatibility between the permissible efforts and adopted by employees in the heavier activities. The company's manager does not hold that, since workers adopt postures and transport loads very inadequate for the type of office held by each, which avoided through this analysis, which provides results that help in taking corrective and preventive measures aimed at the welfare of the worker.
The task switching between employees or adequate breaks for the manual loading of work is the fourth and final topic not as the norm related to lifting goods and loads. The same is not met given that does not happen any turnover among workers and breaks not respected, leaving workers in the same position and without pause throughout the workday.
The reception and unloading of animals is another important item which is also present in the standard, and on which the company adopts requirements consistent with the provisions of the latter. The box of stunning animals is one of those items, and allocated to ensure the safe execution of the activity, as well as having restraints in the event of faulty stunning.
Already based on non-compliant requirements, the standard deals with the planning and organization of activities, which shall comply with requirements concerning the guidance of contractors about the occupational hazards. As well as information on prevention measures at work with live animals, where the company must provide to workers who deal directly with the reception and unloading of animals specific procedures and safety rules. The signage in the areas of passage of animals, vehicles and people and the protection of jobs against weather, with circulation walkways for workers alongside or above the platform are also the company's responsibility.
As could be observed through the workplace analysis, none of these met, since the workers do not receive any specific instruction or procedure on the activities developed by them, getting the mercy of the environmental risks posed by the environment.
The seventh item addressed by standard regulatory 36 (2003) relates to machinery, and the company has only non-compliance in this regard.
One of the requirements contained in it is about the use of emergency stop devices, where they do not find in the refrigerator, causing major accident risks to workers, as the stop devices are an important measure of safety and prevention.
Another condition imposed by the standard, but it is not adopted by the company is the use of control measures to protect against issuance or release of physical, heated fumes from machinery and equipment, and worker contact with hot surfaces. Employees do not have any protective equipment is individual or collective, and the company does not keep track of risks.
Regarding the use of equipment and tools, which is the eighth topic of the standard, there is a balancing enters the compliant and non-compliant measures have adopted by the refrigerator.
Items related to the provision of equipment and tools, favouring the adoption of appropriate postures and movements and ease of use comply with the standard, as well as knives, the company offers and that are appropriate for the tasks and hand workers with formats suitable for each function.
Also present agreement with the NR 36 (2003), tools and equipment in the item specification and suitability for each type of activity, being the same as light as possible and with constant maintenance system.
In relation to non-concordance with the eighth topic of the standard, are present items relating to training and employee orientation, which should, but does not happen in no time from work the employee inside the refrigerator in order to enable them to exercise its function safely and healthily.
Grounding and periodic reviews of wires and cables an item in the standard that is not being done by the company. This procedure is extremely important because it allows the prevention of the risk of serious and fatal accidents involving electricity, as well as the protection of employees, bringing comfort and safety to the desktop.
Finally, employers must educate supervisors about the importance of restoring the sharp knives, and the company about it verified the non-adoption of this measure through interviews with employees who claimed to know about the importance of restoring the sharp knives, but without education.
The environmental working conditions provided for in NR 36 (2003) are noise, air quality in artificially climate-controlled environments, chemical agents, biological agents and thermal comfort. Since the

studied company are irregularities in relation to noise, biological agents, chemical agents and thermal comfort.
Regarding the noise officials responsible for weighing pigs and forward them to the corridor that leads to the location where they will be slaughtered report that the noise is a factor that bother them during the period of the slaughter that lasts four hours. The company has no program to reduce worker noise during exposure time, and employees do not use any personal protective equipment in order to mitigate the damage caused by excessive noise they exposed.
All employees involved in the slaughtering process from what is responsible for weighing up which removes the animal's carcass viscera, are susceptible to biological hazards due to the high contact with swine or the carcass of it.
The company does not carry out any study to identify potential pathogens, the means of transmission does not offer any training or information about them, and the employees do not use gloves.
The company uses ammonia in the refrigeration process, but does not follow most of the measures of collective prevention to adopt due to the use of this chemical agent, which are maintaining the environmental concentrations to the lowest possible levels, implementation mechanism for detecting leaks, control panel installation of cooling system and signalling emergency exits.
The employee responsible for passing the torch in the animal housing back subjected to excessive heat, as noted in Figure 10, and the worker who directs the animal's carcass until the cold chamber exposed to a very low temperature. Both report that these two situations create discomfort for them, using no personal protective equipment or adequate equipment compatible with the room temperature and the activity performed, as the company does not perform this analysis. Furthermore, there is no task switching, searching for the reduction of employee exposure to heat in handling the torch, and is followed by four hours exposed to this elevated temperature.
The company does not provide for employees no hearing protection equipment, gloves and no proper attire to the local temperature and available as established by standard garments that can change daily with sanitation being this employer; they can replace when it is necessary and the company supplies more than one-piece dress meeting the hygienic-sanitary characteristics.
In relation to risk management the employer does not put into practice any planned approach, structured and comprehensive prevention through the management of risk factors Safety and Health at Work and has no program evaluation actions, control and monitoring of risks.
The company has no program for the prevention of environmental risks and medical control of occupational health. Thus, there are technical and administrative controls of noise exposure, periodic monitoring of exposure and control measures, training and information to employees, determination of personal protective equipment and no history of occupational diseases worker.
Employees do not realize breaks during the work lasts four hours. Therefore, the company does not comply with item 36.13 of NR 36 (2003) which states that for workers who develop activities performed directly in the production process, from receiving to shipping. They are also required repeatability or static muscular overload or dynamics of the neck, shoulders, back and arms and legs, pauses must assure twenty minutes for up to six hours of work.
With regard to the way the company organizes the work, they are not adopted technical engineering measures, organizational and management in order to eliminate or reduce risks. The employer does not implement casters within the working hours, which is extremely harmful to workers because it does not provide for change the sitting position to standing posture. In addition, it does not help to minimize the most frequent static and dynamic forces and does not allow the worker alternating with activities of environmental exposure to noise, humidity, cold and heat more comfortable. The company carries out according to the rules established by the standard cleaning of the tables and has a number of workers compatible with the demands and production requirements.
The company does not perform ergonomic analysis of the work and does not follow any of the following rules established by the standard: discussion and dissemination of results with workers and their supervisors, specific ergonomic recommendations for activities performed, evaluation of interventions carried out and evaluating the effectiveness of recommendations.
Employees do not receive any information on the risks related to work, their potential causes and the effects that these cause health thereof, as well as the recommended prevention measures for each activity. Control measures are also not report for workers.

Workers are not subject to the postural changes that help prevent musculoskeletal overload and reduce fatigue and they do not informed about the use of personal protective equipment and its limitations. They do not well informed about the chemical, physical and biological agents to which they are exposed, the biomechanical risks, risks from machinery and its components and precautions concerning communicable diseases. They also do not receive annual recurrent training, which according to NR 36 (2003) should be at least two hours.

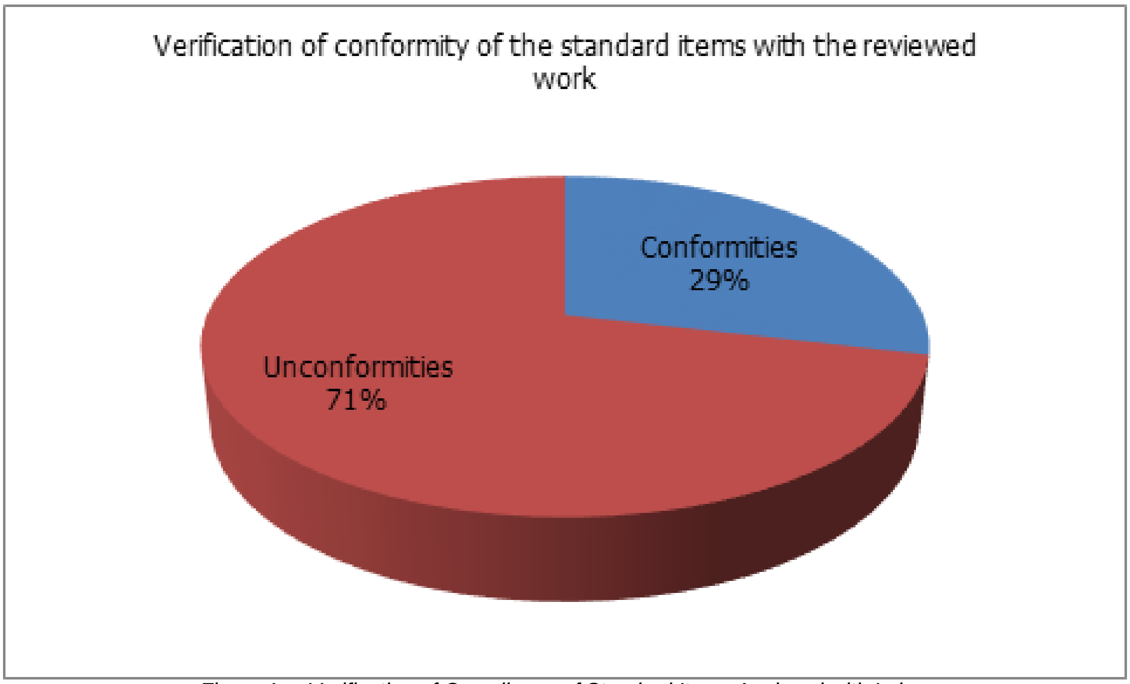

Figure 1 – Verification of Compliance of Standard Items Analyzed with Labor.

The results found in this study are willing, in Figure 1, below which translates into figures the percentage of items that were analysed (101 items), which comply with the provision in question (29 items) and which do not conform (72 items):
Thus, according to it seems it is clear that the company does not follow most of the rules established by the standard regulatory 36 (2003).

4. CONCLUSIONS

Through the study of the principles established in the standard regulatory 36, along with the observation and analysis of the work environment, we found that the company analysed presents both compliance, as non-conformities with the standard.
As compliant, it adopts important requirements, and in relation to platforms, walkways and platforms the company meets all requirements of the same, thus offering greater security for workers to carry out the refrigerator activities.
Regarding the non-compliance, it was found that it does not practice most of the requirements set in the standard regulatory 36 (2003), particularly with regard to machinery and temporal organization of work, which do not have any as.
It conclude that even now adopting various requirements compatible with the standard, the non-conformities are in a much higher number, bringing risks to health and worker safety. Failure to comply with the requirements established by this standard increases the chances of the employees of this company to be victims of accidents and long-term contracting diseases because of inadequate working conditions. In addition, the incorrect way employees perform their activities can cause accidents and the company needs to take responsibility and can suffer financial losses and be subject to lawsuits.

5. REFERENCES

BRAZIL. Ministry of Labor and Employment. NR-36 Safety and Health at Work in slaughtering and processing enterprises of meat and derivados.Brasília: Ministry of Labour and Employment, 2003.Disponível at: <http //: www.guiatrabalhista.com.br/legislacao/nr/nr36 .htm> Accessed on: November 10, 2014.
YIN, RK Case study: Design and Methods. 3. ed. Porto Alegre: Bookman, 2005.

Latest findings and innovations in EU specific psychosocial risks regulation

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Abstract
A strong effort is to be done by engaging psychosocial factors with our working conditions framework, where uprising of mental disorders and psychosocial illness and diseases actually brings and will bring in a short future new challenges for workers health, safety and wellbeing. Our actual legal range shouldn´t stop in social security compensation, it should focus on a complete and holistic compensation of the harm suffered (including in personal aspects such as dignity, integrity, workers honour and non discrimination practices). This whole approach is nowadays necessary from EU policies, but it's also an issue to be faced by non-legislative instruments.
In this paper we may see some good examples of countries that are trying to adapt their national regulation to their working conditions framework to face regulation in a climate of general deregulation, representing how psychosocial regulation is evolving to a new concept.
EU latest drafts on occupational health and safety policy are still not tackling properly these contingencies. Social dialogue at different levels and professionals, EU regulation adaptation and business involvement is more than ever required. Further developments and research in this topic should continue, especially in countries where policies are still less developed.

Keywords: Regulation; Psychosocial, Compensation, EU Law, Working conditions.

1. INTRODUCTION

Background
The safety and health at work is regulated by the EU Framework Directive which was adopted in 1989. The law obliges employers to put in place measures to protect workers against accidents and diseases.

EU countries are required to implement the Directive in their national law but in this paper I will refer those who have chosen the most appropriate method of achieving the Directive's goals in tackling with psychosocial factors in the last years.

In addition, the European social partners signed Framework Agreements on Work-related Stress in 2004 and on Harassment and Violence at Work in 2007 which today become inefficient to face the complexity of these factors in working conditions.

The European Commission strategy Europe 2020 makes employment and workers' well-being a priority, including psychosocial protection. To better protect the more than 217 million workers in the EU from work-related accidents and diseases, the European Commission has adopted a new Strategic Framework on Health and Safety at Work 2014-2020, which identifies key challenges and strategic objectives for health and safety at work, presents key actions and identifies instruments to address these.

One of the main goals to achieve is to improve the prevention of work-related diseases by tackling new and emerging risks without neglecting existing risks

The Strategic Framework identifies three major health and safety at work challenges:

- Improving enforcement by Member States for example by evaluating the performance of national labour inspectorates.
- Simplifying existing legislation where appropriate to eliminate unnecessary administrative burdens, while preserving a high level of protection for workers' health and safety.
- Improving statistical data collection to have better evidence and developing monitoring tools.

This new strategic framework was an incredible opportunity to tackle psychosocial factors from a legal and regulation aspects, nevertheless EU legislation is far from solving this problem, community regulation hasn´t face this question properly; that's why a legal-regulation psychosocial risks definition can´t be found if we study EU Justice tribunal psychosocial related latest declarations except for EU mental stress agreement and violence harassment Directives.

The actual strategy follows the indeterminate strategy of not going deeper into the problem it just tackles with general concepts such as simplifying existing legislation (where most of the times psychosocial issues are not treated) or by improving statistical data, as we may see one of the main issues of psychosocial diseases are its mis-declaration (report cases of certain diagnosed reportable diseases which are linked with occupational exposure to specified hazards).

The potential consequences of psychosocial burdens (pressure, isolation and loss of social support, new communication technologies, flexible working time, impossible deadlines, restructuring…) include cardiovascular diseases, musculoskeletal disorders, dermatologic problems, suicide, relationship problems with colleagues, family and social networks, and increased risk of violence, with consequences for both physical and mental health. In the medium term, companies suffer from absenteeism due to lengthy illnesses, and turn-over and productivity are damaged. It's not anymore an issue just related to harassment and violence at work as main EU regulation cover.

Innovative regulatory approaches, challenges and developments in EU regulations beyond EU Directives. Psychosocial regulation in Belgium:
Recent changes defines psychosocial risks range from an innovative point of view, putting them on the same level as traditional risks; it defines the key actors role associated to this issue, and modifies the intern procedures related to intervention, complaint and refers to victims possibility to ask for a compensation when infringement occurs.
The original regulation figures as follow (come into force 1st September 2014):

Act 28 February 2014 Wellbeing related to violence, sexual and moral harassment Act 28 March 2014
Order April 2014 related to psychosocial work related risk prevention.

Even if it may seem surprising, this regulation puts end to the indetermination that have ruled in the latest national European regulations (EU framework exception, where this definition is more specific) in psychosocial risks/diseases definition.
That´s why this regulation considers a new definition of what it´s understood as work psychosocial risks, not limiting the ambit of the definition to aspects associated with work-related violence such as mobbing or harassment.
This innovative regulation becomes more familiar with Nordic countries legal treatment, by defining with accuracy the key actors and their role in the business structure.
Sexual and moral harassment treatment also suffers several changes, according to justice reparation and compensation economic terms. These aspects widely develops European legal framework when talking about workers protection.

Key roles are better defined: this regulation defines the role that should play managers, Health and Safety Committee, safety practitioners, and work health professionals. The whole related participant integration is developed, while most of EU countries are still obsessed in health and security business integration this Belgium regulation as well as Nordic countries regulation go ahead by focusing the key participants and its roles within business organization.

It's also defined a new role known as "confident person" who will informally participate in the processes. A formal intervention mechanism will be set up (professional advisor participation that will analyse the situation, will report and make a proposal during the process) and informal intervention (interviews, conciliation, third parties involved).
In this integration and key actors definition technical training will be highlighted, as we may see in other regulations there's always a lack of training in related actors (psychologists, health professionals, etc…)

Workers compensation will also be improved in terms of violence and sexual harassment legal claims, by improving the compensation terms for moral and material harms. European and main national security systems framework also lacks of this legal treatment when talking about compensation, reparation and protection where the issue had been tackled partially and unequal.

Psychosocial regulation in Denmark:

Working on this whole approach concept, this regulation will include prevention of violence against workers outside of working hours and workplaces, adapting their regulation to new forms of work (glocalisation, new models of work and organisations)
A law enacted on 1 February 2015 will oblige employers to prevent the risks of violence perpetrated by people outside the firm against their employees, outside of their working hours and workplaces.
The functions performed by the employee, especially if, as part of his duties, the employee takes decisions that could have very significant consequences for customers, private individuals or users.
Nordic countries such as Denmark have in recent years emphasised that employers must also be aware of the use of digital platforms in their business and they should have an active policy on the prevention of sexual harassment using such media. They should also have clear procedures for dealing with cases of sexual harassment and threats via digital platforms
Cyberbullying is an emerging issue because of the increasing pervasiveness of ICT and mobile devices in the workplace. New forms of work and jobs are obliging to include cyberbullying as one new form of violence and harassment at work.

Croatian Psychosocial legislation:
A new law has introduced measures to protect people from stress at work in Croatia.
As Eurofound refers the Law on Occupational Safety (OG 71/14) came into force on 19 June 2014. It has a similar structure to the previous Law on Safety at Work adopted in 1996.
This is the first time in Croatia that a law has introduced measures to protect workers from psychosocial risks (stress) and psychophysiological strain at work.
The act introduces a general principle of risk prevention and protection of health at work. It brings in rules on the elimination of risk factors, procedures for the training of workers and procedures for providing information and consultation.
This regulation has appeared to fight the actual framework that places the country as one of the EU partners with the highest number of workers who perform monotonous and repetitive jobs. Almost 65% of their labour force is involved in such tasks every day.

United Kingdom Psychosocial non-legislative approach:
The way we work is changing and in-demand skills such as teamwork, collaboration, joint problem solving, flexible, lone working and staff development all require employees who are mentally healthy, resilient, motivated and focused. Open and supportive workplaces benefit everyone; employees, employers and the bottom line.

Mental Health Campaign and Business agreement: *We're ready to talk. Rethinking the approach to mental wellbeing in the workplace*. Time to Change is England's biggest programme to end the stigma and discrimination faced by people with mental health problems. Over 200 organisations have made a public commitment to tackle mental health stigma.

This innovative business agreement tries to overcome the regulation barriers in this issue. Yet there remains a culture of silence around mental health at work and businesses are reluctant to report publicly on the proactive steps that are being taken to foster mental wellbeing. Employers and employees are unwilling to talk about stress, anxiety and depression openly hiding an issue with economic, health and legal consequences.

2. MATERIALS AND METHOD

EU Strategic Framework on Health and Safety at Work 2014-2020 EU framework directive (89/391/EEC)
EU mental stress agreement and violence harassment Directives EU national regulations

Literature review and legal compared analysis.

This paper is placed within a PhD Project related to a law comparative researching project in the exciting area of psychosocial work related illness and risks under University Carlos III and IOSH Institution of Occupational Safety and Health collaboration and support.
This paper work may entail national and international expert contacts, it will also imply a deep legislation study including several countries; it will also require an immersion through different legislation, judicial sentences and legal or courts affairs.

3. RESULTS AND DISCUSSION

On 6 June 2014, the European Commission adopted a Communication on an EU strategic framework on health and safety at work for the years 2014-2020. It shows new emphasis on work-related diseases, tackling new risks but the treatment is as complete as it should considering that we are talking of a 6 years strategy. The new strategy will also grant specific attention to the impact of changes in work organisation on physical and mental health which could result in psychosocial work related disorders, stress, anxiety and depression, nevertheless it only cover general issues lacking a deeper analysis.

As EUOSHA states, nature of many of the complex interactions between work-related psychosocial risk factors, risk behaviours and chronic diseases and health conditions, including occupational diseases and disorders, is not well studied or understood. A better understanding of the links between work related psychosocial risk factors and morbidity and mortality is needed for the development of evidence-based policies and effective prevention strategies. Further research in this issue will be needed in the following years.

At the moment we are attending to new work processes which turn into new work related illness, where victims are totally unconscious till nowadays, related to emerging psychosocial risks produced by work environments deterioration when pernicious practices arises such as violence at work, mobbing, harassment or stress factors. Taking this for granted it may be understand, though not justify, the unsatisfactory work related illness protection and regulation, the updating lack, concerning to occupational illness list, and its lack of adaptation to technological changes, new ways of work, new productive processes and new psychosocial risks.

There´s an urgent necessity to adapt the actual occupational illness list to the theoretical or ideal occupational illness system according to EU criteria, by updating the list and establishing not only a mandatory list but a complementary or optional list in order to consider these kind of psychosocial risks as occupational illness.

4. CONCLUSIONS

Nowadays none of the EU countries has specific regulations on work-related stress, but all countries general legal frameworks refer to psychosocial risk factors that are the cause of work-related stress. In some countries, the legal provisions go further than the framework directive but specifying the need for employers to act against factors considered to be psychosocial risks that cause work-related stress. This is the case in Belgium, Denmark, Germany, Netherlands and Sweden.

Analysing Health and Safety at work 2014-2020 framework it doesn’t represent from legal scope the strong OSH strategy that Europe needed in terms of psychosocial knowledge.
More efforts on development of psychosocial factors regulation are required. Despite the EC Strategic Framework 2014-2020 focuses in better protecting workers against traditional accidents at work and occupational diseases, it still doesn’t tackle breaking down European legislation in psychosocial aspects.

The Commission’s traditional action try to avoid making any legislative proposal in psychosocial risk regulation until the evaluation of the entire body of EU OSH legislation has been completed. This delay have provoked a legislation blocking as a result which will not benefit EU working conditions scene.

According to EU authorities, work-related diseases linked to psychosocial risk factor, won´t collect enough scientific evidence in order to be admitted in the privileged occupational illness catalogue regulated by a list, open or close system.

It can´t be denied that this EU legal debate is associated to a great concern to fix this issue to the emerging social reality and for the latest years solutions had not appeared from EU Commission.

5. ACKNOWLEDGMENTS

Since EU has adopted more than 24 directives on the OHS aspects of specific risks at work it's true that psychosocial regulation development it's actually paralysed. Framework Agreement on Work-Related Stress, Violence, Directive 89/391/CEE, 93/104/CE, 2003/88/CE are becoming "old fashioned" regulation to actual times. That's one of the main reasons that national regulation countries are improving their legal framework to adapt their labour markets necessities.

6. REFERENCES

BITC Workwell, Public Reporting Guidelines www.bitc.org.uk/our-resources/report/bitc-publicreporting-guidelines-employee-wellness-andengagement

2014 BITC Workwell FTSE 100 Benchmark findings www.bitc.org.uk/our-resources/report/ftse-100-publicreporting-wellbeing-and-engagement

2015 Workwell Public Reporting Benchmark www.bitc.org.uk/programmes/workwell/public-reporting

Workwell Benchmark Support Programme www.bitc.org.uk/programmes/workwell/reportingworkwell/public-reporting-benchmarking-supportprogramme

Centre for Mental Health www.centreformentalhealth.org.uk/employment/presenteeism.aspx Health and Safety Executive Guidelines www.hse.gov.uk/pubns/indg163.pdf

Mind www.mind.org.uk/work

Time to Change www.time-to-change.org.uk/bitc

NHS Health at Work www.nhshealthatwork.co.uk/dhguidance.asp

Correa Carrasco, Manuel Accidente de trabajo, responsabilidad empresarial y aseguramiento, Editorial Bomarzo

Correa Carrasco, Manuel Acoso moral en el trabajo Concepto, prevención tutela procesal y reparación de daños. Thomson Aranzadi

Correa Carrasco, Manuel. Los medios de tutela frente al acoso moral en el trabajo. Editorial Comares.

García Jiménez, Manuel; de la Casa Quesada, Susana; Molina Navarrete, Cristobal. Regulación de los riesgos psicosociales en los ambientes de trabajo: panorama comparado de modelos y experiencias en Europa y América. Editorial Bomarzo.

Vallejo Dacosta, R. Riesgos psicosociales: prevención, reparación y tutela sancionadora, Pamplona (Thomson-Aranzadi), 2005

Lerouge, Loïc. Les risques psychosociaux, une analyse juridique comparée entre le Nord et le Sud de l'Europe (2012) Les risques psychosociaux en Europe - Analyse jurisprudentielle. Editeur : L'harmattan, Paris

Lerouge L. : (avec Naito S) « Harcèlement, "*Power Harassment*" et droit au Japon » *in* Lerouge L.(dir), *Les risques psychosociaux au travail en droit social : approche juridique comparée. France - Europe - Canada - Japon*, Dalloz, 2014 EU Occupational Safety and Health (OSH) Strategic Framework 2014-2020 http://www.eurogip.fr/en/projects/eu-official- documents-eurogip/3771-eu-occupational-safety-and-health-osh-strategic-framework-2014-2020

DENMARK: New regulations to prevent violence against workers outside of working hours and workplaces http://www.eurogip.fr/en/eurogip-infos-news?id=3954

BELGIUM: New legislation relating to psychosocial risks (PSR) http://www.eurogip.fr/en/eurogip-infos-news?id=3732 Croatia: Psychosocial risks mentioned in new health and safety at work legislation http://www.eurofound.europa.eu/news/news-articles/working-conditions-law-and-regulation/croatia-psychosocial-risks- mentioned-in-new-health-and-safety-at-work-legislation

Evelyn Kortum, Stavroula Leka, Tom Cox. Psychosocial risks and work-related stress in developing countries: health impact, priorities, barriers and solutions.

Eurofound (2015), Violence and harassment in European workplaces: Causes, impacts and policies, Dublin. Authors: Mario Giaccone and Daniele Di Nunzio, Associazione Bruno Trentin

Bruselas, 6.6.2014 COM(2014) 332 final COMUNICACIÓN DE LA COMISIÓN AL PARLAMENTO EUROPEO, AL CONSEJO, AL COMITÉ ECONÓMICO Y SOCIAL EUROPEO Y AL COMITÉ DE LAS REGIONES relativa a un marco

estratégico de la UE en materia de salud y seguridad en el trabajo 2014-2020

European Agency for Safety and Health at Work. ISSN: 1831 935 Priorities for occupational safety and health research in Europe for the years 2013–2020 Summary report – (updated Jan 2014)

CSEE ETUCE COMITE SYNDICAL EUROPEEN DE L'ÉDUCATION Région européenne de l'IE Position du CSEE sur le cadre stratégique de l'UE en matière de santé et de sécurité au travail 2014-2020

Safety as an Emergent Property of the Production System: Work Practices of High-Performance Construction Supervisors

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Abstract
Construction work involves many dynamic and hazardous processes that are adapted to the project-specific requirements and context. Combined with high production pressures and workload, these processes create high potential for errors and accidents. Successful operational performance requires both high production and high safety performance. Thus, a significant challenge for construction researchers and practitioners is to develop resilient production systems that are simultaneously highly productive and highly safe under the demanding, complex, and dynamic conditions of construction projects. Towards this aim, this study investigated the work practices and principles of exceptional field supervisors who consistently achieve very high levels of both productivity and safety. The research used a case study approach. In-depth field studies documented the work management practices of exceptional supervisors in four high-risk construction trades—residential framing, masonry, concrete, and roofing). In each case, these practices were compared with the practices of an average performing supervisor from the same organization. The findings indicate that the exceptional supervisors used a combination of strategies that aimed primarily at preventing errors, rework and incomplete work. Their strategies included: (1) task management strategies that mitigated the task demands on the workers, and (2) crew management strategies that enhance the work group's ability to cope with high demands. The findings provide significant empirical evidence that the production practices that prevent errors are essential in preventing accidents, as they create "high quality work assignments." As a result, the safety performance can be considered "an emergent property" of the production system.

Keywords: construction safety; Production system design; High performance supervisors; Production safety trade-off; Production practices.

1. INTRODUCTION

Construction work involves dynamic and hazardous processes that are adapted to project-specific requirements and context. The very dynamic environment is considered a key feature of hazardous work environments (Scarf et al 2001). The hazardous work processes combined with high production pressures and workload, create high potential for errors and accidents. In 2013 the US construction industry employed 6% of all industries and had 20% of the fatal work injuries (Bureau of Labor Statistics 2015).

In the construction sector, compliance with safety standards are the most commonly considered antecedents of safety performance. Safety Management Systems (SMS) aim at preventing incidents by increasing the workers' levels of compliance with advocated safety conditions and behaviors (Garner 2004, Vredenburgh 2002). Safety Management Systems emphasize training, organizational support (such as management, resources, etc.), inspections and enforcement, and workers' motivation (Garner 2004, Manscini and Bacharias 2012). Safety culture and behavior-based safety also aim at increasing the workers' compliance with safety rules and procedures (Choudry et al 2007, Cooper and Philips 2004, Gundelmund 2007, Flin et al 2000). This approach to safety has contributed to the reduction of accidents, but it also has limitations as it neglects the important role of production processes in the production of accidents.

Successful operational performance requires both high production and high safety performance. Thus, an important challenge for construction researchers and practitioners is to develop production systems that are highly productive and safe, and can function effectively in the dynamic and complex conditions of construction projects—in other words, they are resilient.

In construction, the organization of the production is typically performed by field supervisors (a. k. a. foremen) who operate within organizational, financial, and project constraints. The supervisors determine to a large extent the work structure, task allocation, sequencing, workload and pace, work coordination, controls, etc. In order to identify production practices that support both high production and high safety performance, this research investigated the work practices of exceptional field supervisors—that is supervisors who consistently achieve very high levels of both productivity and safety.

2. BACKGROUND

2.1. Safety paradigms

Rasmussen and colleagues (1994) identify three paradigms of safety research: (1) normative paradigm, (2) human error paradigm, and (3) the cognitive engineering paradigm. **The normative paradigm** focuses on prescriptive theories concerning the way people ought to act with regards to hazards. Efforts to prevent occupational accidents focus on safe rules of conduct. **The human error paradigm** focuses on deviations from the normative, "best way" of working, and views errors and violations as a human "malfunction." This paradigm includes studies of errors (Rasmussen et al.1982), management errors and resident pathogens (Reason 1990). **The cognitive engineering paradigm** is concerned with the characteristics of the work system (the features of the task, tools and operating environment) that shape the decisions, behaviors and the possibility of errors and failures (Rasmussen et al. 1994, Woods and Wreathall 2003, Hollnagel 2009, Dekker 2006). From a cognitive perspective, an error is not simply a human failure but a symptom of a problem in the work system. The cognitive approach to safety attempts to prevent accidents by designing work systems that are adapted to people and avoid operators' overload and errors.

In construction, the primary approach to accident prevention is based on the normative paradigm and focuses on compliance with rules and procedures. Safety programs focus on the control of hazards and aim primarily at compliance with safety rules though training, inspections and enforcement, management support and workers' motivation (Garner 2004, Manscini and Bacharias 2012). Efforts towards safety culture and behavior-based safety also aim at increasing the workers' compliance with prescribed hazard controls (Choudry et al 2007, Cooper and Philips 2004, Gundelmund 2007, Flin et al 2000). This approach has contributed to the reduction of accidents, however it also has important limitations as it does not address the important role of the production system in the production of accidents. For example, compliance with safety requirements is influenced by the production system elements that shape the work situations and worker behaviors (McLain and Jarrell 2007; Mitropoulos et al. 2009, Mitropoulos and Memarian 2013, Veltri et al 2013).

2.2 Influence of production system on safety

Safety and operations have developed separate areas of research, and the interaction of operations and safety has received limited attention. However, conflicting safety and production demands can negatively affect production, safety or both. Production–safety trade-offs are an important element of the safety of production operations (Hollnagel 2009, Rasmussen 1997, Reason 1997, Mikkers et al 2014). Production employees make many large and small trade-off decisions every day (Woods et al 2010). Woods and Wreathal (2003) call them "sacrifice decisions." Hollnagel 2009 refers to the "Efficiency-Thoroughness Trade Off" (ETTO). The safety climate literature also recognizes the trade-offs between safety and production (Zohar 2000, Ford and Tetrick 2008, Das et al. 2008). Zohar (2000) posits that there is a trade-off between production goals such as quality improvement and cost reductions, and safety goals such as accident reduction. Ford and Tetrick (2008) argued that workers either avoid errors or maximize production by taking short cuts and working around the safety system to meet production goals. McLain and Jarrell (2007) found that reduced compatibility between production and safety demands influences safe work behavior.

From a cognitive perspective, Rasmussen et al. (1994) describe how the production system shapes the behaviors and performance of the individuals in the system. Workers' behaviors tend to migrate closer to the 'boundary of loss of control' due to the production pressures for increased efficiency, and the tendency for least effort, which is a response to increased workload. Safety programs attempt to counter the above pressures and prescribe "safe behaviors" away from the boundary. However, the continuous pressures due to efficiency and workload result in a "systematic migration toward the boundary of acceptable performance (Rasmussen et al. 1994).

The construction literature provides extensive evidence that the production system has a strong effect on safety performance. Suraji et al. (2001) argued that project conditions, design decisions or management decisions can cause responses that may lead to accidents. Hinze and Parker (1978) suggested that job pressures are more important than safety policies in preventing accidents. Studies of construction operations identified how project features and production practices influence the level of task demands on the workers (Saurin et al. 2008, Memarian & Mitropoulos in press).

The literature recognizes the potential conflict and trade-offs between production and safety. However, successful project performance requires achieving both efficient production and high levels of safety. Research in operations productivity and safety are typically conducted independent of each other and their interaction has received limited attention. As a result, there is significant lack of studies on the practices that support at the same time both safety and production.
The aim of this study is to investigate what production and safety practices support both high production and high safety performance. The approach used was to identify exceptional supervisors in high-risk construction trades who consistently achieve high levels of production and safety, and investigate how they organize and manage the production system—including their production practices, safety practices, crew management practices, etc. The practices of these supervisors successfully manage or mitigate the efficiency-safety trade off in their operations.

3. METHOD

The practices of exceptional supervisors were investigated using in-depth field studies of selected supervisors. The practices of each exceptional supervisor were compared to the practices of an average-performing supervisor from the same contractor. This involved extensive observations, interviews and discussions with many project participants (supervisors, workers, managers, safety professionals, etc.).

3.1. Research Activities

To identify exceptional supervisors, each participating contractor evaluated their supervisors based on the following: (1) Safety incident rate and severity over the previous three years, which was calculated based on the labor hours each foreman supervised, the number of incidents that occurred under their supervision, and the direct cost of incidents. (2) Production performance during the previous three years. This was evaluated using actual cost data (if available) or subjective data using the evaluation of the foremen by the company's operations manager. The assessment was based on the difficulty of the projects the foreman managed, and the foremen's productivity and schedule performance.
Interviews with the operations manager and safety manager were conducted to understand the organizational context, including the safety management policies, hiring policies, foremen and crew training, compensation and bonuses, work method selection, and foremen's level of decision-making regarding the work process. Safety incidents over the previous three years were reviewed to identify hazards and high-risk activities.
After securing the necessary permissions, the researchers performed extensive field observations and interviews with the selected supervisors, their crew members and other project personnel. About 20 site visits were conducted for each trade, including observations of average performing foremen. Operations were observed and often videotaped. The foremen were interviewed multiple times regarding all aspects of the work organization.

3.2. Cases

The study focused on trades with significant safety risk, as reflected in high rates of injuries and fatalities. This paper summarizes the findings from (1) residential framing, (2) concrete and (3) masonry supervisors.
The residential contractor employed about 85 framing crews. All crews performed very similar work in terms of complexity, size and schedule. The exceptional foreman was the one with the highest production score and zero incidents. The average foreman had productivity slightly above average, and incident rate just above the company average, and average workers' compensation cost. Both crews had 7 crew members.
The masonry contractor performs residential, commercial and industrial work. The company employed more than 700 workers including about 60 foremen. The exceptional foreman was observed on a large project that involved several buildings. Another foreman was also on this project. Each foreman was assigned different buildings and each had a crew of 45-55 workers (2 masons to 1 laborer). The project had a complex design and an accelerated schedule.
The concrete company was a large contractor who performs primarily commercial and industrial work. The contractor had about 20 supervisors. The selected supervisor was observed on a project that involved the construction of a 10-story office building, with a cast-in-place concrete frame and post-tensioned concrete slab. Each floor was 2,500 Square Meters. The design complexity was low. The main challenges were the tight schedule of 13 weeks and the high

temperature. The supervisor was in charge of the entire concrete operation that included a deck crew (19 members), a wall crew (9) and a night crew (8).

4. FINDINGS

Table 1 summarizes the key findings from the cases, which include: the guiding principle, a set of task management strategies, and a set of crew management strategies. The findings indicate that the primary focus of exceptional supervisors was to prevent errors, rework and incomplete work. All their practices and strategies supported this guiding principle. Their strategies mitigated and balanced the demands of the task, as well as the capacity of their crew. An unexpected finding was that the safety practices of high-performance foremen did not always involve extensive control of hazards and exposures.

Table 1. Production practices of high performance supervisors

Guiding principle	**Prevent errors, rework and incomplete work**
Task management strategies	• Organized the process for speed by completing smaller batches of work, overlapping activities and managing the dependencies. • Actively looked for production difficulties and risks, while the average supervisors operated largely based on repetition (do as before). • Simplified and standardized the activities to reduce complexity and physical demands. • Prepared the activities in detail to avoid production surprises and interruptions. • Mitigated the production pressures on their crews to prevent rushing and errors.
Crew management strategies	• Secured adequate manpower. • Kept the crews informed and focused. • The task assignments matched the crew capabilities with the demands of the operation. • The task assignments balanced the need for efficiency with workers' learning and development. • Continuously monitored for errors, threats and difficulties, and responded fast to excessive workload and problems.

3.1. Guiding principle: Focus on preventing errors, rework and incomplete work

All high performing foremen had a strong focus on preventing errors, rework and incomplete work. For the framing foreman, the largest productivity losses happen when he has to go back and fix something. The masonry foreman emphasized that it is critical to have everything correct when he is finishing each area. Problems and mistakes are identified and corrected immediately and he rarely had any punchlist items. For the concrete supervisor, it was critical to avoid mistakes and delays, and to complete all the planned activities every day, in order to meet the aggressive schedule. This emphasis on avoiding mistakes and rework guided most of their work practices.

4.2. Task management strategies

4.2.1. Organized the process for speed

The foremen organized the work process for speed by reducing the batch size, overlapping operations, and managing the dependencies. The masonry foreman divided the crew in smaller groups, who worked at different locations on the same floor. He focused on completing each area fast by assigning several masons in one area—masons were working closer together, which also reduced their walking "empty-handed. To accelerate the concrete operation, the supervisor divided each floor in two sections so the deck and walls operations could overlap. This overlapping created new resource dependencies: the concrete crews and crane. Each operation was assigned to a different crew so they could proceed independently. The dependency due to the crane was managed with better planning to reduce the number of lifts, and allocate the crane time to the different crews.

4.2.2. Anticipated threats and difficulties

The HR foremen were constantly looking for potential problems—difficult work areas, missing resources, coordination difficulties, mistakes and omissions. The framing foreman was always looking for details or options that his crew was not familiar with. He discussed them with the crew and asked them to wait for him before they start working on those **a**reas, to prevent errors. The masonry foreman was checking for complex block patterns, penetrations, and changes in the block that the crew needed to be aware of. The concrete supervisor was considering the potential difficulties of every activity, and actions to reduce them.

4.2.3. Designed the activities to reduce complexity and physical demands

The foremen were looking for opportunities to simplify and standardize the work methods. The concrete supervisor selected methods and components that required less onsite assembly (aluminum tables configured for ease of installation), and less measuring and cutting ("Z metal" for the beam forms). He had the crew pre-mark the table legs to reduce measuring and prevent errors. When a wall involved complex block patterns, the masonry foreman had the block laid out in the correct order, to reduced complexity for the masons and prevent errors.

To reduce physical demands, the masonry foreman raised the scaffold more frequently to reduce cutting block due to rebar. The concrete crew used rubber mallets that deliver a softer blow and reduce the workers' discomfort. The framing foreman had little discretion regarding the material, method or tools—even then, he was using longer than usual temporary braces for truss erection that made the installation easier. These strategies reduced the physical demands, and task complexity, which reduces the potential for errors.

4.2.4. Made extensive preparations to reduce disruptions and delays

All high performance foremen put significant effort to ensure that the crew had all the material and resources needed to perform the work as planned. This was critical in order to avoid interruptions and incomplete work. The framing foreman checked if the lumber, hardware and trusses packages were complete and that no components were missing. The concrete supervisor assigned crew members dedicated to preparing the material, equipment, tools, for the activities. The masonry foreman checking all the material delivered, "knowing" that there was always something missing. He was also checking if the crew had on the scaffold everything they needed—the right block (type and color) and mortar, inserts, wire, ties, projection pieces, lintels or steel beam with all stirrups, etc. According to the masonry foreman, the ability to prepare the activities determined the number of work areas where he could work.

4.2.5. Mitigated production pressures

To prevent excessive pressures and workload the high performance foremen: (1) Set realistic production goals and tried to establish a pace that was not rushed. Having adequate manpower was an important consideration. The framing and concrete foremen had the authority to determine their crew size, and emphasized low absenteeism. Absenteeism was high in the masonry operation—the crew was "over-manned" by the management which was very tolerant to absenteeism. (2) Prepared tasks ahead of time (organized material in the order needed, pre-measured and pre-marked) to reduce pressures during installation. (3) "Shielded" the crew from being rushed by the following activities. The framing foreman was ordering the crane with a small time buffer to prevent it from arriving early and rushing his crew. The goal of these practices was to reduce excessive workload, rushing and fatigue, and reduce mistakes. However, when high pressures could not be avoided, the close monitoring enabled fast adaptations.

4.3. Crew management practices

4.3.1. Secured adequate manpower

The crew management practices of the high performing foremen aimed at preventing excessive workload, rushing and mistakes. Preventing absenteeism was critical for the concrete crew, as they were under time pressure and working overtime, and every absence would mean excessive workload for the rest of the crew. Absenteeism was high in the masonry operation, where the crew was "over-manned" by the management which was very tolerant to absenteeism.

4.3.2. Kept the crew informed and focused

Crew planning was essential in keeping the crew informed and aware of their next step. Every day, the concrete crews reviewed the timetable, specifying what time each task had to be finished. The crew had a clear work plan which specified when, where, and how to do the work.

To keep the crew focused, the workers were assigned one task at a time. In the masonry crew, the foremen and leadmen had very clear plans about what work to do, and they crew had clear directions and production goals.

4.3.3. Task assignment matched capabilities with task demands

The task assignments balanced the demands of the task with the crew capabilities. In the concrete crew, task rotation was used for some physically demanding tasks. Tasks that required high accuracy (in areas with low tolerance) were assigned to the most skilled carpenters. A leadman with strong engineering skills was performing the layout. A dedicated grader was used to set the table legs at the correct elevations. In the framing crew, only the leadman and another carpenter were allowed to perform the high risk tasks (setting trusses and install the first row of plywood). The masonry leadman and foreman prepared and checked the layout, and a dedicated group of four laborers was responsible for the scaffold.

4.3.4. Task assignment balanced efficiency and learning

The task assignments also supported workers' development. The masonry foreman was assigning the same tasks to the new workers as the experienced workers, so the new workers can learn how to perform all tasks. At the same time, he was assigning an experienced worker to monitor and correct the inexperienced ones. He also gave opportunities to crew members to take more responsibilities (e.g. oversee the rebar). The framing foreman framed the complex details himself and used them as an opportunity to train his crew members. the In the concrete operation, because of the very high schedule pressures, the supervisor assigned tasks based on the workers' capabilities, rather than learning opportunities.

4.3.5. Monitoring and cross-monitoring

The exceptional supervisors had close monitoring of both the task performance (in terms of progress and quality) and workers' conditions (such as fatigue, frustration, attention). They established multiple checks especially for critical operations where errors would be very costly. The framing foreman double checked the walls before they were lifted in place, and personally released the trusses during truss erection to ensure they were installed correctly. For the masonry foreman, layout, block patterns and openings, and raising the scaffold were the activities with the high consequences of errors. He was continuously checking to identify and correct any mistakes before the crew left the work area. The concrete supervisor had established multiple checks for the elevation of the tables, and embeds, as well as several daily milestones to check progress.

Cross monitoring by the crew members was another strategy for identifying threats and difficulties. The concrete supervisor trained the crew to recognize the symptoms of dehydration and asked them to cross monitor each other for symptoms. Early recognition of mistakes and difficulties combined with a clear plan to address the problems made it possible for the crew to correct errors quickly or redistribute the workload. To prevent problems in one task affecting other tasks, the concrete crew was instructed to not stop their activity and help with production problems, but to notify the deck foreman immediately. The foreman knew the status of all tasks and redistributed the workload so that other tasks were not delayed.

4.4 Differences in safety management

Although all three supervisors had excellent safety performance, the three cases had significant differences in terms of the safety risks and control of hazards. The framing crew had limited safety measures and high exposure to hazards. Their most significant risks were falls from elevation, saw cuts and nailgun injuries. At the time of the study, the residential framing sector was exempt from conventional fall protection requirements. Consequently, the protection from hazards was limited and the exposures were high. The jobsites did not have a dedicated safety professional and the crew did not have safety toolbox talks.

For the masonry crew the most significant safety concerns were scaffold safety, saw cuts and heavy load lifting. A safety manager was assigned part-time on the project and safety toolbox talks were held once a week. For the tower scaffolds the masonry foreman had four laborers dedicated to inspecting, monitoring and raising the scaffold. Overall, the safety efforts were good but the remaining exposures to hazards were considerable. Scaffold inspection was performed daily.

The concrete operation had extensive safety measures to reduce exposures. The main safety concerns were falls, crane safety, falling objects during removal of the table forms, and dehydration. The crew had daily planning and safety meetings. Perimeter railing and 100% tie-off policy with zero tolerance were used to reduce exposures to falls. Crane activities were planned extensively and monitored closely. The risk of dehydration was mitigated by providing extra water and rotating workers to work in shaded areas. The safety measures significantly reduced the workers' exposures to hazards, and the exposures were relatively low.

The study resulted in some surprising findings with regards to safety management. First, although the high performing supervisors had exceptional safety, safety was not in all cases their top priority. Second, high safety performance was achieved even with minimal safety rules and controls, as the residential framing case highlights. Thus, high levels of safety were consistently achieved with greater emphasis on production controls, rather than hazard controls.

5. DISCUSSION

The study of high performance supervisors identifies production system design principles and strategies that are important for achieving at the same time high production performance and high safety performance in construction operations. The findings provide the basis for the following suggestions:

5.1. The high performance supervisors achieve exceptional performance on both production and safety by creating high quality work situations.

The critical common characteristic in the three cases was that the high performance supervisors emphasized the quality of work assignments in order to avoid errors, defects and incomplete work. To reduce the likelihood of errors, exceptional supervisors used multiple strategies that (1) mitigate the task demands on the workers, and (2) kept the crew informed, focused, and attentive. As a result, their work practices produced "**high quality" work situations**. The extensive preparations minimized unpredictable situations, and reduced unexpected problems (such as not having the right tools and material), frustration, rushing and errors. The management of production pressures reduced rushing, and the need for shortcuts or violations to meet production goals. At the same time, the crew management strategies prevented excessive workload and reduced distractions and frustration. The assignment of more capable personnel to more demanding tasks prevented overloading crew members with excessive task difficulty. The extensive monitoring increased the ability to recognize excessive workload and threats (such as fatigue or dehydration) and redistribute the load.

5.2. The production practices that prevented errors also prevented accidents.

The high quality of work assignments appears to reduce the likelihood of accidents in several ways: it mitigated the task demands on the workers (i.e. prevent excessive efforts, complexity or fatigue), it reduced the need for shortcuts and violations due to production reasons (such as not having the correct tools, manpower, rushing, etc.), and it reduced the likelihood of errors even when the workers were exposed to hazards.

This underlies the nature of accident prevention as error prevention rather than hazard controls. In dynamic, uncertain work situations as in construction, where exposures to hazards are unavoidable, the ability to avoid errors is critical.

5.3. The quality of the work situations may be more important determinant of safety than the safety management system.

The study of residential framing illustrated that high levels of safety can be consistently achieved even with very limited safety regulations and hazard controls. Informal discussions with construction practitioners tend to support this argument—the practitioners indicated that if the quality of work assignments was poor, it would be very difficult to achieve high safety performance even with extensive safety management efforts.

In summary, the findings support that safety is an emergent outcome of the production system design, rather than an outcome of compliance, or control of hazards. This investigation found that the production system design is critical for safety performance because it generates the work situations that workers face. An ineffective production control system generates low quality work situations with excessive task difficulty and increased opportunities for errors and violations. Even with significant safety effort, there will be extensive friction with production, and the safety outcomes are likely to be poor. This is not to say that strong safety efforts are not important, but they are not sufficient to overcome the problems of an ineffective production control system.

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7. REFERENCES

BLS (2015) Revisions to the 2013 Census of Fatal Occupational Injuries (CFOI) counts, April, US Bureau of Labor Statistics http://www.bls.gov/iif/oshwc/cfoi/cfoi_revised13.pdf. accessed May 2015.

Choudry RM, Fang D, Mohamed S. (2007) "The nature of safety culture: A survey of the state-of-the-art." Safety Science, 2007; 45(10):993–1012.

Cooper MD, and Philips RA. (2004) Exploratory analysis of the safety climate and safety behavior relationship. Journal of Safety Research, 35(5):497–512.

Das, A., Pagell, M., Behm M., and Veltri A. (2008) Toward A Theory of the Linkages Between Safety and Quality" J. of Operations Management 26 (2008) 521–535.

Dekker, Sidney 2006. The Field Guide to Understanding Human Error. Ashgate

Flin R, Mearns K, O'Connor P, Bryden R. (2000) Measuring safety climate: Identifying the common features." Safety Science, 34(1–3):177–192.

Ford, M.T., Tetrick, L.E., 2008. Safety motivation and human resource management in North America. The International Journal of Human Resource Management 19 (8), 1472–1485.

Garner, C. (2004) Construction Safety Program Essentials. In Construction Safety Management and Engineering (Darryl C. Hill, ed.), American Society of Safety Engineers.

Guldenmund FW. (2007) "The use of questionnaires in safety culture research: An evaluation. Safety Science, 45(6):723–743.

Hinze, J., and Parker, H. W. (1978). "Safety, productivity and job pressures." J of the Construction Division, 104(1): 27-35.

Hollnagel E. (2009), "The ETTO: Principle: Efficiency Thoroughness Trade-Off. Why Things That Go Right Sometimes Go Wrong."Ashgate Burlington.

Manscini, P., and Bacharias, Y. (2012) "Integrating a Top Down and Bottom-Up Approach: Formal and Informal Risk Handling Strategies in a Utility Company." Risk Analysis, 32(9): 1547 – 1560.

McLain, D. L., and Jarrell, K. (2007) "The Perceived compatibility of safety and production expectations in hazardous occupations. J Safety Res. 2007;38(3):299-309.

Memarian, B. and Mitropoulos, P. (in press) "Production Practices Affecting Worker Task Demands in Concrete Operations: A Case Study" WORK: A Journal of Prevention, Assessment, and Rehabilitation.

Mikkers, M., Henriqson, E. and Dekker, S. (2014) "Managing Multiple and Conflicting Goals in Dynamic and Complex Situations: Exploring the Practical Field of Maritime Pilots" J. Maritime Research 9(2): 13-18.

Mitropoulos, P., Cupido, G., and Namboodiri, M., (2009). "Cognitive Approach to Construction Safety: Task Demand-Capability Model." Journal of Construction Engineering and Management, 135(9): 881-889.

Mitropoulos, P. and Memarian, B. (2013) "Task Demands in Masonry Work: Sources, Performance Implications and Management Strategies" J. Constr. Eng. & Manage., 139(5): 581-590.

Rasmussen, J., (1982) Human errors. A taxonomy for describing human malfunction in industrial installations. J Occup Accid 4:311-33

Rasmussen, J. (1997) "Risk management in a dynamic society: a modelling problem." Safety Scie 27(2):183-213.

Rasmussen J., Pejtersen A.M., and Goodstein L.P (1994). Cognitive Systems Engineering. John Wiley & Sons, Inc. New York, NY.

Reason, J. T. (1990). Human Error. Cambridge University Press, New York, NY.

Rigby, L. 1970. "The Nature of Human Error." Annual Technical Conference Transactions of the American Society for Quality Control, pp. 475-566.

Reason, J. T. (1997). Managing the risks of organizational accidents (Vol. 6). Aldershot: Ashgate.

Saurin, T, Formoso C., Cambraia, F. (2008). "An analysis of construction safety best practices from a cognitive systems engineering perspective." Safety Science, 46(8): 1169-1183.

Scharf, T., Vaught, C., Kidd, P., Steiner, L., Kowalski, K., Wiehagen, B., Rethi, L., and Cole, H. (2001). "Toward a Typology of Dynamic and Hazardous Work Environments." Human and Ecological Risk Assessment, Vol 7 (7): 1827-1841.

Suraji A., Duff, A. R., and Peckitt S. J. (2001). "Development of Causal Model of Construction Accident Causation." J. Const. Eng. & Manage., 127(4): 337-344.

Veltri A., Pagell M., Johnston D., Tompa E., Robson L., Amick B. C. III, Hogg-Johnson S., Macdonald S. (2013) "Understanding safety in the context of business operations: An exploratory study using case studies" Safety Science, 55 (June), pages: 119-134.

Vredenburgh, A. (2002) Organizational Safety: Which management practices are most effective in reducing employee injury rates? Journal of Safety Research 33: 259-276.

Woods, D. D., Dekker, S., Cook, R., Johannesen, L., and Sarter, N. (2010) Behind Human Error, Ashgate, Burlington, VT.

Woods, D., & Wreathall, J. (2003). Managing Risk Proactively: The Emergence of Resilience Engineering. Columbus: Ohio University.

Zohar, D., 2000. A group level model of safety climate: testing the effects of group climate on micro-accidents in manufacturing jobs. Journal of Applied Psychology 85 (4), 587–596.

Projective guidelines for the construction of sorting centers with emphasis on its occupational health and safety aspects: case study in Recife - Brazil

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Abstract

This work presents a proposal of projective guidelines for the structuring and organization of the space regarding the treatment of recyclable material (paper, glass, plastic and aluminum) to be implemented on sorting centers. The guidelines were based on visits and interviews made in intermediate companies and recycling cooperatives from Recife - Brazil, and also the analysis of the Brazilian Technical and Regulatory Standards that regulates construction, facilities and health requirements, safety and comfort for workers. By applying the guidelines to a studied cooperative, it was possible to simulate an operation flow of logistics in a environment capable of receiving, triage, pressing and trade up to 22 tons of recyclable material per day. In addition, it allows 160 collectors to be distributed in 3 shifts, and comfortable facilities for meals, toilets, changing rooms with double closets, storage for personal protective equipment, and appropriate lighting, ventilation, parameterized exhaustion and minimum height for the ceiling, according to the present regulatory requirements for living areas. The proposal aims to elaborate adequate screening centers and to contribute to emancipate the health, safety and dignity of workers in this sector.

Keywords: Recycling, Solid Waste, Waste Collectors, and Health and Safety Work.

1. INTRODUCTION

The waste collectors have great collaboration in current society because, in addition to environmental benefits, the scavenging activity also exempts the local government with considerable part of urban waste (Alencar, 2008). However, the industries that purchase recyclable materials, acquire through intermediates, also known as “aparistas” (chippers). These play the main role to intermediate recyclable raw materials, leading directly and indirectly an extensive network which include small and medium traders, and a huge contingent of waste collectors. For collectors entities, the intermediates end up with much of a profit on resale process. It is assumed that the low volume of direct sales between collectors and industries lies in the fact that political, social and productive organization of recycling cooperatives is recent in Brazil and so many still failed to fit the requirements imposed by buyers, such as legal registration and own transportation.

The recyclable waste collectors originated from a group of workers what were jobless. Now they seek to organize in cooperatives and associations as a way to provide to their families and to improve their working conditions and quality of life; market a larger volume of recyclables; have access to negotiation with the Government; seek autonomy in selling recyclables; defend their rights and receive investments that benefit all members (Public Ministry of Minas Gerais [MPMG], 2013). The profession was officially incorporated into the Brazilian Classification of Occupations (CBO) in 2002 through specific ordinance n° 5.192-05.

However, despite the gains arising with waste collectors, associated with the figure of the collector, the professional is banned from the conventional production system, which keeps most often unhealthy and dangerous working conditions (Ramos 2012). According to Hoefel et al. (2013): “Accidents in such an environment usually happen as a result of insecurity and lack of adequate working conditions, translated in injury and loss of members, by running over and pressed in compression equipment and motor vehicles, and animal bites (dogs, rats) and insect bites.”

The doctoral thesis of Alencar (2008) was presented a study on the production of collectors. This study analyzed the physical efficiencies, economic and 20 cooperatives market. Physical

efficiency is measured by the average productivity (kg per month); economic efficiency is measured by the value traded of physical production (Brazilian real per month); and market efficiency is the ratio of economic efficiency and physics. The study showed that "a cooperative that does not have constructed space per capita suitable for receiving, sorting, processing, packing, storage and marketing, as well as social and physiological living space, lost in efficiency". This study identified a number of 160 collectors to be an efficient cooperative.
To improve safety, health and dignity of collectors, guidelines are presented to simplify structures of sorting centers, that will enable the segregation of activity and proper disposal of recyclable materials. The result was applied in a study case in a Recife’s collectors' cooperative, evaluating its peculiarities, production potential and adequacy of their physical infrastructure, considering constructive and regulatory requirements of Work Health and Safety (WHS).

2. GENERATION AND MANAGEMENT OF SOLID WASTE OVERVIEW

The total of local solid waste - LSW in Brazil in 2013, is estimated to be 76.387.200 tons, has increased in a 4,1% rate compared to 2012, representing a higher rate than population growth in the same period, which was 3,7% (Abrelpe, 2014). In Pernambuco, the numbers are no different, as shown in Table 1.

Table 1 - Collection and generation of LSW in the State of Pernambuco (day) by Abrelpe (2014)

Total Population		LSU Coletado				LSU Gerado (t/day)	
		(Kg/hab./day)		(t/day)			
2012	2013	2012	2013	2012	2013	2012	2013
8.931.028	9.208.550	0,797	0,804	7.118	7.401	8471	8561

The final disposal of solid waste in the state of Pernambuco occurs in landfill site, controlled landfill and dump in the proportions shown in Figure 1.

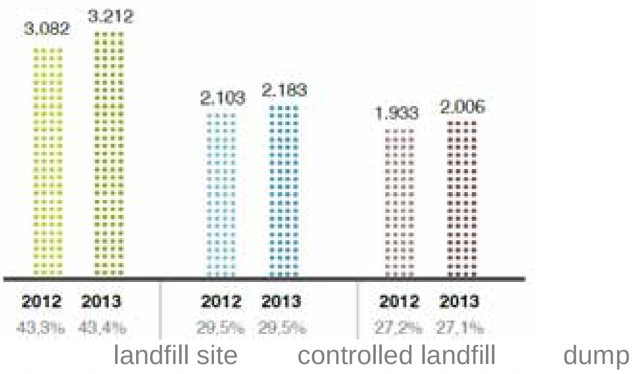

Figure 1 - Disposal of LSW in the state of Pernambuco by Abrelpe (2014)

The city of Recife produces the equivalent to 66 thousand tons of waste. Of these it is estimated that a portion of 25% to 35% could be recycled, but unfortunately this number does not reach 10% (Revista Algo Mais, 2011). If the amount to be recycled reached 35%, the average reused would be around 23,100 tons per month. From the monthly volume of waste produced in the city, it would be required 35 sorting centers, with the ability to receive up to 22 tons of material per day, preventing the dumping of this material on landfills.

2.1. Technical requirements and regulatory

To define the constructive aspects in work environments, the guidelines set out in the Regulatory Norm nº 24 (NR-24) of the Brazilian Ministry of Labor and Job should be followed, because they contain adequacy guidelines for sanitation and comfort in the workplace. This standard establishes criteria for the toilets, changing rooms, accommodations, dining, kitchen and recreation areas that must be met in order to ensure obtaining the Operating License (LO), required by local government agencies. In reform works, one must still adopt the Brazilian Association of Technical Standards (BATS) NBR 16280:2014, which establishes the obligation of compliance with current legislation and the adoption of management systems and requirements processes, projects, performance and security buildings reforms. For the following steps, it is necessary that other policy recommendations are obeyed, such as: ISO/CIE 8995-1 for illumination of workplaces; NBR 5410 for Electrical Installations; NBR 12693 for protection systems for fire extinguisher; NBR 9077 for emergency exits in buildings; NBR 14432 that establishes the fire resistance requirements of constructive elements of buildings; and the Law 11.186 of 1994 of the State of Pernambuco, which defines criteria about the fire safety systems for buildings.

2.2. Identification of environmental hazards present in recycling cooperatives

According to the regulation P4.261 of the Environmental Company of São Paulo (CETESB, 2011), risk is the "measure of harm to human life resulting from the combination of frequency of occurrence of one or more accident scenarios and magnitude of physical effects associated with these scenarios". Environmental risks are physical, chemical, biological, ergonomic and accidents that present in the workplace, that are capable of causing damage to workers' health.

For NR-9, "are considered environmental risks the physical, chemical and biological agents existing in the workplace which, because of their nature, concentration or intensity and exposure time, are capable of causing damage to workers' health. "(Ministério do Trabalho e Emprego [MTE], 1978a)

The activity of collecting, performed in the screening centers, has a maximum degree of unhealthy character according to Annex 14 - Biological Agents – of the Regulatory Standard n° (NR-15), because the worker is in permanent contact with urban waste (collection and industrialization) (MTE, 1978b).

Due to unhealthy work, if the collectors were formally linked to the National Institute of Social Security (NISS) of the Ministry of Social Welfare of the Federal Government of Brazil, they would be entitled to receive payment of a benefit of 40% of base salary, according to labor laws.

Besides the exposure to biological agents, Ramos (2012) and Hoefel et al. (2013) have identified chemical, physical, biological, ergonomic and accidents in the activities performed in the sorting centers.

According to Ramos (2012), the most frequent accidents of collecting activities are: cuts and punctures with sharp objects such as thorns, nails, needles and syringes skewer, as well as other accidents and occupational diseases linked to biological and physical hazards.

The contact with substances from hazardous residues mixed with recyclables that arrive at sorting centers in local selective collection trucks or in the trucks of sorting centers, can contaminate recyclable waste with hazardous chemicals such as mercury, cadmium, lead, beryllium, insecticides, fungicides, oils composed of toluene, benzene, dust and sawdust, glass powder, aluminum powder that can cause numerous negative health impacts on workers.

Other diseases such as fungal meningitis, leptospirosis, tuberculosis, malaria and possible poisoning by venomous animal bites such as snakes, spiders, centipedes and scorpions are examples of accidents that can affect workers linked to scavenging activity within the sorting centers.

3. MATERIALS AND METHODS

Visits were made to two intermediate companies and a cooperative of waste pickers in Recife to identify the activities carried out by the collectors, their working conditions, raising the necessary infrastructure and specify the equipment necessary for the operation of a sorting center. In addition to the observation and photographic records, interviews were held with the directors of the two companies and the administrators of the cooperative.

The rules and laws used in the preparation of the guidelines included: Regulatory Standard nº 9 (NR-9) -classification of environmental agents and risks, the NR-15 - classification on the hazard degree of collecting activity, the NR-17 - Ergonomics, and NR-24 for adequacy guidelines on sanitary conditions and comfort in the workplace. For the reform planning was considered that the procedures of the Brazilian Association of Technical Standards (BATS) NBR 16280:2014, prior consultation with the state standards by the Fire Department and BATS concerning standards regarding the resistance of materials against fire in construction elements and fire extinguishers. Lighting and electrical installations should be consulted and applied in posterior steps for an effective implementation of the guidelines suggested here.

4. DESCRIPTION OF THE ANALYZED COOPERATIVE

The Cooperative of Professional Recyclers in Recife ("Cooperativa de Catadores Profissionais do Recife", Pro-Recife), study object, started its operation in April 2006, with 42 cooperatives the slum of "Caranguejo Tabaiares". Currently has 28 collectors, 20 women and 8 men working on average 48 hours per week. Aged 18 to 70 years, only 3 to 8 have the 1st degree range (as

illustrated in Figures 2 and 3) and none of the cooperative is linked to social security for retirement purposes and other labor rights.
According to the cooperative representative, the Brazilian average in the collecting activity is 60% of women and 40% of men.

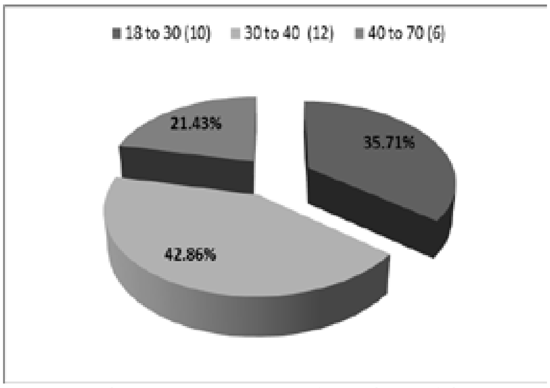

Figure 2 - Age range of members of the Pro-Recife.

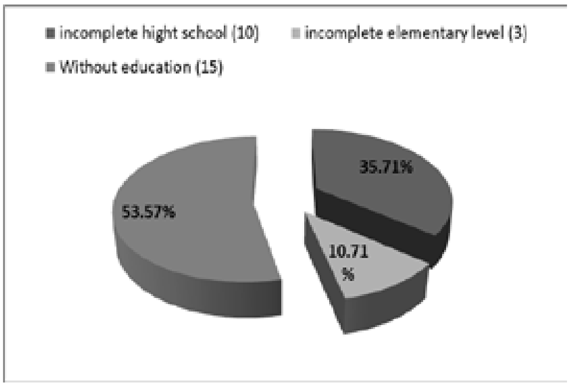

Figure 3 - The level of education of members of the Pro-Recife.

The material that reaches the cooperative goes through a sorting according to their composition. According to data, the cooperative receives around 50-60 tons of waste per month, and from this total about 30% is rejected, i.e. material that is not meant to be recycled and therefore needs to be separated and placed in the outer area of the Cooperative to be collected once again by the responsible urban company.
In collecting activities the workers wear uniforms and gloves. The lunch meals are made within the cooperative, in the same area for education and meetings with companies and government officials. The following risk factors were observed: shed discharge material with inappropriate lighting, small space for the volume of material collected, risk of cuts and punctures caused by materials found in waste, ergonomic strain on the body due to manual lifting, heavy physical work, poor posture, repeatability, work standing or squatting, trunk twisting and spinal flexion, as well as an accumulation of disordered material, especially tailings (unprofitable for recycling), within the receiving material shed can lead to the proliferation of synanthropic vectors, and diseases and accidents at the workplace.
On the day of the visit, the Pro-Recife: 1 press, with over 10 years of use; 1 electronic scale; 3 screening tables; 1 truck and 2 machines to grind glass. The cooperative operates on the lower floor, as well as workflow, represented in Figure 4.

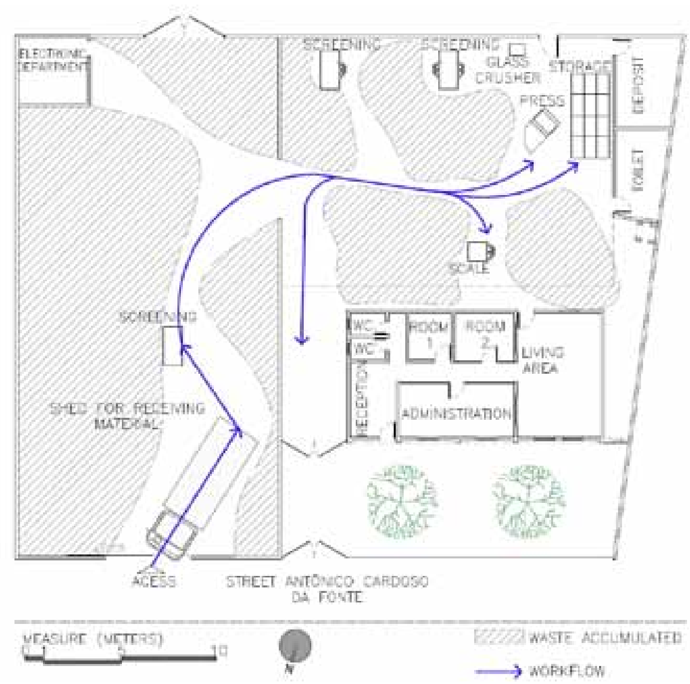

Figure 4 – Lower Floor Plan of the Pro-Recife Cooperative

5. RESULTS AND DISCUSSION

5.1. Constructive Guidelines and Reform to the Screening Center

Given the observed aspects, it is understood the need for standardization of the design specification guidelines for both the desktop, as well as living areas for workers. Thus, they encompass the recommendations of national and international Technical Standards for Electrical Installations, Sanitary Conditions and Comfort in the Workplace, ensuring appropriate conditions for meals; minimum areas for health facilities; changing rooms with double closets; places to keep personal protective equipment (PPE); lighting, ventilation; exhaustion and parameterized minimum height for ceiling, according to the living area.

The guidelines for sorting centers behave 160 workers, distributed in three shifts of 8 hours of work per day, according to results presented by Alencar (2008). The considered demand in the calculations was of 22 tones per day (which would correspond to the recyclable waste for a population of approximately 47,000 inhabitants), and the proportion of men and women considered was of 40% and 60% respectively, by the national average.

The project layout should be designed so that the processing path of the various materials (receiving and sorting, pressing and storage) occurs in a covered area.

For an efficient cooperative, the amount of equipment for every 160 pickers should be of 3 mechanical scales (capable of weighing up to 1 ton); 10 mats for screening; 6 balers; and 03 forklifts. Predict sectors for each type of material, including sub-sectors for paper, which are divided into: white paper, corrugated, paper magazines, catalogs, and newspapers and graph paper.

It is suggested the use of simple trapezoidal galvanized with thermo and acoustic isolation, e.g. with expanded polystyrene filling, between the two tiles at the ceiling, because its retardant action on flames and do not absorb water; or the use of a green roof, which affords indoor thermal and acoustic comfort.

As instrument of social inclusion, it is suggested the creation of a cultural and educational open space for tours. A classroom space can be created for conducting workshops for manufactured goods using recycled materials; this location can be set in the same space for the meetings. A sales stand can be placed in the reception area or living for manufactured products. These areas can be viewed in Figure 3.

Based on the presented case study, it defined the main environments that a screening center should house as well as the minimum and equipment needed areas, as shown in Table 2.

Table 2 - Detailed structure of the Screening Center

ENVIRONMENT	AREA	AMBIENCE	EQUIPMENT	QUANTITY	AREA (m^2)
GROUND	Screening Center	Electronic Department	-	-	12,37
		Shed for receiving material	Glass Crusher	2	355,36
			Hidraulic Press	2	
			Mat for screening material	3	
		Weighing	Scale	1	51,20
			Forklift	1	
		Deposit	-	-	27,30
		First Aid	-	-	2,00
	Collector's support	Men's locker.	-	-	35,67
		Women's' locker	-	-	45,52
		Living Area	-	-	43,15
		Closets for PPE	-	-	8,20
		Cafeteria	-	-	15,70
		Kitchen	-	-	12,37
	Public	WC	-	-	2,12
		WC	-	-	2,12

	Reception	-	-	9,63
Restricted Employees	Administration	-	-	16,86
		TOTAL AREA	**BULIT**	639,57m²

5.2. Occupational Safety Guidelines for construction and / or renovation of the sorting center

According to the NR-24, the establishments where there are from 30 to 300 employees, although it is not required a cafeteria, there should be guaranteed for workers sufficient conditions for comfortable meals. The cafeteria should be built in an appropriate place, not communicating directly with health facilities and workplaces. The tables should have flat tops and waterproof material, banks and chairs should be kept clean, the area should be ventilated and with good illumination, and tables and chairs in number corresponding to amount of users, and have a device to warm the food, stove or similar (MTE, 1978c).

Guidelines for the storage and maintenance of PPE are regulated in the NR-06 that considers "PPE, every device or product, for individual use used by the worker, for the protection of susceptible risks to threaten the safety and health at work".

To guarantee the conditions of use of PPE is suggested the adequacy to the regulation NR-06, regarding the obligation to use it only for what it is intended and be responsible for its care and conservation. Thus, it is proposed to have suitable areas for the custody of PPE, in individual single cabinets, located in the living area to better assist the conservation of the protective equipment (MTE, 1978d).

According to the NR-24 (1978c) in unhealthy activities, as well as in activities incompatible with body cleanliness, the cabinets should be of dual compartments. It was chosen for the case study, which has the following minimum dimensions: 0.80m in height and 0.50m wide and 0.40m deep, with a vertical division, so that the compartments with a width of 0.25m establish, rigorously, the isolation of the common use of clothes and work.

In addition to the guidance in the areas of health, locker rooms, cafeterias, considering the luminance of the site, ventilation and cabinets, the NR-24 specifies parameters of water consumption for per worker, for toilets and for consumption during daily work, as well as the amount of drinking fountains, sinks, and showers per worker. It is recommended the use of shower for decontamination and first aid box in accessible locations, without obstruction by equipment or materials for urgency and emergency situations, and the adequacy of signaling standards and fire protection in screening centers. Table 3 shows the quantitative dimensions based on NR-24 for the living areas and sorting center.

Table 3 - Guidelines for the design of the living areas of the sorting center

LIVING AREAS	NR 24 - HEALTH CONDITIONS AND COMFORT THE WORKPLACE FOR SCREENING CENTER	PROPOSED RECOMMENDATIONS FOR THE SCREENING CENTER
Sanitary Facilities	Sanitary with 1m² minimum area for each group of 20 workers	Ensure health with 1m² minimum area for each group of 20 workers
	Toilets separated by sex	Build toilets separated by sex in the changing rooms and sign to divide by sex in public toilets
	Carp windows and glass inclined c / 45 degrees with 1/8 of the floor area	Provide 1/8 area of the floor area in WCs Male, Female and to the public toilets
	Provide 60 liters / day / worker	Provide 9600 liters of water per day for 160 workers
	Guarantee a minimum illuminance of 100 lux, with light bulbs of 100W/8.00 m² with ceiling height of 3.00 m maximum, or other lamp with the same effect	Provide electronic fluorescent lamp compatible with the luminance requested by standard
Washbasins	1 washbasin for 10 workers if conditions are unhealthy	2 (two) washbasins for male bathrooms
	Space between taps 0.60 m	4 (four) washbasins for female bathrooms
Shower	1 shower for 10 workers	2 (two) showers for male bathrooms

		4 (four) showers for female bathrooms
Sinks	Automatic flush	Install automatic flush on toilets
	Minimum height of 2,10m from the division between sink areas	Minimum height of 2,10m from the division between sink areas
Lockers	Minimum area of 1,5 m² for each worker	Minimum area of 33 m² for male lockers
		Minimum area of 48 m² for female lockers
	The windows must have carp windows, with fixed inclination of 45°, with an area of 1/8 from the floor area	Minimum area of 4,2 m² for the male lockers windows
		Minimum area of 6 m² for the female lockers windows
	Illumination of mín de 100 Lux, with encandescent lights of 100W/8m², with ceiling of 3,00m	4 bulbs of 100 Lux on male's lockers
		6 bulbs of 100 Lux on female's lockers
	Individual double closets with dimensions (d) (1,20x0,30x040) or (0,80x0,50x0,40) with screens or air vent	66 lockers with d=(0,80x0,50x0,40) on male's lockers
		94 lockers with com d=(0,80x0,50x0,40) on female's lockers
Fountain	Fresh and potable water for the consumption on the proportion of 1 fountain for every 50 employees	2 fountains
	Potable water disposal: 1/4 liter of water every hour/person/day/shift	106 liters
Cafeteria	In establishments where work more than 30 to 300 employees ensure sufficient conditions of comfort for the occasion meals	Tables and chairs in sufficient numbers to accommodate 53 employees / shift

Figure 5 shows the first floor plan according to the guidelines applied to the cooperative.

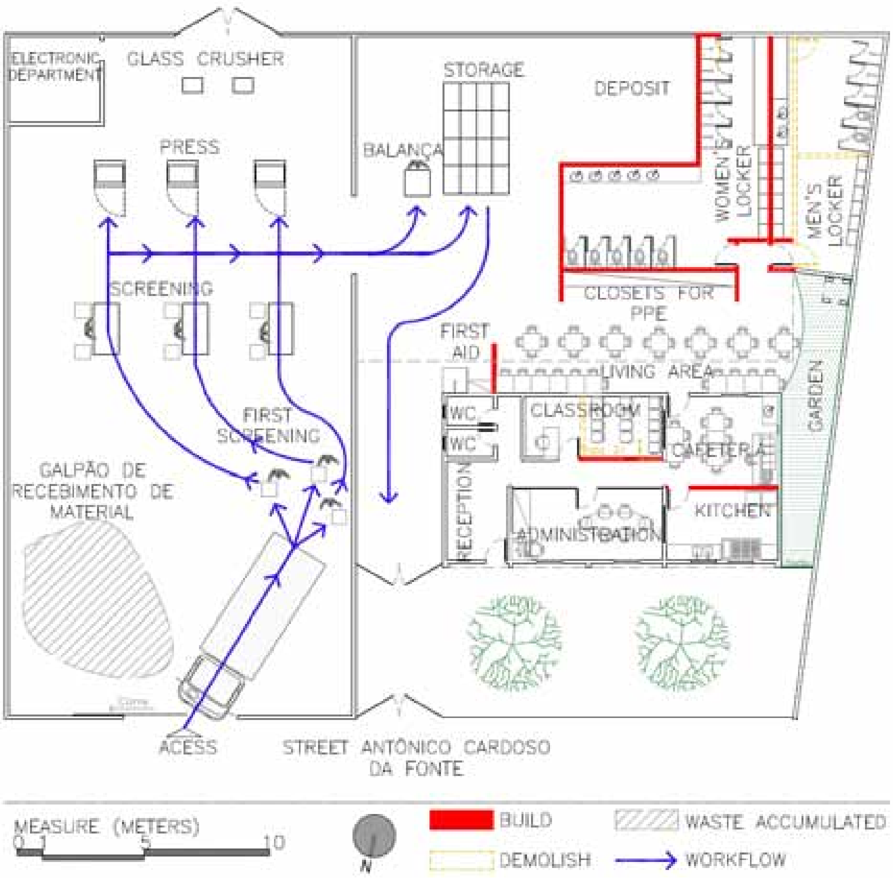

Figure 5 - Floor Plan Reform for the Pro-Recife Cooperative

6. CONCLUSIONS

The results obtained in this study aim to organize the workflow and higher profits for the recycling cooperatives, through the construction of sorting centers, where workers, using the same space and uninterrupted shifts, can carry out the screening activities, pressing, storage and distribution ofrecyclable materials pressed to industries with more comfort and safety, while the employee category can be recognized by the Brazilian legislation.

The idea of structured recycling centers, permeates the concepts of citizenship, living in groups, decent work, physical structure, cleanliness, organization, preservation of health and protection from occupational diseases in the recycling area. From this perspective, the guidelines proposed can positively contribute to the sustainable aspect, not just in the structuring of sanitation and decent work, as well as in the recovery of citizenship for both the collectors and the communities in its surroundings.

7. REFERENCES

Alencar, Bertrand Sampaio de (2008). *Emergência de novos atores no desenvolvimento sustentável: a contribuição dos catadores de materiais recicláveis o Brasil*. (Doctoral dissertation) - Universidade Federal de Pernambuco.

Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais [ABRELPE]. (2014). *Panorama dos resíduos sólidos no Brasil 2013.* from http://www.abrelpe.org.br/panorama_apresentacao.cfm

Brasil. Lei nº 12.305, Política Nacional de Resíduos Sólidos. (2010). Diário Oficial da União, Brasília-DF, 3 ago. 2010. Seção 1. Retrieved from: http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm

Companhia Ambiental do Estado De São Paulo [CETESB]. (2011). *Norma técnica P.4.261*: Risco de Acidente de Origem Tecnológica - Método para decisão e termos de referência. São Paulo. 2 ed., Dez. 2011. Retrieved from: http://www.cetesb.sp.gov.br/userfiles/file/servicos/normas/pdf/P4261-revisada.pdf

Hoefel, M.G. et al. (2013). *Acidentes de trabalho e condições de vida de catadores de resíduos sólidos.* Rev Bras Epidemiol. 2013; 16(3): 764-85

Ministério do Trabalho e Emprego [MTE]. (1978a). NR 9 - *Programa de Prevenção de Riscos Ambientais.* Brasília,DF: Brasil. Retrieved from: http://portal.mte.gov.br/data/files/FF80808148EC2E5E014961B76D3533A2/NR-09%20%28atualizada%202014%29%20II.pdf

Ministério do Trabalho e Emprego [MTE].(1978b). NR 15 - *Atividades E Operações Insalubres*. Brasília, DF: Brasil. Retrieved from: http://portal.mte.gov.br/data/files/8A7C816A47594D040147D14EAE840951/NR-15%20(atualizada%202014).pdf

Ministério do Trabalho e Emprego [MTE].(1978c). NR 24 - *Condições Sanitárias e de Conforto Nos Locais de Trabalho*, Brasília, DF. Brasil. Retrieved from: http://portal.mte.gov.br/data/files/FF8080812BE914E6012BF2D82F2347F3/nr_24.pdf

Ministério do Trabalho e Emprego [MTE].(1978d). NR6 - *Equipamento de Proteção Individual – EPI,* Brasília, DF. Brasil. Retrieved from: http://portal.mte.gov.br/data/files/FF8080814CD7273D014D34C6B18C79C6/NR06%20%28atualizada%29%202015.pdf

Ministério Público de Minas Gerais. (2013). *O Catador é Legal:* Um guia na luta pelos direitos dos Catadores de Materiais Recicláveis. Brasília, DF: Brasil. Retrieved from: http://www.coopcentabc.org.br/documentos/CARTILHA_CATADORES.pdf

Moraes, G. (2010). *Elementos do Sistema de Gestão de SMSQRS: Sistema de Gestão Integrada.* (2a. ed.). Rio de Janeiro, Brasil: Gerenciamento Verde editora e Livraria Virtual.

Ramos M. M. G.(2012). *Importância do uso dos Equipamentos de Proteção individual para os catadores de lixo*. Monografia (Especialização)-Curso de Enfermagem do Trabalho. Salvador.

Revista Algo Mais (2011, october). *O Destino da Gestão do Lixo*, 67, 56-57. Available from: http://revistaalgomais.com.br/edicaodigital/index_digital.php?end=http://www.revistaalgomais.com.br/blog/wp-content/ea/edicao67.pdf

Secretaria de Meio Ambiente e Sustentabilidade [SEMAS]. (2012). *Plano Estadual de Resíduos Sólido*s. Recife, PE: Brasil. Retrieved from: http://www.cataacao.org.br/wp-content/uploads/2012/08/PlanoResiduoSolido_FINAL_002.pdf

Guidelines proposals for environmental indicators and for occupational and health safety in public and private organizations

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Abstract

This work presents guidelines proposals for creating environmental and social indicators applicable to public and private companies. The guidelines were design considering visits, interviews and documentary analysis carried out in a public company in Pernambuco - Brazil. From the analysis on building maintenance activities and equipment, restoration, traffic control and environmental management, environmental management activities and maintenance of equipment were chosen. To validate these indicators, they were analyzed along with regulatory occupational health and safety requirements. To assist in data collection of environmental indicators, softwares for mapping processes were used for planning and imagining the flow of activities. The guidelines proposals aims to serve as an indicator for any public or private company, with or without profits, allowing to measure and compare how the funds have been distributed, representing a practical way to influence the equilibrium of sustainable development.

Keywords: sustainable development, social aspects, environmental aspects, occupational health and safety.

1. INTRODUCTION

Over the years, organizations have tried to validate their commitment to environmental preservation, quality, safety and health at workplaces. These actions are intended to present a good corporate image, engaging employees, customers, shareholders, all in accordance to the regulations, thus developing an organizational culture dedicated to the social and environmental issues demanded by society, valuing their products and services. Furthermore, enhanced by the global economic crisis, it is observed an increase in temporary works, an aging workforce and migratory fluxes, favoring the acceptance of unsafe conditions, no health monitoring, the lack of verification of environmental working conditions, absence of proper records and reports of occupational diseases.

Therefore, what elements of these systems in the so-called “sustainable companies” consider the health and safety of their employers (HSE) in the workplace? And which management tools could help these public and private companies to evaluate and monitor the HSE as an intrinsic element of sustainability?

For Elkington (2015), founder of the British sociologist Sustainability NGOs and creator of Triple-bottom line expression, social and economic dimensions need to be more integrated to the environmental issues. The social aspect is concerned with the present and future generations, as the labor that supports development. In this scenery, progress verses sustainability, government, business and society have the same directive, demanding from each other involvement and commitment, urging a long term planning, under the risk of compromising the upcoming generations. There is no consensus of the meaning of “sustainability” and the operationalization of strategic plans to face this reality. Thus, one method to get a broader understanding of Sustainable Development (SD) is the establishment of operational tools to measure, evaluate, monitor and indicate the development progress verses sustainability.

According Kohlman Rabbani et al. (2013, p.95), indicators are generally used to simplify and communicate complex information that can be used to access, diagnose, monitor and, for example, compare the various aspects of sustainability. This paper proposes to analyze quantitative and qualitative indicators for workplace security that can be incorporated into the evaluation of the social aspect of SD.

2. SUSTAINABLE INDICATORS

"The purpose of the indicators is to aggregate and quantify information so that its significance becomes more apparent" (Bellen *apud* Fonseca et al., 2008, p. 42). To create tools to synthesize complex data, it is necessary to establish criteria to make it easily understood, unambiguous and practical.

Currently, there are some indicators that measure the SD of private and public organizations, profitable or non-profitable, through the use of Global Reporting Initiative – GRI, and the Genuine Progress Indicator - GPI, which demonstrate the questions of civil society beyond the Policy Performande Index - PPI used to check the performance of governments. According to Fernandez-Feijoo & Romero (2014), the GRI indicators have great coverage, because they can be applied in different sectors and sizes of organizations. In its fourth version (G4), the GRI has international recognition, and it's used in more than two thousand companies in Africa, Asia, Europe, America and Oceania.

Fernandez-Feijoo, Romero and Ruiz (2014), comment that GRI indicators are reliable and leaders in the international market have been using it to portray the sustainability of companies in economic, environmental and social categories. Table 1 shows some features of the GRI.

Table 1 - GRI features adapoted by the author based on Table 1 of Fonseca et al. (2008, p.13).

INDICATORS	GRI (GLOBAL REPORTING INITIATIVE)
Indicator's Objective	To develop and disseminate guidelines that can harmonize the reports of accepted organizations according sustainability criteria.
Target	Organizations from different sectors and sizes, corporate, public, or non-profit, but it is in the private sector that takes its greatest application
Sustainable Development Concept	Balance between economic, social and environmental development
Data gathering and processing	Report issued regularly by the organization, so that one can compare the evolution of its performance, as well as in relation to other organizations. The report contains questions relating to/or by a specific segment proposed by the general program indicators.
Periodicity	The most widely used is the yearly, but larger or smaller periods can be used. It is recommend the use of a uniform regularity, depending on the comparison.

The GRI Report provides a guide for mapping and preparation of indicators. The environmental dimension covers the organization's impacts on natural systems including ecosystems, land, air and water; for these indicators will be evaluated if the organization's practices are in compliance with laws and efforts for the preservation, recovery and conservation of the environment. For social aspects, are considered the organization's impacts related to labor practices, the relationship between workers and management, health and safety, training and retraining, including subcontractors. (Glogal Reporting Initiative [GRI], 2015a).

In GRI standards, the indicators are composed of acronyms, which G4 means the version used, and the remaining letters indicate the category of the indicator. For example, a company that wants to display to society its social and environmental responsibility, could choose the following criteria for measuring and monitoring in the Environment Category - EN (ENVIRONMENTAL): percentage of used materials that are recycled (G4-EN2) , energy consumption reduction (G4-EN6), total water withdrawal by source (G4-EN8), percentage and volume of recycled and reused water (G4-EN10), and total environmental expenditures by type (G4-EN31) .

For social class indicators - LA (LABOR PRACTICES AND DECENT WORK), a possible choice would be the following criteria: total number and rate of new jobs, hires and turnover by age group, gender (G4-LA1); type of injury and injury rates, occupational diseases, lost days, absenteeism and work-related fatalities by region and by gender (G4-LA6); workers with high incidence or high risk of diseases related to occupation (G4-LA7); average hours of training per year per employee, by gender and employee category (G4-LA9); programs for skills management and lifelong learning that support the continued employability of employees and to manage career endings (G4-LA10), and the proportion of basic salary and remuneration of women to men by employee category (G4-LA13) (GRI, 2015a).

3. MATERIALS AND METHODS

In order to validate the collection and analysis of indicators chosen, it was applied the same to air company in Pernambuco - Brazil. The used methods were: visits interviews, document analysis, description of the programs applied in environmental areas and man support, photographic documentation and information gathering information between April and August 2015.

The GRI was chosen for its international recognition, applicability to different segments of the economy, and its foundation in the principles of quality, clarity and consistency report. These standardization features facilitate understanding and comparison reports for all the countries and institutions that follow their directives.

For this work, analyzes were made from collected data and, for example purposes, only environmental indicators were chosen (EN2-G4 and G4-EN8 indicators). For social category - LA, it was chosen the G4-LA9 indicator.

In order to assist in the imagining, data collection frequency and interrelation of external sectors involved used the environmental management activities software, Bizage Modeler free version.

4. RESULTS AND DISCUSSION

The studied organization has its headquarter in Pernambuco – Brazil. It has about a thousand employees, spread in 10 states in northeastern Brazil. Concerned to adapt it self to the SD, the company has developed projects that support the improvement of the environmentm and its social and environmental responsibility. A case study was not accomplished specifically in this company, but was only observed among the processes of their action fields.

4.1 Social Indicators

For the proposed social indicators was created flowchart of its activities in Figure 1, of the areas of maintenance operations, renovation work (performed by third party companies), traffic control and environmental management. For building cleaning and reform activities, Brazilian law states that companies that hire and contractors have a relationship of co-responsible for damage to health and safety of employees and the environment.

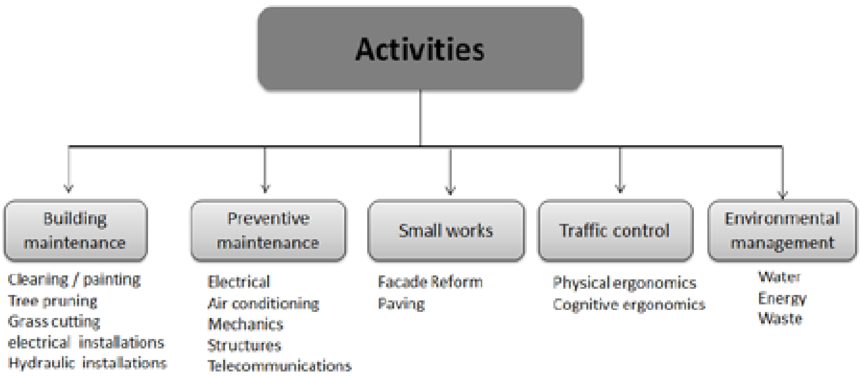

Figure 1 - Proposed activities for data collection

Among the activities described above, it is suggested the design of indicators by mapping the environmental conditions as discriminated in Figure 2. Other suggested indicator is the G4-L2, concerning the working conditions of general services teams (outsourced companies), with information as to respect for labor rights compared them with those accorded to employees of the company's own staff.

For traffic control activity, the main branch of the institution, suggests the creation of indicators (G4-LA7) that specifies the number of workers with high incidence risk of occupational diseases. Such indicator is suggested, because this activity demand periods of extreme concentration and mental stress, object of study of ergonomics area.

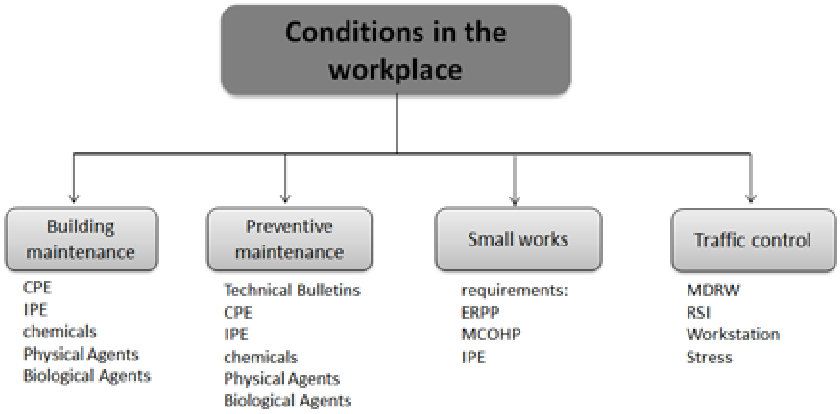

Figure 2 - Proposals for items to be analyzed for mapping environmental conditions

Subtitle:
Environmental Risk Prevention Program – ERPP
Collective Protection Equipment - CPE
Individual Protection Equipment - IPE
Medical Control of Occupational Health Program – MCOHP
Musculoskeletal Disorders Related to Work - MDRW
Repetitive Strain Injury – RSI

The management training in companies that develop activities with environmental risks is an item that deserves special attention, because can contribute to the decision making on how to spend on acquiring training, warn about the validity of applied training, the dates for revision training, and new training needed to improve functional performance. The management of training, besides training employees preventively, avoids accidents, helps to prevent possible costs with legal skills and labor penalties. For this theme, it is suggested the creation of an indicator (G4-LA9) to quantify the average hours of training per year, per employee, by gender and job category.

For the training for the item, it can be mentioned the obligatory application of basic training and biennial periodic review courses, with at least 8 hours required to work at height, according to Regulatory Standard 35 (NR 35). To analyse the G4-LA9 indicator, it was held in April 2015, an assessment of training for working at heights in the studied company. The activities of building, preventive and corrective maintenance already discriminated previously in Figure 2 are essentially performed by males; such activity sometimes subjects employees to heights above the limit set by NR 35, (Brazil, 1978). During the evaluation, it was noted that from the 50 employees who performed these activities, only 12 had basic training. And even so, such officials had their qualifications outdated since May 2013.

On the data collected and plotted indicators, actions were taken by senior management. In the graphs below, it is shown the amount of training conducted and planned for the second half of 2015. According to the guidelines of the G4-LA9 indicator (average hours of training per year, per employee, by gender and job category) were plotted in Figure 3, the training carried out and planned and the goal of training for the year 2015. Figure 4 shows the minimum hours required by the NR-35, the actual amount applied hours, and the average hours per year per employee; Figure 5 shows the number of employees trained by education level and hours of applied training.

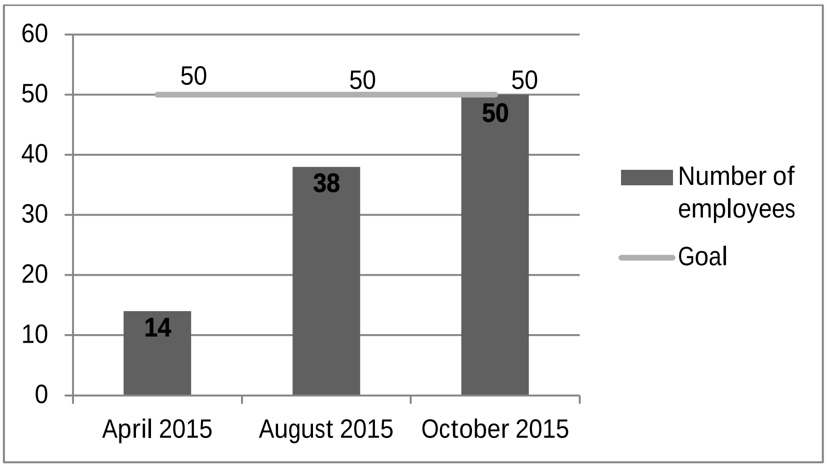

Figure 3 - Number of male employees trained

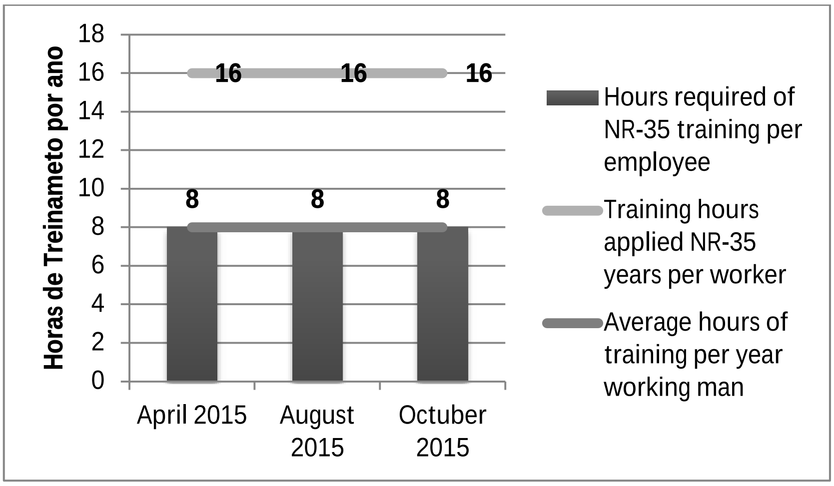

Figure 4 - Average hours of training in NR 15 applied in 2015

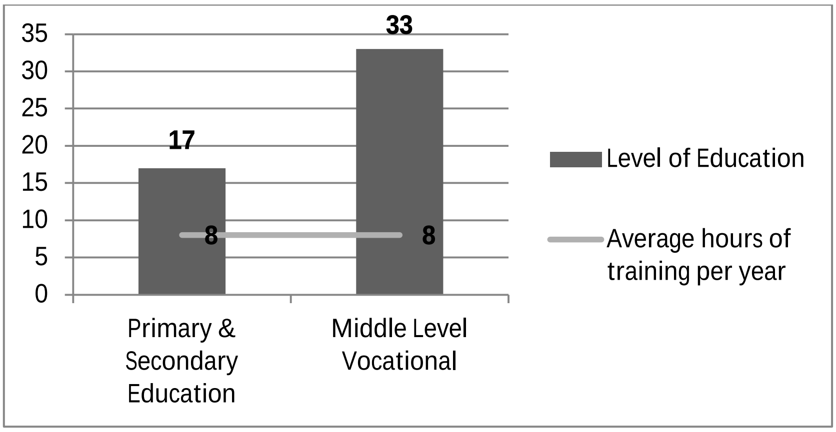

Figure 5 - Staff Trained by Education Level for hours of training per year

To analyze the environmental employment conditions, there shall be guaranteed environmental measuring instruments to verify agents, such as light meter, thermometer, sound level meter are properly calibrated and calibration performed by laboratories that they are accredited by national and international organization. This is a positive item for the studied company, because it is certified by INMETRO, Brazilian agency with international accreditation to calibrate instruments.

4.2 Environmental Indicators

Public and private companies generate daily waste of different types. Wastes such as: cooking oil, residual oil machinery and equipment, fluorescent tubes, scrap tires, printer cartridges and batteries must be managed and properly disposed by organizations. Proper disposal should be

considered because many materials have in their composition toxic elements, and once in nature can contaminate soil and groundwater and still pose chemical risks to workers. Thus, the amount of management indicators and compliance could be plotted to point environmental liabilities that could have a material impact on the financial, environmental and social situation of the institutions. In order to map the processes of generation, collection and disposal of waste, it is suggest the use of modeling softwares, such as Bizage Modeler, which have free versions on internet that can perform effectively the mapping process.
To illustrate the process of data collection for the creation of the G4-EN2 indicator, modeling was performed with the Bizage software, that presents possible flows to the Waste Management Program (RMP) in any institution. For creating the hypothetical flow, it was considered an establishment that discards recyclable (plastic, paper, cardboard, glass, iron, aluminum);

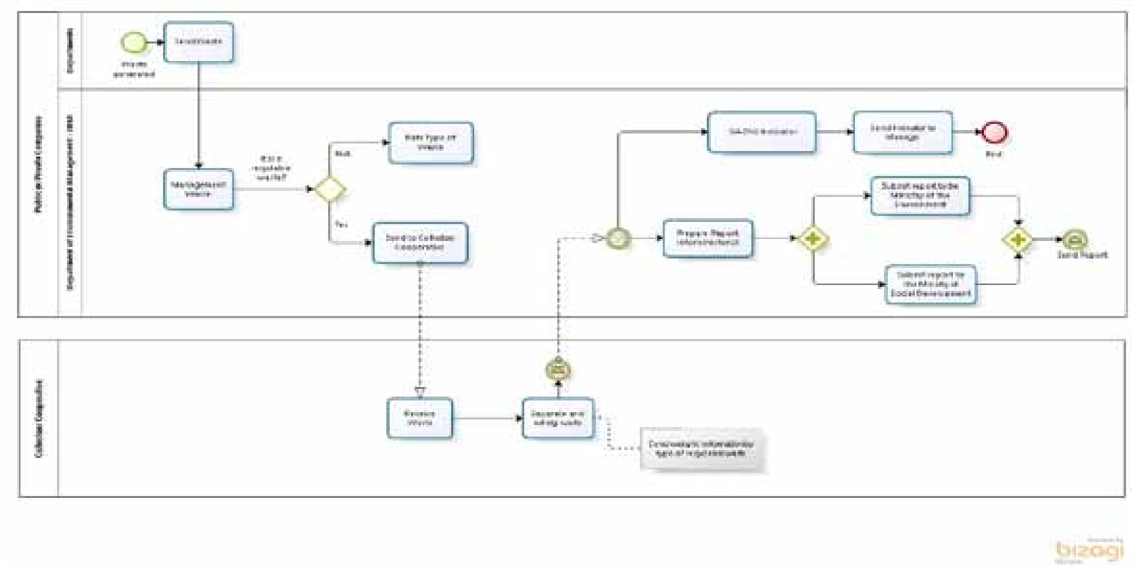

Figure 6 - Management Mapping Program for data collection and creation of G4-EN2 indicators (percentage of materials used that are recycled)

In Brazil, the Federal Public Institutions must comply with Decree 5.940 of 2006, which is set up "the separation of recyclable waste discarded by the organs and entities of the direct and indirect federal public administration, at the source, and its allocation to associations and cooperatives of waste collectors" (Brazil, 2006). As an example of good practice, some companies, regardless of the obligation, have adopted such a position, destining their recyclable waste to recycling cooperatives and associations; this consideration was made in Figure 6 for the creation of G4-EN2 indicator.
The total consumption of water withdrawal by source and potability analyzes can also be indicators of object. To create the G4-EN8 indicator, a specific program can be created to perform modeling of these processes, as seen in Figure 7. The analysis of potable water consumption, can consider the indication of water parameters used for human consumption in accordance with the standards set by environmental and public health agency.

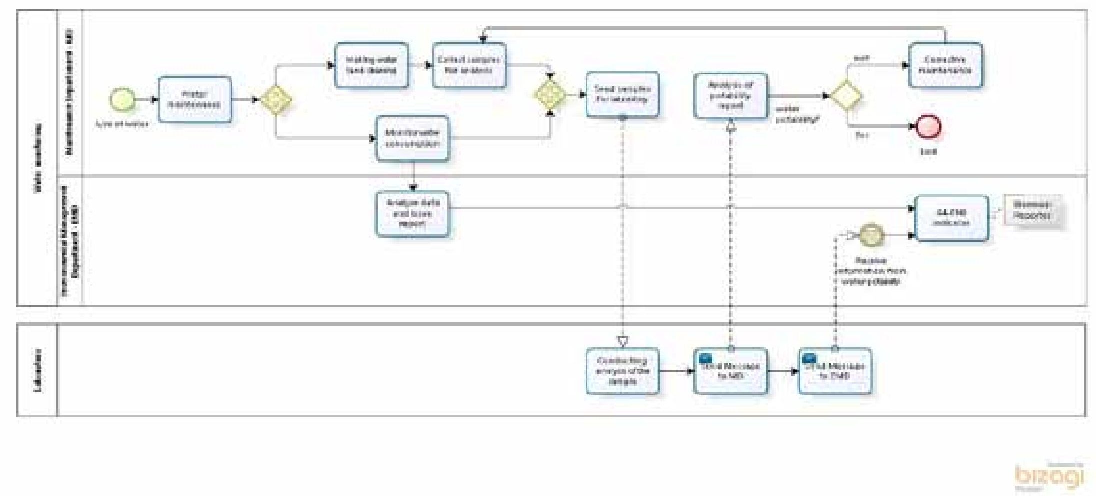

Figure 7 - Management Mapping Program for creation of G4-EN8 indicator (total water withdrawal by source)

Moreover, investments in proper disposal and technologies to minimize impacts to the environment and occupational health, and other investments in the environment, can be quantified as: Biodiversity indicators G4-EN13, that indicate protected and restored habitats, in actions such as Recovery degraded areas, measuring the costs of hiring specialized man-hour, compost, earth, water, plants, gardening supplies, and composting machines.

5. CONCLUSIONS

The creation of indicators of environmental and social management aims to guide any public or private company, with or without profits, in order to identify working conditions, training, collective and individual security devices, greeting legal obligations and other aspects relating to the social and environmental aspects of the DS in organizations. The proposal for the institutions that adopt these indicators is that investments made in the aspects of the DS allow comparisons between companies, and that these can be verify the application of resources are distributed in a way that represents in practice that their greatest asset are the people's lives that compose it.

Given the above, it is suggested to future completion of the study, performing the diagnosis of the environmental conditions experienced by evaluating working conditions, follow the safety guidelines for labor stated in contracts and prevailing norms. It is recommended the completion of the study through other programs to evaluate costs, conducted in the company, in order to effectively compare the cost invested in the environmental and social aspects of sustainable development.

6. REFERENCES

Brasil. (2006, october 26). Decreto 5.940 de 25 de outubro de 2006: Institui a separação dos resíduos recicláveis descartados pelos órgãos e entidades da administração pública federal direta e indireta, na fonte geradora, e a sua destinação às associações e cooperativas dos catadores de materiais recicláveis, e dá outras providências. *Diário Oficial da União*, Brasília-DF. Retrieved from: http://presrepublica.jusbrasil.com.br/legislacao/95338/decreto-5940-06

ELKINGTON, J. Enter the Triple Bottom Line. In: HENRIQUES, A.(Org.); RICHARDSON J. (Org.); The Triple Bottom Line: Does It All Add Up. 1th ed. London: Earthscan, 2004, Chapter 1, p. 1-16. Retrieved from: http://kmhassociates.ca/resources/1/Triple%20Bottom%20Line%20a%20history%201961-2001.pdf.

Fernandez-Feijoo B.; Romero S.; Ruiz S. (2014). Commitment to Corporate social responsibility measured through global reporting initiative reporting: factors affecting the behavior of companies. *Journals elsevier - Cleaner Production***,** V. 81, p. 244 – 254. 2014. Retrieved from: http://www.sciencedirect.com/science/article/pii/S0959652614006222

Fonseca, A. M. et al. (2008). Proceedings from *II SEMINÁRIO SOBRE SUSTENTABILIDADE, 2*. Curitiba, PR. Retrieved from: http://www.unifae.br/publicacoes/pdf/IIseminario/pdf_indicadores/indicadores_01.pdf

Global Reporting Initiative [GRI]. (2015b). *G4 Sustainability Reporting Guideline* – Reporting Principles and Standard Disclosures. Retrieved from: https://www.globalreporting.org/reporting/g4/Pages/default.aspx

Kolman Rabbani, E. R. et al. (2013). *Segurança do Trabalho no contexto da construção Sustentável:* uma visão geral. Recife,PE: EDUPE.

Ministério do Meio Ambiente [MMA].(2015). *Indicadores Ambientais*. Retrieved from: http://www.mma.gov.br /governanca-ambiental/informacao-ambiental/sistema-nacional-de-informacao-sobre-meio-ambiente-sinima/ indicadores

Soligo, V.(2012). *Indicadores:* conceito e complexidade do mensurar em estudos de fenômenos sociais. São Paulo, v. 23, n. 52, p. 12-25. Retrieved from: http://www.fcc.org.br/pesquisa/publicacoes/eae/arquivos/1724/1724.pdf

Design and assessment of effective signs for railroad crossing

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Abstract

An effective warning sign for railroad crossings that had an alarm but not a gate bar was designed and examined, in order to reduce risk-taking behavior of drivers at the crossings. Based on psychological perspectives and the analyses of past accidents at railroad crossings without gate bars, four different warning signs were developed. A questionnaire inquiring about risk-taking process was also developed to assess effective designs of the warning signs. Participants in the study drove in a driving simulator. In the simulator program, they encountered a railroad crossing without a gate bar. After they finished driving, the participants responded with their impressions of the warning signs seen in the simulator program using the provided questionnaire. The analyses of their responses indicated that two designs were effective: the sign "Train is right here," which tells drivers the "trains are already in front of them when they hear the alarm," and the sign "Thank you for stopping," which shows the driver "appreciation." These two signs could have affected different psychological characteristics to provoke intentions of performing safety behaviors. Following the risk-taking process, the "Train is right here" sign prompts risk perception, resulting in drivers' intention to behave safely. On the other hand, the "Thank you for stopping" sign provided kind appreciation of drivers, resulting in drivers intending to drive safely because of the norm of reciprocity.

Keywords

risk-taking, railroad crossings, pictogram

1. INTRODUCTION

According to "information regarding train transportation safety 2014" published by The Japanese Ministry of Land, Infrastructure, Transportation, and Tourism, 248 accidents occurred at railroad crossings in the last year in Japan, showing a yearly decreasing trend. However, fatal accidents at railroad crossings account for 32.1% of all driving related fatal accidents, signifying the necessity for the prevention of accidents at railroad crossings for railroad safety [The Japanese Ministry of Land, Infrastructure, Transportation, and Tourism, 2015].

When looking at accidents by the type of railroad crossings, 212 accidents occurred at Class I railroad crossing, and 9 accidents at Class III railroad crossings. (Class I railroad crossings are crossings with gate bars to intercept traffic, whereas there are no gate bars at Cass III railroad crossings, but only an alarm warning passing trains and cars [Railway Technical Research Institute, 2006]). Although the accidents rate seems higher at Class I railroad crossings when glancing at the number, the accident rate per 100 railroad crossings in the past five years reveals that the Class III crossings resulted in 1.03 accidents per 100 railroad crossings whereas Class I crossings resulted in 0.82 accidents. That is, Class III railroad crossings have a higher accident rate than Class I railroad crossings at which there is more traffic and more trains crossing at a faster speed.

At Class III railroad crossings, drivers are required to make a stop regardless of the presence of trains. However, it is possible for drivers to drive without stopping, engaging in risk-taking behavior, because there is no gate bar and trains rarely pass the crossings. An effective warning sign at crossings without gate bars that would be effective for making drivers stop would be beneficial for preventing accidents.

A small number of studies have examined the effects of warning signs at railroad crossings on drivers' risk-taking behavior. For example, Tey, Ferreira, and Wallace [2011] examined the effectiveness of three types of warning signs using a driving simulator: a stop sign generally seen in Australia, a stop sign with a blinking red light, and a stop sign with a short gate bar. The results indicated that the stop sign with a blinking red light prompted drivers to slow down more gradually and stop at a safer position before the stop line, when compared to conventional stop signs.

On the other hand, other studies have indicated contradictory results. For example, Lenne et al. [2011] developed three types of stop signs, a conventional stop sign, a stop sign with a flashing red light, and a stop sign with three-color traffic lights, and examined which stop sign was most effective using a driving simulator. The results indicated that participants decelerated the vehicle most gradually when they saw the conventional stop signs, as compared to the other types of signs.

The findings of these studies suggest that the implementation of LED and traffic lights at stop signs do not guarantee the inhibition of drivers' risk-taking behavior. Thus, we limited our design to signs without devices such as LEDs, and examined designs that would modify driver's risk-taking behaviors by using a questionnaire.

It is imperative to design warning sign that prevent drivers from engaging in risk-taking behavior. Furthermore, the questionnaire has to assess the process of risk-taking behavior, that the "underestimation of a risk leads to risk-taking behavior," when assessing the effectiveness of a design. Thus, in addition to the design of a warning sign, we developed a questionnaire that integrates the process of risk-taking behavior. Using this questionnaire, we examined whether the intention for risk-taking differed depending on a warning sign seen by drivers.

2. METHOD

2.1 Participants

The participants of the present study were 41 men (M = 30.5 years old, age range: 23 to 34 years) who holds driver's license for ordinary vehicles. The participants took part in the study for monetary reward. The recruiting criteria for participants included vision better then 0.7, more than one year of driving experience, and driving least 2, 3 times a month, no susceptibility to motor sickness, no history of psychiatric disorders, and normal hearing ability.

2.2 Criteria for sign development

Of that four signs that were developed, two signs reminded of dangerous behaviors in front of railroad crossings, one sign contained an appreciative message for safe behaviors, and one sign showed an image of being monitored. Figure 1 shows the signs that were developed.

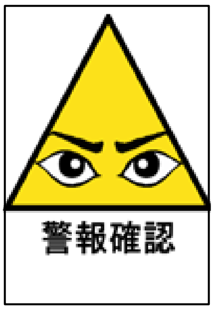
(C)SlowLife

(a) Train is in front of you when you hear the alarm

(C)SlowLife

(b) Release your gas pedal when you hear the alarm

(C)SlowLife



(c) Thank you for stopping

(d) Be aware of the alarm

Figure 1. The develop signs

Two signs that contain remainders to drivers were developed based on the analysis of past accidents reported in the section on "accidents at railroad crossings by objects, causes, and types of railroad crossings (2010-2014)" reported in "information regarding safe railroad transportation (2014)" [The Japanese Ministry of Land, Infrastructure, Transportation, and Tourism, 2015]. According to this report, 42 accidents occurred at the Class III railroad crossings (Class III railroad crossings are currently placed at 775 locations) from 2010 to 2014. Of these accidents, 28 cases (66.7%) involved vehicles, and 25 cases (59.5%) happened because drivers had crossed the railroad immediately before the trains passed. Therefore, the warning signs in the present study were designed to target vehicle drivers and to contain pictograms and messages to stop immediate crossing. The first sign was created to tell drivers that trains are already right in front of them when they hear the alarm, showing a pictogram and the message "Train is in front of you when you hear the alarm (train is right here)." See Figure 1(a). The second sign was designed to alert drivers that accelerate and try to cross railroads when they hear the alarm. Thus, the sign contained the message and pictogram to release the gas pedal when they hear the alarm, "Release you gas pedal when you hear the alarm (Release your pedal)." See Figure 1(b).

The next signs showed appreciation to drivers for their safe behaviors. To date, a number of signs and messages for stopping nuisance behaviors have included prohibition or punishment [Kitaori & Yoshida, 2000]. However, previous studies suggest that messages with prohibition and punishments trigger negative feelings and offend recipients [Yuo & Yoshida, 2012]. Thus, we developed a sign that shows appreciations to drivers for their safe behaviors. Of particular, the sign included a pictogram a message that appreciated drivers for stopping before the stop line, "Thank you for stopping (appreciation)." See Figure 1(c).

The next sign showed drivers being monitored. A number of studies have indicated that gaze, whether it is real or a picture, automatically catches people's attention [Friesen & Kingston, 1998; Driver, Davis, Ricciardelli, Kidd, Maxwell, & Baron-Cohen, 1999]. Moreover, angry facial expressions are detected more quickly than other facial expressions, which is a phenomenon known as the anger superiority effect [Fox, Lester, Russo, Bowles, Pichler, & Dutton, 2000]. Furthermore, previous studies have indicated a stimulus that seems like a person's eye can provoke cooperative behaviors including real life prompts [Bateson, Nettle, & Roberts, 2006; Burnham & hare 2007; Haley & Fessler, 2005]. Based on these studies, we created a sign imitating a human face to express staring eyes. Of particular, the sign indicated two eyes monitoring the drivers listening to the alarm the a message, "Be aware of the alarm (monitoring)." See Figure 1(d).

We requested the co., Office Slow Life, which is a professional graphic design company, to create the signs in Figure 1 (a), (b), and (c).

2.3 Procedure before responding to the questionnaire

The present study required participants to experience real feeling when crossing the railroad crossings without gate bars. Therefore, one participant at a time sat in the driving simulator [i-Drive (PR-R-PW-AT-100)] that was placed in a room and repeatedly drove to the railroad crossing at which one of the warning signs was posted. The driving scene was projected onto three 42-inch smart televisions screens (42LA6650) from LG electronics.

In this procedure, the participant drove 20 trials per session for a total of 2 sessions with a break in between. One trial was consisted of gradual curve and straight courses for 900 meters, and they were required to cross the railroad crossings without a gate bar with one of the designed warning signs placed right in front of the crossing. The order of presentation of warning signs was random, however, each sign was controlled to appear an equal number of times in one session. The participants responded the questionnaire after driving for two sessions.

2.4 Questionnaire assessing warning signs

In order to assess the effectiveness of warning signs that aimed to reduce risk-taking behaviors, a questionnaire was developed to reflect the process of risk-taking behavior that emphasized “underestimation of risk leads to risk-taking behaviors.” Therefore, the questionnaire was developed based on the questionnaire used to assess animal warning signs in a study conducted by Noro, Shimmori, and Hara [2004].

In their study, a questionnaire was created to assess the effectiveness of animal warning signs placed in roads where animals may suddenly cross. The questionnaire included questions to assess risk cognition, how much drivers recognize the danger of collision with animals, and to assess implementation intention, and the degree of intentions drivers have for decreasing their speed, instead of increasing the speed. These questions are similar to the process of risk-taking behavior, in which the perception of risk precedes risk-taking behavior. We referred to this questionnaire when developing the questionnaire for the present study. The developed questionnaire included three questions assessing risk perception: how much danger drivers recognize at railroad crossings, and two questions assessing intentions for implementation, or how much drivers intend to behave safely at railroad crossings. The effective railroad crossing signs were assumed to indicate higher intentions for implementation scores.

Furthermore, in addition to these two types of questions, we created questions to assess attitude about safety. Risk perception that determines risk-taking behavior is not only affected by gender, but also the attitude about safety of individuals [e.g., Cooper, 2003].

Therefore, we developed three questions assessing individual’s attitude about safety and examined whether safety attitude affects risk perception and implementation intentions. The Table 1 shows the developed questionnaire. The participants in the present study responded to one set of questionnaires for each type of signs, responding to a total of four sets of questionnaires. Each question was randomized, and they responded to the questions by using a 5-point scale.

Table 1. Items in the questionnaire assessing the effectiveness of railroad crossing warning signs

Types of questions	**Question**
Risk perception	Do you think many trains pass this railroad crossing?
	Do you think there is a possibility of collision with a train?
	Can you imagine the damage to cars and trains in case of a collision?
lementation intention	Do you stop in front of railroad crossings?
	Do you look left and right at railroad crossings?
Safety attitude	Do you drive without attending to trains and train alarms?
	Do you try to avoid collisions with trains and drive safely?
	Do you try to avoid collisions with trains and drive so as to protect yourself?

3. RESULT

A two-way ANOVA was conducted with designs of the warning signs (4 levels: train is right here, release your pedals, appreciation, monitoring) and types of questions (3 levels: risk perception, implementation intention, safety attitude) as independent variables and average scores for each type of question as the dependent variable.

The result indicated a significant interaction effect of the designs and types of questions, $F(6,240) = 5.749$, $p < .001$, $\eta_p^2 = .126$. The pairwise comparison revealed a simple main effect of the design for risk perception and implementation intention, $F(3,120) = 7.450$, $p < .001$, $\eta_p^2 = .157$； $F(3,120) = 8.155$, $p < .001$, $\eta_p^2 = .169$, respectively.

Furthermore, a multiple comparisons using Bonferroni method was conducted for risk perception and implementation intention. The results indicated that the average score for risk perception was significantly higher for “train is right here” sign, than for the “release your pedal” and “appreciation,” signs. Moreover, risk perception score for the “appreciation” sign was significantly lower than for the “monitoring” sign (all p values > 0.05). The “train is right here” had the highest risk perception score among the four types of warning signs, and the “appreciation” sign scored the lowest for risk perception. On the other hand, the “train is right here” and “appreciation” signs scored significantly higher for implementation intention than for the "release your pedal" (p> 0.05). Both the “train is right here” and “appreciation” scored high in the implementation intention. Figure 2 shows the average score for each sign.

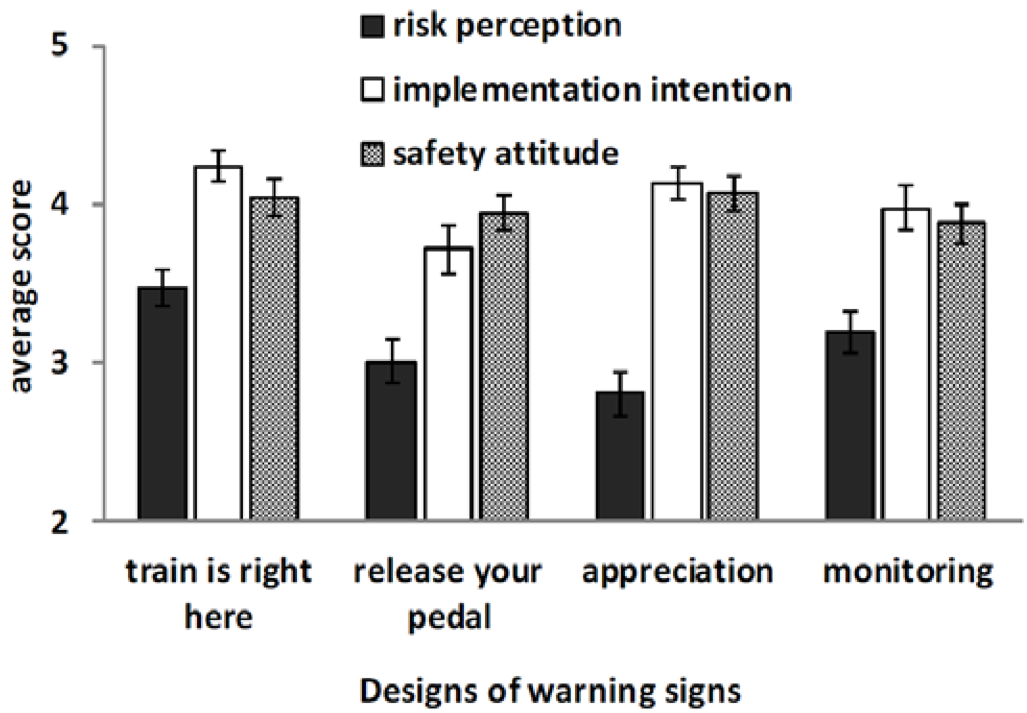


Figure 2. The average scores of each sign

4. DISCUSSION

The results indicated that the sign “train is right here” scored the highest for risk perception, and the “appreciation” sign scored the lowest. On the other hand, the score for implementation intention was highest for the “train is right here” and “appreciation” signs.

In the general risk-taking process, when the risk for railroad crossings was estimated high, one would translate the estimation to a particular safety behavior (in this case, the stopping in front of crossings). Following this process, the sign “train is right here” scored the highest for risk perception among the four designs, leading to high implementation scores. Therefore, the “train is right here” was the most effective sign among the four signs that were developed after considering the process of risk-taking.

On the other hand, the “appreciation” sign scored the lowest for risk perception; however, its implantation intention score was high, indicating that in this case, a risk-taking process did not take place. Drivers did not assess the crossing as being dangerous, however, they decided to stop in front of the crossings. Thus, this result implies that different psychological characteristics from the risk-taking process prompted the safe behavior.

The present result in which drivers behaved safely to gain appreciation can be explained in terms of norms of reciprocity. The norm of reciprocity is a psychological model that one should return the same degree of goodwill gained from others [Gouldner, 1960]. For example, Yuo and Yoshida [2009] created the imaginative situation in which the sign “thank you for recycling” was placed in front of the trash bins. As a result, participants had higher intention to separate trash for recycling compared to when messages other than those of appreciation were placed in front of trash bins. They described that appreciative messages triggered the norm of reciprocity. Applying this finding to the results of the present study, the “appreciation” sign prompted the norm of reciprocity leading to higher intentions to behave safely.

Moreover, prohibiting negative behaviors could offend individuals, resulting in weaker long-term effects on desirable behavioral modification [Yuo & Yoshida, 2013]. The appreciative message is known to trigger positive feeling [Yuo & Yoshida, 2009]. One study compared the effects of prohibiting and appreciative messages in a computer task that elicited numerous illegal movements. The study not only indicated that the effects of inhibiting illegal movements was larger, when participants saw the appreciative message than the prohibiting message, but also that they made less and less illegal moves from middle to the end of the task as comparison to the beginning of the task [Igarashi, 2015].

These previous studies show that the “appreciation” sign promoted safe behaviors based on different psychological factors related to the risk-taking process. Moreover, the scores for implementation intention of the “train is right here” and “appreciation” signs were not different, however, the continuous inhibition of the prohibited behavior might be higher for the “appreciation” sign among of the four signs developed in the present study, as a result, the “appreciation” sign was the most effective railroad crossing warning signs.

Furthermore, the present analyses did not reveal significant differences in attitudes about safety between the four types of signs, indicating that glancing at a sign affected risk perception and implementation intentions, but not attitudes about safety. The present result showed contradictory results from previous studies that had indicated that attitudes about safety affected risk perceptions. At least, the warning signs for railroad crossing did not affect attitudes about safety, but affected risk perception and intentions of implementation.

5. CONCLUSION

The result of the present study indicated that, four warning signs designed for railroad crossings without gate bars, the “train is right here”, and “appreciation” signs scored higher for risk perception and implementation intention. Since the implementation intention score shows the intention to engage in particular safe behaviors, the “train is right here”, and “appreciation” signs were more effective than the other two signs.

However, these two signs affected different psychological characteristics when participants behaved safely. The “train is right here” sign elicited risk perception following the risk-taking process, whereas, the “appreciation” sign elicited norm, or reciprocity, and both signs lead drivers to engage in safe behaviors. Therefore, both signs are effective, however, with consideration to continuous inhibition effects triggered by the appreciative message suggested by previous studies, the “appreciation” sign could be the most effective sign.

6. REFERENCES

Bateson, M., Nettle, D., & Roberts, G. 2006. Cues of being watched enhance cooperation in a real-world setting. *Biology Letters*, 2: 412-414.

Burnham, T. C. & Hare, B. 2007. Engineering human cooperation: Does involuntary neural activation increase public goods contributions? *Human Nature,* 18: 88-108.

Cooper, D. (2003). Psychology, risk & safety: Understanding how personality & perception can influence risk taking, *Professional Safety*, 48: 39-46.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. 1999. Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition*, 6: 509-540.

Fox, E., Lester, V., Russo, R., Bowles, R. J., Pichler, A., & Dutton, K. 2000. Facial expressions of emotion: Are angry faces detected more efficiently? *Cognition and Emotion*, 14: 61-92.

Friesen, C. K., & Kingston, A. 1998. The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, 5: 490-495.

Gouldner, A.W. 1960. The norm of reciprocity: A preliminary statement, *American Sociological Review*, 25(2): 161-178.

Haley, K. J., & Fessler, D. M. T. 2005. Nobody's watching? Subtle cues affect generosity in an anonymous economic game. *Evolution and Human Behavior*, 26: 245-256.

Igarashi, A. 2015. *The effects of warning expression to inhibit illegal actions and its timing of presentation*. Osaka, Japan. Osaka University, Unpublished undergraduate's thesis.

Kitaori, M. & Yoshida, T. 2000. The effects of message towards deterring socially deviant behaviors: An on-campus experiment on bicycle parking. *The Japanese Group Dynamics Associatio,* 40:28-37.

The Japanese Ministry of Land, Infrastructure, Transportation, and Tourism. 2015. Information regarding safe railroad information (2014). http://www.mlit.go.jp/common/001097996.pdf, accessed in August2015.

Lenné, M. G., Rudin-Brown, C. M., Navarro, J., Edquist, J.,Trotter, M., & Tomasevic, N. 2011. Driver behavior at rail level crossings: Responses to flashing lights, traffic signals and stop signs in simulated rural driving. *Applied Ergonomics*, 42: 548-554.

Railway technical term dictionary (2nd ed.). 2006. Railway Technical Research Institute Ed. Tokyo, Japan. Maruzen.

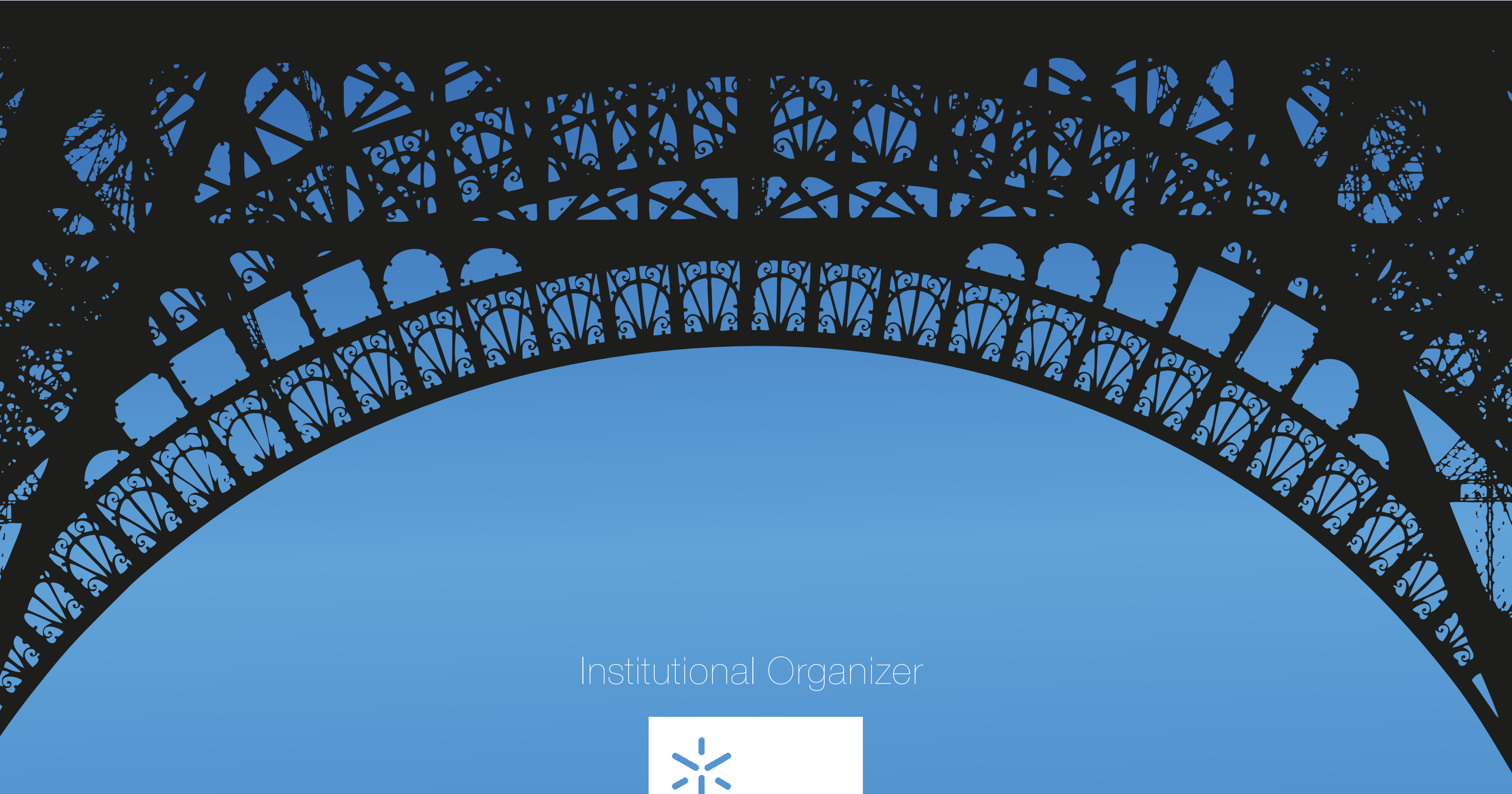
Noro, M., Shimmori, N. and Hara, F. 2004. Evaluation of animal warning signs based on driver's awareness and behavioral modification process. *Papers of Research Meeting on Civil Engineering Planning*. 19: 202-205.

Tey, L. S., Ferreira, L., & Wallace, A. 2011. Measuring driver responses at railway level crossings. *Accident Analysis and Prevention* 43: 2134-2141.

Yuo, S. & Yoshida, T. 2009. The effect of appreciative message and descriptive norms on inconsiderate public behavior and affect. *Japanese Journal of Applied Psychology*. 34(2): 155-165.

Yuo, S. & Yoshida, T. 2012. The effect of the norm of reciprocity in deterring inconsiderate behavior: The gratitude message and knowledge of the sender's identity. *Japanese Journal of Social Psychology.* 28(1): 32-40.

Yuo, S. & Yoshida, T. 2013. Favor as a deterrent for inconsiderate public behavior.
Japanese Journal of Experimental Social Psychology. 53(1): 1-11.



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