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# Integration of Safety in the Building Delivery System

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## Abstract

It is important to see safety and health in construction as an integrated part of the way in which designers, architects, constructors, engineers and others carry out their consulting services. The philosophy is simple – if the demands for safety and health are incorporated early in the solving of a building assignment, then it becomes much easier to organise the construction site in a safety wise responsible way. In Denmark a report has been drawn up which illustrates how this could be done. The method for implementing this illustration is based on the lean construction model, which is the method recommended as the most suitable for a construction process, since it ensures that considerations for health and safety at work do not conflict with considerations for economical, efficiency wise, quality wise and architectural objectives. The goal is to have the considerations for health and safety at work become a natural part of the construction process and thereby also have them incorporated into the detailed design process. The practical value of the concept depends on how you manage and organise the detailed design process. Keeping health and safety at work in mind through all phases of the construction process will ensure due considerations with regard to organisation, demands for the outcome, analysing and fulfilling demands for buildability and thereby incorporating the demands for health and safety at work into the project material.

**Keywords:** Lean construction, safety and health, design, buildability.

## Introduction

It is a well known fact, both nationally and internationally, that the construction industry is a generally risky business (Work and Health in the EU – A Statistical Portrait 1994-2002, Eurostat; Jørgensen, 2008; Gambatese et al, 2008; Smallwood, 1996; Toole et al, 2006; Behm, 2005). The EU has documented that 1/3 of the comparatively many and serious occupational

accidents are a result of flaws and defects in the client's and the consultant's detailed design, and 1/3 are a result of flaws and defects in the contractor's planning (The European Foundation for the Improvement of living and Working Conditions, 1991). A series of research projects likewise demonstrate that the design forms the basis for safety (Gambatese et al, 2008; Smallwood, 1996; Toole et al, 2006; Behm, 2005). The necessity of incorporating the question of safety into the construction process early on has been a recurring theme through the last 20 years. The ideal situation for the safety of the construction workers is to make this an important parameter for the planners and designers of the conceptual and preliminary design phase (Szymberski, 1997; Gambatese et al, 2008). This served as the basis for the EU directive of 92 (Council Directive 92/57/EEC of 24 June 1992) concerning minimum demands for health and safety at temporary construction sites, where the role of the building planner, be it the client as well as the architect and consultants, is emphasized as having the responsibility for drawing up a plan for health and safety during the execution of the construction project.

The nature of the construction project presents a barrier in it self when wanting to implement both safety and quality into the building process (Loushine et al, 2006). The construction industry is a project based industry which exists in a dynamic and ever changing environment (Lindgard and Rowlinson, 2005). The tenderers' focus on price instead of e.g. safety often makes the contractors leave out the cost for health and safety from their bids (Brooks, 1993). And even though it is required to include health and safety in the pricing this is not incorporated as well as it should be into the preliminary work on the construction project (Oluwoye and MacLennan, 1994). These circumstances strongly indicate how the work environment during the execution phase depends on the previous planning and on considerations for health and safety in the planning phase. They also indicate a need for clarifying the requirement of incorporating the demands for health and safety into contracts and tendering materials. Research, publications and guidelines on safety and problems with the work environment in the construction industry primarily focus on contractors and the work environment during the construction phase. Traditionally it has been the sole responsibility of the contractors who employ the construction workers, and the working environment legislation supports this (Gambatese & Hinze, 1999; Hinze and Wiegand, 1992). A series of research analyses give examples on how designers and planners generally do not see it as their responsibility to consider the safety of the construction workers. The analyses report statements such as the following: "An architectural firm rarely gets involved in the design of safety issues – we do not make decisions that pertain to construction worker safety. **We are a structural form and as such are responsible only for the final product**" (Hinze and Wiegand, 1992); "Traditional in the construction sector safety on the construction site is the responsibility of the contractors" (Gambatese et al, 2008); "The Engineers Joint Contract Documents Committee clearly state that designers have no responsibilities for means and methods affecting the safety of construction workers (Toole, 2002); "The initial premise is that clients and designers have been slow in taking up their responsibilities. Construction work covers many activities, techniques, materials and hazards and it is this diversity that increases the probabilities of accidents occurring" (Baxendale et al, 2000); "Clients have a positive role to play in lowering injury rates and influencing contracts" (Smallwood, 1998).

In a series of research and development projects terms like "safety design" and "total safety management in construction" have gained a footing. In these projects it is pointed out how

much the designers actually influence the safety during the construction phase and how decisions, design and construction has a direct impact on the safety of the construction workers (Hinze and Wiegand, 1992; Gambatese & Hinze, 1999). Safe design is defined as the deliberate decisions concerning the safety during construction which have been made during the design phase with the purpose of reducing the risks facing the construction workers' (Toole et al, 2006). As mentioned earlier, several studies show a clear connection between the designers' decisions and safety during construction (Hecker et al, 2005; Gambatese et al, 2008; Weinstein et al, 2005; Trethewy and Atkinson, 2003). Since the considerations for health and safety at work were already ensured during the detailed design phase, as well as during the preparation of the construction phase, it is safe to assume that the risk of accidents and other work-related injuries are reduced – including psychological injuries and work-related musculoskeletal disorders (WMSDs). The objective has to be to clarify how the construction workers can easily set up and carry out their work in a safe and healthy environment (Szymburski, 1997; Gambatese et al, 2005; Gambatese et al, 2008). But there also seems to be a need for formulating a best practise in which the designers, planners and contractors can seek inspiration for their attempt to minimize the risks of the construction process. This is thought necessary because the personnel at the consulting architects and engineers have very limited knowledge of how they can take the safety of the construction workers into consideration (Gambatese et al, 2005; Gambatese & Hinze, 1999). When asked what safe design or safe buildability is a series of different ideas were offered which are generally concerned with purely technical directions, but also with planning methods (Toole et al, 2006). An example of this could be, among others: "Tools for Construction Safety Design" (The Construction Industry Institute, 2009) containing over 400 design proposals. England has extensive material on The Health and Safety Executive's homepage (UK HSE, 2009) and in Australia they recommend a special design review form called CHAIR (Workcover, 2001).

The fundamental principles of safe buildability are among others described in the following manner (Baxendale, 2000):

- Safety has to be considered systematically step by step from the very beginning of a project
- Everyone who influences safety are to participate
- Good planning and coordination must be implemented from the beginning of the project
- Health and safety should be handled by competent personnel
- Communication and the sharing of information between all parties should be included
- A formal record of safety information for future use should be made

The philosophy behind improving health and safety management begins with establishing a team with competencies and resources to manage the project in a way which incorporates safety. The planning supervisor for safety should be appointed as early as possible and is the client's central responsibility (Baxendale et al, 2000).

## **MODEL FOR IMPLEMENTATION ILLUSTRATION OF HOW TO CREATE SAFE DESIGN**

A Danish research project has accepted the challenge and attempted to illustrate to designers and planners how safe design could be obtained in more specific terms. The method for this illustration follows the model for "The Lean Project Delivery System", which is described by the fathers of lean constructions – Ballard (2000) and Koskela (2002), and is shown in figure 1. The illustration only includes the first 3 steps or the first 7 phases from programme to preparation of construction.

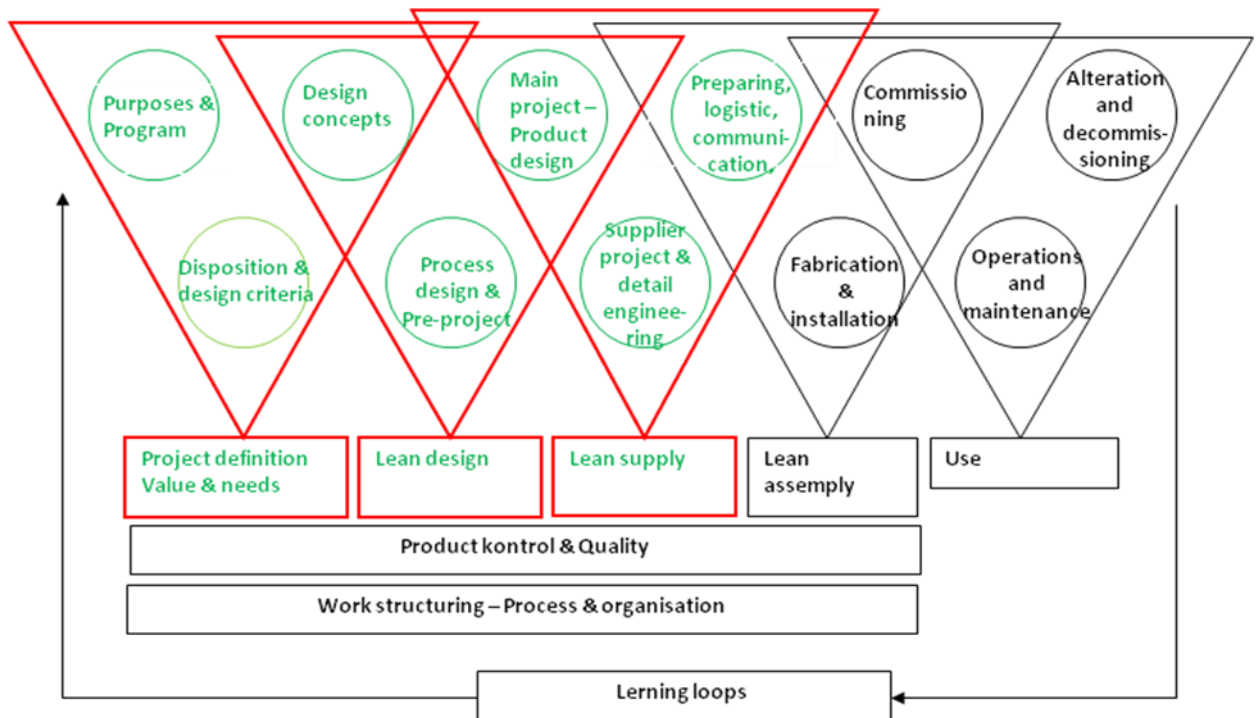


Figure 1: The basic concept for drawing up the illustration for how health and safety at work can be implemented into the construction project's design and planning phases, Ballard (2000) and Koskela (2002).

Lean construction has two governing principles: "Maximise value and minimize cost" (Ballard, 2000; Koskela et al, 2002). This happens by emphasizing flow, simplicity and manageability, and planning production according to necessity, in this case the client's wishes (Kamp et al, 2005). When looking at themes such as quality, safety and economy, a concept based on these principles can be especially interesting. In this context you can view accidents and illnesses as a special form of waste of human resources. It is the practical experiences of the authors' with applying this concept that you can create good health and safety conditions for construction projects that do indeed work.

### Workshops as method for creating value

Planning the phases can be supported by workshops where as many stakeholders as possible are represented. A basic concept of the lean idea is that all involved parties are included in the

entire construction process from beginning to end. This entails that the contractors participate early in the planning process and that the planners are involved well into the execution period. The workshop method is proposed for securing this involvement and participation in the process, but other forms can also be used as long as the process and participation of all involved parties is secured throughout the build. This calls for a continuous project manager and a well structured meeting schedule.

## Project definition, value and needs

The values of the construction is settle during the first 2-3 phases of the construction process both for the end product as well as for the construction process. All following phases must necessarily be based on the decisions, strategies and framework determined during these first phases. This also applies to health and safety, where the conditions during construction are totally dependant on how much health and safety is incorporated into the design process and overall requirements for e.g. buildability, materials, planning et al. Of course the main objective is not to limit the possibilities of the construction, but by incorporating health and safety from the beginning as an outcome influencing parameter you could reach new solutions that comply with both the wishes of the client and at the same time enables a safer and healthier construction process. The client leads the way in the opening phases. He can state his terms for the finished construction as well as for the construction process. The degree to which the client is able to formulate his/hers demands for health and safety and to demonstrate his prioritization of this during the opening phases will influence the entire construction process and the realisation of the values.

The construction estimating contains the clients basic ideas and requirements and the architect's design which forms the basis for the rest of the construction process. The foundation stone is laid down for that which you wish to build and at what cost, the time frame, quality and health and safety at work including the safety and health for the construction workers.

**The programme** must contain goals and values for the construction, which means that the client determines the basic values for the construction with regard to: function of the construction i.e. size, location, quality, economy, time frame et al. It is important at this stage that the client sets a definite level for the health and safety of the construction since it affects the choice of collaborators, contracts, suppliers, organisation et al.

Two significant areas influence this stage – the formulation of the vision and strategy of the construction project and the formulation of the plan for carrying out the construction process.

A vision expresses what the client desires for the construction in terms of character and values. This could be expressed as in the following:

- The construction is to be a model project wherein the managerial values, including health and safety at work, are communicated to the collaborators during the entire construction process.
- That health and safety at work is a joint responsibility for all parties involved in the construction process, possibly in an alliance where all parties have well defined duties and tasks aimed at improving health and safety at work.

The strategy is an expression of the way in which the client wishes to fulfil his/hers vision. This could be expressed as in the following:

- That the construction process is to focus on the time frame as well as economy, quality and health and safety at work. This includes minimizing health and safety risks as much as possible during the design and planning phase and is to take place as a purposeful planning of the health and safety process during construction.
- That an objective and measurable goals are set up for the project considering health and safety during construction, and that risks are prevented by identifying them and planning to avoid them early on in the construction process.
- That an organisation is set up managed by e.g. the client's health and safety coordinator and the head of design and planning. They are to ensure information and knowledge for everyone involved so these can take responsibility and act with regard to the vision for health and safety at work including continuous collection of reports on discrepancies, accidents and near accidents as well as carry out supervision and control e.g. during an audit.
- That everyone involved are motivated towards fulfilling the clients vision for health and safety at work through contracts, bonuses and consequences when the requirements are not met or when they are excellently complied with. This could be carried out by the client's health and safety coordinator.

**The design criteria** contains the general design criteria, but should still be drawn up in such an explicit way that the following processes understand what it is they are to include in their considerations. The conceptual design can even contain very precise information on what is included in the stated goals and values. When considering health and safety at work it could be expressed as in the following:

- Building components must be manageable in order to minimize heavy lifting. As an alternative, in cases where heavy lifts can not be avoided, suitable lifting tackle is to always be made available.
- Substances and materials that might present a nuisance to the ones working with them are not to be used. As an alternative, in cases where use of these substances or materials can not be avoided, necessary safety equipment is to always be made available.
- The sites and means of access are to provide room enough for the construction workers to apply good work postures. As an alternative, in cases where this is not possible, a special work place evaluation is to be carried out for the assignment with regard to health and safety.

- Traffic roads and transport forms on the construction site are to be designed in such a way that they create a high level of safety for those who move around and work at the site. Areas for walking and driving could e.g. be kept separate. As an alternative, in cases where this is not possible, a work place evaluation is to be carried out and necessary safety precautions are to be taken for when unsafe transportation takes place on the construction site.

It is thought that the health and safety requirements only should be written down in a set of a few general rules with referring to the law. But experience shows that if this is the method then health and safety considerations are not incorporated into the design and planning of the construction. Only if the client explicitly states his demands there are possibilities of creating change in this area.

## Lean Design

During the phases from "design concepts" to "process design and pre project" to "the main project" planning moves from the overall parameters to a more specific definition of how to solve the minor and major details of the construction. When these phases have been completed there is only a small possibility of changing the conditions under which the construction will take place. Therefore it is important to incorporate considerations for health and safety into these phases. When the client has made specific values and goals for health and safety they will be reflected in the detailed decisions and solutions made during the process from the design concepts to main project just like the clients other values – and thereby they ensure that health and safety at work is in fact considered in accordance with the requirements.

The lean design largely contains the planning work based on the design concept.

The method signals that the design concept is also an integrated part of the planning and that it can adapt to and be altered within the process.

Because of this the lean design forms the more detailed part of the construction planning consisting of many different elements. The finished construction is the focus of this phase: How it is going to look, which elements it is to consist of, the construction, installations etc. But this is also where the more precise decisions are made on what is to be built and how.

**The design concepts** establishes what the building is going to look like, its outer appearance, floor plan, choosing the structural engineering principle, choosing materials and installations. This includes identifying the risks that can create difficulties and which are to be a part of considering the choice of construction, materials etc. The deliberations ought to evolve around whether there are alternative solutions which can minimize the need for specific safety requirements later in the process.

Furthermore procedures for communication and cooperation between the involved parties throughout the construction process could be established here. This could e.g. be a decision stating: that the construction process is to be carried out as a lean project; how coordinating health and safety is to take place et al.



Furthermore the architect puts forward demands for how the clients goals, values and specifications from the programme are to be met. This also includes how to handle the requirements for health and safety at work during both construction and during use and maintenance of the building.

This is also the most suitable time for determining and describing structural elements as basis for drawing up control charts for quality assurance and similar control charts for health and safety evaluations.

**The process design and pre-project** includes documentation from pilot studies and possibly of new methods which are to be applied if possible and clarification of specifications, testing materials and inquiring on possibilities and needs with those involved e.g. end users and authorities. Acceptances are obtained from the authorities, it might be investigated what is possible in areas which have not been clarified and the main project is defined. Moreover this includes the first rough sketch of a plan for health and safety and a specification of which actual risks are to be corrected in the main project. In the process design and pre-project the designer's demands are transformed into concrete actions and the overall solutions are determined. Moreover the operational action plans for the execution of the construction project are determined.

To a wide extent this is where the final lines are determined for health and safety. Therefore it is important that the plans for product and process with regard to requirements and choices in relation to which consequences it might have on health and safety during both construction and later maintenance of the building are thoroughly looked through during this phase. All structural elements must be scrutinized at this stage ex. the ground, the materials, the building site etc. which have been sketched or decided on. Every part of the construction project is looked through in order to assess the risks concerning health and safety at work based on the safety list for structural elements. There is a definite need for defining buildability and especially safe buildability during this phase and it is therefore necessary to enter into dialogue with the entrepreneurs, who is going to make the construction. The demands stated in the design criteria that may not have been fulfilled in the design concept are to be incorporated in the planning at this point and solutions must be found. The process design very much includes managing and operating the processes – both vertically and horizontally in relation to the entire chain of deliverables being both planning element deliverables and detailed planning deliverables as well as product and material deliverables and output in the form of e.g. the execution of a task.

The overall lines for the process during the execution of the project are added to the demands for the process to be plannable via e.g. lean methods.

## Lean Supply

During the phases from "the main project" to "the supplier project" and to "production preparation" the construction project is planned and defined in detail and the execution of the construction is prepared. Furthermore it is determined which minor and major structural element deliverables are to be agreed upon with which suppliers. The transition and hand over of objectives, decisions knowledge and solutions are based on written and verbal forms of

communication where particularly the workshop method and involving the contractors can ease this process. However the final decisions and agreements must always exist in written form.

It is important that the contracts and agreements entered into with both contractors and suppliers contain information on those health and safety risks to which a solution has not been found as well as those demands and requirements for health and safety that were formulated from the beginning by the client and have been incorporated into the design and planning.

Thereby a plan for health and safety becomes a visible product of the considerations and decisions made by the client's health and safety coordinator during the planning phase in collaboration with the project manager.

In principle the project consists of planning the construction and organising the execution of the construction project. This is usually carried out so that the contractors need only carry out the final detailed planning, which usually takes place during the construction period with the planners, the suppliers and with the construction workers.

The project includes timetables, logistics, agreements, contracts, staffing, detailed plans etc., and among these the construction site plans, the plan for health and safety during the build, the workplace evaluation, the drawings and work sections.

Today the suppliers constitute a more and more significant part of the construction process by delivering system solutions, finished factory-made solutions et al. Because of this part of the planning and preparation of a construction depends on what the product in question consists of and which information, technical materials and mounting instructions those constructing the building need to receive. This makes the suppliers an equally important partner to include in the dialogue on how to solve engineering questions concerning health and safety as well as quality and efficiency

**The main project – product design** includes the detailed description of how to solve and carry out the construction assignment. During this stage, the main plan, general drawings, building component drawings, detail drawings and detailed descriptions explaining the demands for materials and for carrying out the tasks are drawn up. This is also the phase during which the final plans for health and safety on the construction site are determined as well as the basis for those workplace evaluations that are to be carried out by the ones working on the project regarding risks that have not been addressed during the design and planning phase.

In connection with the main project the construction has to be scrutinized with regard to buildability and execution.

Detail drawings and detailed descriptions are drawn up in which links between the various building components and mounting details, including their function and buildability, are specified, controlled and determined. In connection with this it has to be evaluated which risks it has not been possible to eliminate during the design and planning phase, and which therefore have to be addressed through precautionary measures during the execution of the construction project. The evaluation will result in requirements for the ones involved in the project to implement the identified measures. The risk assessment will include the client's values e.g. time frame, price, quality and health and safety at work. This, in combination with Lean Construction's 7 preconditions for a healthy activity, ensures that obstacles do not arise during the execution of the construction project.

The purpose of **the supplier project and detail engineering** is to determine which materials, outputs and possible prefabricated building components that are to be delivered by who and when. Choices have to be made concerning choice of product, choice of suppliers and thoughts on delivery times, mounting sequence and mounting method.

This also includes thoughts on the risks possibly connected with handling and processing before mounting and a demand for the suppliers to be a part of the on-site work because of their specialized knowledge about the products.

A series of analyses show that the suppliers are the primary source of new information on products and materials for others involved in the projects. The suppliers are responsible for the set-up and content of the products, and the suppliers are also responsible for providing the product buyers with satisfactory and uniform information on the products such as statutory manufacturer's manual.

The purpose of the **production preparation** is to ensure that all goals, requirements and specifications are fulfilled in the material describing what is to be built. The project material must be evaluated in order to assess the buildability and to determine the actual methods for executing the construction project. This is also the stage at which the collaboration between the client's health and safety coordinator, the planning manager, the construction manager and the contractors is developed. They are to coordinate and communicate the health and safety measures during the build. The client's health and safety coordinator for design and planning is to hand over the process to the health and safety coordinator for the build. It may be the same person who carries on the work, but often it will be two different health and safety coordinators, since the coordinator for design and planning needs to possess special competencies within planning and the coordinator for the construction needs competencies within executing the construction process. Furthermore the health and safety coordinator for the construction needs to possess special skills in facilitating cooperation and motivation among everyone employed at the construction site.

**Workshop based process planning** has presented good results with regard to collaboration between the building trades and the mutual communication and coordination within the construction process which are vital to complying with the timetables, plans for quality and plans for health and safety at work.

Included in this are planning kickoff meetings and time-outs throughout the construction period, organising foreman meetings, continuous and dynamic planning, arranging introduction meetings for new site employees and involving the construction workers in quality and safety procedures.

## CONCLUSION

A general theme in literature on the subject is that the construction industry brings along major safety costs for the construction workers worldwide **and that occupational injury or fatalities are rather common**. Another general theme is that architects, designers and planners have not seen it as their responsibility to provide safety during the execution of the construction projects. They have passed on this responsibility to be solely in the hands of the contractors.

This is given since the employer is responsible for the safety of the employees with reference to the health and safety at work act.

But at the same time the importance of incorporating health and safety into the planning from the very beginning is pointed out, which has led to a legislation which orders the client to make sure that health and safety is handled during the construction design and planning phase.

On the other hand the literature points out again and again that the designers and planners do not possess the knowledge necessary to incorporate health and safety into their work. This is a problem which the Danish report on integrating health and safety in the design and planning phase tries to compensate for. But it is to be considered as a small step on the way and it will not suffice on its own. There is a need for developing methods and gaining experiences and good examples which can form the basis for a development. This development needs to happen fast, if further accidental deaths in the construction industry are to be prevented.

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