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RESEARCH PAPERS FOR
EUROFM'S 16TH RESEARCH SYMPOSIUM
EFMC 2017

25-28 APRIL 2017 IN MADRID, SPAIN

SUSANNE BALSLEV NIELSEN, PER ANKER JENSEN AND RIKKE BRINKØ
(EDITORS)

RESEARCH PAPERS FOR EUROFM'S 16TH RESEARCH SYMPOSIUM
EFMC 2016

PREFACE

The general conference theme for EFMC 2017 is *"Consolidating the Global Scope of Facility Management"* and this is also the theme of the 16th EuroFM Research Symposium, which is organized as part of the conference. The objective of the research symposium is to present original research that contributes to the understanding of the role of FM in organisations and to encourage discussions and the development of new knowledge amongst researchers, FM professionals and educationalists on this important topic.

This year the research symposium is partly integrated with the business conference to support a strong cross-fertilisation between research and practice. There are 3 sessions dedicated to research papers and 2 sessions include a combination of research and business presentations. All research presentations are based on research papers, which have been through a rigorous review process as used for earlier EuroFM research symposia.

All together 32 abstracts was received and after the review process 19 papers were accepted and they are all included is this publication. Out of the 19 papers, 15 are presented at research sessions and 4 are presented at combined sessions.

EuroFM has agreed an open access mandate. This ensures that the full text of all published research symposium papers (and conference proceedings arising from EuroFM sponsored work) should be deposited in an open access institutional repository, or if that is not available, on the ResearchGate database after the conference.

The publication of the printed proceedings is sponsored by Centre for Facilities Management – Realdania Research (CFM) at the Technical University of Denmark.

We thank all authors and the scientific committee for their dedicated time and efforts. We wish the reader an enjoyable learning experience and lots of inspirations for further research and the application into education and practice.

May the 16th Research Symposium at EFMC 2017 in Madrid become a successful event that will help consolidating the global scope of FM!

Susanne Balslev Nielsen   Per Anker Jensen
Chair of the Scientific Committee   Head of CFM

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Environmental indicators for non-residential buildings: When, what, and how to measure?

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ABSTRACT

Purpose: The purpose of this research is to present state of the art within the scientific literature for assessing environmental building performance of non-residential buildings (NRB), and to guide facility managers' choice of environmental indicators to monitor the environmental performance of non-residential buildings like corporate buildings, public institutions etc.

Design/methodology/approach: 20 papers from a systematic literature review are analysed to determine main environmental building performance indicators/indicator sets as well as indicator management role and relevance in relation to the life cycles of NRB.

Findings: The reviewed literature states clearly that the use phase of NRB in general has the highest environmental impact in a building life cycle perspective. Furthermore, the literature reviewed identifies building environmental indicators in eight categories and determines two dominating assessment methods for compiling sets of indicators for assessing environmental building performance: The Life Cycle Assessment (LCA) method, and the criteria-based certification method with references to BREEAM, DGNB, LEED etc.

Practical implications: Decision makers such as building owners and facilities managers should focus on the building use phase in order to improve the environmental performance of NRB. Energy management is a topic of paramount importance, but not the only indicator category to be considered when addressing environmental building performance.

Based on our study, the paper recommends application of the LCA method for assessment of the building use phase and for improving the environmental performance of NRB. LCA can facilitate the determination of more environmentally friendly solutions based on lifetime calculations. Prior to LCA, Facilities Management (FM) data investigation should be conducted, in which the actual FM data regarding environmental performance should be evaluated.

Originality/value: This paper is a systematic literature review intended to provide the accumulated scientific knowledge on how to measure and manage environmental building performance. Such knowledge is relevant for facilities managers in the process of implementing an environmental strategy, but also for software developers who want to improve FM systems like e.g. Integrated Workplace Management Systems (IWMS).

Keywords: Facilities Management, Life Cycle Assessment, Building performance, Performance indicator, FM data.

1 INTRODUCTION

This paper provides an overview and conclusion about the most applied environmental building performance indicators. To limit the scope of the paper, the focus is narrowed down to non-residential buildings as a significant building type in most urban areas and due to their high energy and resource consumption (Abu Bakar et al. 2015; Balaban et al. 2015). Non-residential buildings (NRB) are in this paper defined as large corporate and public buildings with many users used for collective purposes.

The interest in environmental building performance assessment started to flourish already in the early 1960'ies with Silent Spring (Carson 1962). Since then, a significant amount of research has focused on the quantification of environmental impact of buildings, and appropriate environmental building performance indicators, but in various ways. Environmental impacts of buildings are typically summarized into two impact groups: embodied impacts (i.e., impacts embodied in the constructed building) and operational impacts (i.e., impacts occurring over the lifespan and hence use of the building) (Anderson et al. 2015; Soust-Verdaguer et al. 2016). Buildings as products are complex structures with a long service lifetime compared to most other products and they induce considerable environmental impacts throughout their life cycle (illustrated in Figure 1). The environmental performance of a building is dependent on many attributes: building design, selection of building materials, location, and use pattern which can be optimised through e.g. maintenance, renovations and changed use (Harris 1999; Pajchrowski et al. 2014).
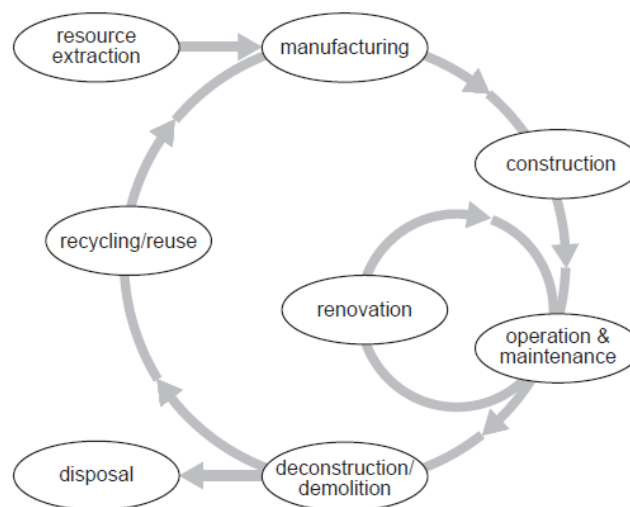
Figure 1 Schematic life cycle of a building (Melià et al. 2014).

Once designed and built, it is not easy to change environmentally impactful decisions made in relation to building design such as building orientation, window-to-wall ratio, and HVAC system (Russell-Smith et al. 2015). The processes used to operate and maintain buildings have an even larger cost and environmental impact than the design and construction process (Lewis et al. 2010). In fact, many of the environmental impacts of a building occur during its operational phase (Khasreen et al. 2009).

Relevant reviews of the FM literature have recently been conducted by Ebbesen (2015) and Nielsen et al. (2016). However, these reviews are lacking a comprehensive identification of studies specifically on environmental building performance indicators. To address this topic, our paper investigates the following research questions:

1. When in a building life cycle do non-residential buildings have the highest potential for improving environmental performance?
2. Which environmental indicators are most used for non-residential buildings?
3. How can environmental performance be quantified for non-residential buildings?

2   METHOD

A literature study is chosen as a research method for answering the research questions and to get an overview of recent research on environmental indicator categories for non-residential buildings. A systematic literature review was conducted according to Okoli & Schabram (2010) in the period March-September 2016. The literature was analysed to determine main environmental building indicator sets, their role and relevance in relation to non-residential building life cycle.

Journal selection and first screening round
The literature search was conducted using 5 research databases (DTU FindIt, Google Scholar, ScienceDirect, Scopus, Web of Science). Initial search on "building environmental indicator" in the selected databases returned 1,125 papers from 12 international journals. To limit the amount of results, the scope was further limited in terms of time and topic. The time limitation is set to include only journal papers published from 2010 to 2017. This limitation was introduced to include only more recent research. Furthermore, since the research focus is on the built environment, only papers addressing buildings are considered topic-relevant. Introduction of time limitation and topic-relevance criteria reduced the amount of papers to 107 and excluded 4 journals.

Second screening round
Each article title and abstract was studied in depth afterwards, returning in the end 68 papers from 8 journals on building environmental indicators. 20 of the 68 identified papers relate to non-residential buildings and they constitute the basis of this paper.

Data extraction and analysis
The method choice brings both benefits and limitations to the paper. The final choice of 20 peer-reviewed journal papers is a result of the systematic approach applied as well as broad and comprehensive literature study of internationally acknowledged research papers. On the other hand, relevant research conducted before 2010 is constrained by the time limitation. Since the paper is based on journal papers, it only considers academic literature in the review process, without taking practice into account.

The selected dataset is subsequently used to document and illustrate which building life cycle phases, environmental indicator sets and assessment methods are most often considered in research when addressing environmental performance of NRBs. The analysis is carried out through a quantitative approach in which the research literature has been used to quantify the amount of papers working with different building life cycle phases, environmental indicator categories and assessment methods. The analysis results are summarized in one table in section 3 Results showing which building life cycle phases, environmental indicator categories, and assessment methods are addressed in selected research papers. Based on findings from section 3, the conclusion is made in the end.

3   RESULTS

An overview of the overall results of our study is shown in Table 1. The table encompasses 4 column groups in which the first column lists all 20 research papers used in the study. Second column group is named Building life cycle phase and is divided in 4 building life cycle phases: Manufacturing, Construction, Operation & Maintenance (Use) and End-of-Lifetime phase. This column is used to determine which building life cycle phases are covered by the selected papers and relates to the first research question, when in a building life cycle do NRB have the highest potential for improving environmental performance. Third column group in Table 1 shows which environmental indicator categories are addressed in the selected literature, and is used for disclosing what environmental indicator categories are most frequently used for NRB. fourth column group presents assessment methods considered in research papers and is included for answering the last research question, how can environmental performance be measured in NRB. The assessment methods are distinguished in two main categories: Life Cycle Assessment (LCA) and Certification-based method.

Table 1 Results of a literature review of 20 research papers.

Publication	Building life cycle phase				Environmental indicator category								Assessment method	
	Man	Con	O&M	EoL	Energy man.	GHG emissions	Land use	Water man.	Waste man.	IEQ	Building mat.	Reuse pot.	LCA	Certifi-cation tools
1 Elle et al. 2010														
2 Lombera et al. 2010		1	1	1	1		1	1	1		1	1		
3 AlWaer et al. 2010	1	1	1	1	1	1	1	1	1	1	1			
4 Malmqvist et al. 2011	1	1	1	1	1	1	1	1	1			1	1	
5 Sharma et al. 2011	1	1	1	1	1	1			1				1	
6 Conte et al. 2012	1		1		1		1	1	1	1				1
7 Grant et al. 2012			1			1					1		1	
8 Kim et al. 2013					1	1				1				
9 Toller et al. 2013					1	1			1				1	
10 Asdrubali et al. 2013		1	1	1	1	1	1						1	
11 Cabeza et al. 2014	1	1	1	1	1	1							1	
12 Holopainen et al. 2014			1							1				
13 Seinre et al. 2014			1		1		1	1		1	1			1
14 Melía et al. 2014	1				1	1	1						1	
15 Napolano et al. 2014	1	1	1	1		1					1		1	
16 Russell-Smith et al. 2015	1				1	1							1	
17 Abu Bakar et al. 2015	1	1	1	1	1									
18 Balaban et al. 2016			1		1	1		1		1				
19 Munarim et al. 2016	1	1	1	1	1	1	1	1				1	1	
20 Kylili et al. 2016					1	1	1	1	1	1		1		
Totals:	10	9	14	9	16	14	9	8	7	7	5	4	10	2

Man: Manufacturing; Con: Construction; O&M: Operation & Maintenance; EoL: End of Lifetime

3.1 Building life cycle: When to improve environmental performance?

The results from Table 1 show that most papers (14/20) focus on Use (O&M) and Manufacturing (Man) phase (10/20) for non-residential buildings. The Construction phase (Con) and End-of-Lifetime (EoL) phase are considered in 9/20 papers. The results indicate that most research concentrates on the Manufacturing and Use phases, while there is less focus on environmental impacts during the Construction and EoL phases for NRB. The minor focus on Construction and EoL phase might be ascribed to the fact that the Construction phase is a goal-oriented process mainly focusing on a building assembly, while the EoL phase is often disregarded due to lack of data or is heavily simplified. On the other hand, most of the research is focusing on the Manufacturing and Use phases of NRB. The research on the Manufacturing phase concerns manufacturing of building materials and components as well as their characteristics in a relation to environmental building performance. The research on the Use phase usually studies different environmental building performance optimization possibilities like e.g. retrofitting projects.

Deeper analysis of the literature from Table 1 reveals that the operating energy for non-residential buildings usually accounts for 80-90% of the total impacts, while embodied energy accounts only for 10-20 % of the building total impacts. For example, Russell-Smith et al. (2015) refer to earlier research conducted by Junnila & Horvath (2003) and Junnila, S., Horvath, A., Guggemos (2006) who found that for commercial structures over 90% of life cycle energy consumption and 80% of carbon dioxide emissions stem from the use phase of the building. Russell-Smith et al. (2015) refer also to Scheuer et al. (2003) who found earlier that over 95% of the life cycle energy related impacts in a case study of a new university building are a result of use phase consumption. Asdrubali et al. (2013) note that up to 85% of the total impact of the office building stems from the operation phase, while the impact of the construction phase is between 14% (office building) to 21% (detached house). Another comparative study of 13 buildings (4 NRB) found that commercial buildings have more impact on the environment compared to the residential buildings (Sharma et al. 2011). Sharma et al. (2011) also conclude that 80–85% of the total energy use during the life cycle is used during the phase of occupancy/use. These data indicate that the maximum energy consumption occurs during the use phase, when a building is in use.

A comprehensive study of 73 cases from 13 countries conducted by Abu Bakar et al. (2015) found that the range of Energy Efficiency Index (EEI) among the case buildings was 150-400 kWh/m^2/year (primary) for residential buildings and 250-550 kWh/m2/year (primary) for office buildings, indicating that the EEI values of the office buildings are slightly higher than for the residential buildings covered by the case study. According to the researchers, this observation is caused by the different life cycle of office buildings and can be attributed to the fact that an office building generally requires more operating energy due to high occupant intensity, large electrical load usage and higher energy demand to maintain comfort conditions inside the building compared to the residential building.

Cabeza et al. (2014) present an example of an office building in Finland showing that the most of the impacts are associated with electricity use and building materials manufacturing. Particularly, electricity used in lighting, HVAC systems, heat conduction through the structures, manufacturing and maintenance of steel, concrete and paint, and office waste management were identified as the most impacting activities. In another example described by Cabeza et al. (2014), a 7.300 m^2 six-floor university building in Michigan, USA, was studied, showing that the use phase alone accounted for more than 83% of total environmental burdens.

Additionally, Cabeza et al. (2014) consider building life cycle prediction. The authors note that the building life cycle in previous research is ranging between 10 and 100- years, with 50% of the papers considering 50-year, 19% considering 40- year and 9% considering 80 or 100-year. These results are in accordance with our observations in which we also have noted different building life cycles (30-50-100 year), with a majority of research using 50-year period as a reference building life cycle.

Relating to building life cycle predictions, Grant & Ries (2012) argue that maintenance and service life prediction assumptions contribute significantly to environmental impacts, by as much as 4–25% depending on the impact category, which is also supported by the comparative study of office buildings in Europe and the United States, wherein maintenance impacts comprised 4–15% of the total impact (Junnila et al. 2006). Another comparative study of nine building envelope systems at Rinker Hall, university building in Florida, USA, concludes that maintenance impacts may range 2-55% of the total life cycle impact, depending on the assumed service life, the assumed maintenance regime, and the frequency and intensity of replacement (Grant & Ries 2012).

The results from this section highlight two important issues: First, the use phase of NRB accounts for majority of environmental impacts from a life cycle perspective; Second, the estimations on a building life cycle in the literature are diverse and range between 30 and 100 years, making the actual use phase period difficult to estimate.

3.2   Environmental indicator categories: What to measure?

Having determined that the use phase of non-residential buildings accounts for the majority of environmental impacts, the study moves forward to indicator categories mostly applied for assessing environmental performance of non-residential buildings.

The environmental indicators for NRB are in the literature usually grouped into several categories. For example, Kylili et al. (2016) distinguish the environmental KPI category into 12 sub-categories, while Toller et al. (2013) select six indicators for environmental monitoring of the Swedish building and real estate management sector. This paper presents eight main environmental indicator categories observed in the literature study (Building materials, Energy management, GHG Emissions, Indoor environmental quality, Land use, Reuse/recycling potential, Waste management and Water management) and shows which categories are most used in studies of environmental performance of NRB.

To gain a better overview, the results on Environmental indicator categories from Table 1 are converted into Figure 2. The figure shows that Energy management and GHG Emissions are the two most studied environmental indicator categories in the selected literature. Energy management is addressed in 16/20 papers, while 14/20 papers focus on GHG emissions. Energy management category relates to energy consumption, energy saving potentials, and energy supply (renewable, non-renewable energy) topics for NRB. GHG Emissions category addresses climate change impacts through the emissions of green-house-gases such as CO_2, NOx, SO_2 etc.

Land use and Water management are considered in 9/20 and 8/20 papers respectively. The land use category focuses on space management inside and around the NRB, and how efficiently building space is utilized etc. Water Management category includes water consumption, water saving potentials, water supply, water pollution etc.

The waste management category studied in 7/20 papers looks into how daily waste or building waste in NRB is produced, treated, disposed of etc. Indoor environmental quality (IEQ), addressed also in 7/20 papers, refers to indicators like thermal comfort, daylight, air quality etc. IEQ indicators are often described as social indicators, but since many IEQ indicators have an impact on environmental building performance, they are included as an environmental category in this paper.
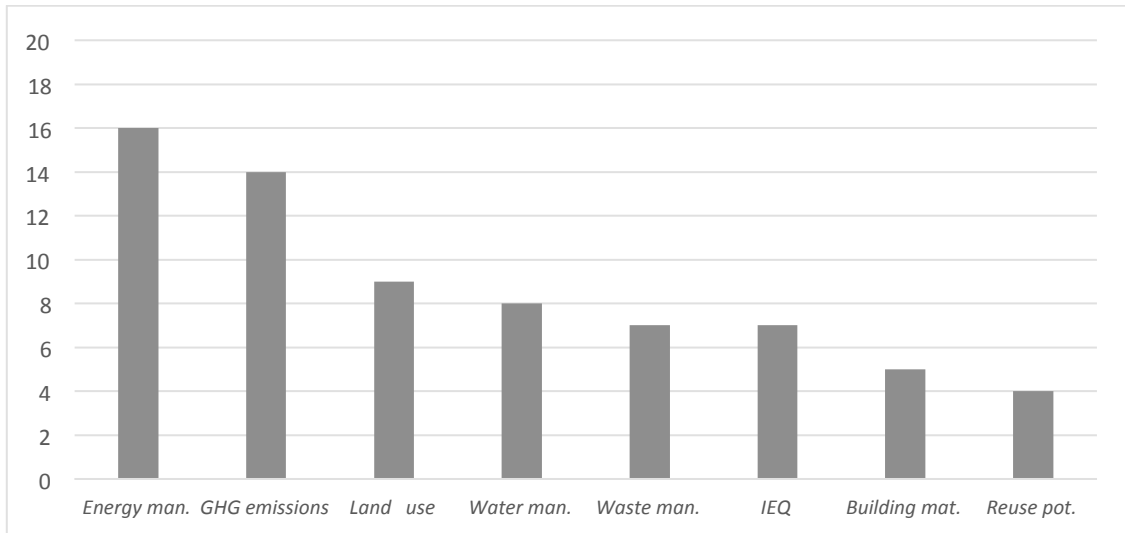
Figure 2 The amount of research papers addressing identified environmental indicator categories (n=20)

The least focus in the literature is on Building materials and Reuse potential: 5/20 papers consider building materials while only 4/20 papers focus on the reusing potential. The building materials category addresses building materials used for constructing the buildings. This category works with building material properties such as aesthetics, durability, thermal properties, maintenance properties etc. The reuse potential category looks into potentials for recycling and/or reusing existing building components and materials for other purposes after their ended lifetime.

Deeper analysis of the results from Figure 2 shows that most research conducted on environmental indicators for NRB is relating to energy management and GHG emissions. The literature study conducted by Abu Bakar et al. (2015) shows that the energy consumption in NRB is largely dominated by the Heating, Ventilation and Air-Conditioning systems (HVAC), and followed by lighting. A case study of six public buildings with retrofit actions points out that the most significant benefits related to energy savings and reduction of CO_2 emissions are mainly related to the improvement of the envelope thermal insulation (Cabeza et al. 2014). But the case study also concludes that substituting lighting and glazing components provide significant energy benefits. On the other hand, both solar and wind plants involve lower energy savings and higher payback indices than predicted. Furthermore, San-José Lombera & Aprea (2010) highlight that the sustainability of industrial buildings should not only be structured around energy consumption, but also include land, water, and material usage.

Research on IEQ points out that if higher comfort expectations in NRB are set as a target value, this could have a direct effect in building environmental performance, as a larger use of energy by the HVAC systems to maintain these comfort expectations is likely to be required (Holopainen et al. 2014; Seinre et al. 2014). IEQ indicators are also considered in Conte & Monno (2012) and Kim & Todorovic (2013).

Reuse potential of NRB is not covered substantially in the literature, but there is for example research showing that the recycling of building materials in masonry buildings generates environmental benefits due to avoided impact of virgin material production (Napolano et al. 2015). Related to reuse potential, Munarim & Ghisi (2016) look at building rehabilitations and present a case in which the construction of a new office building would take about 250 years to recover the investments in energy when compared with the adaptation for the same use of the old hotel Grand Central Arcade, Seattle. This is due to a very small difference in estimated operation energy consumption for the new and the rehabilitated building. The authors also argue that the lifespan of a building can be continuously extended by successive renovation, restoration or rehabilitation investments. In the end, Munarim & Ghisi (2016) conclude that the reuse of an existing building, through its rehabilitation, conserves natural resources and energy that would be used to build a new building.

The results from this section point out that most research relevant to our study focuses on energy management and GHG emissions. There is less focus on building materials and reusing potential, even though there might be hidden considerable potentials in these two categories for improving environmental performance of NRB.

3.3 Assessment methods: How to measure?

The results so far show that the research reviewed is mostly focusing on energy management and GHG emissions during the use phase of NRB, in which the highest environmental impacts from NRB also occur. But it is also relevant to know which assessment methods are applied when environmental performance of NRB is quantified.

There are two basic assessment approaches applied to obtain environmental indicator sets for buildings: the first one is based on LCA while the second one on the use of criteria-based certification tools (BREEAM, DGNB, LEED etc.). Certification tools are popular amongst practitioners, but can lead to erroneous conclusions, seen from a scientific point of view (Elle et al. 2010). When working with certification tools, it might be difficult to select relevant indicators from a broad range of data on the system under study, and since environmental quality does not refer to the objective characteristics of a building but is essentially a value-driven concept. Furthermore, criteria-based certification tools lack vital indicators that can be used to assess the sustainable performance of building envelope such as material efficiency, energy efficiency, economic efficiency and indicators with life time parameters such as life cycle cost, embodied energy etc. (Mwasha et al. 2011).

The results from Table 1 show that the LCA method is a dominating assessment method in research when it comes to assessing environmental building performance of non-residential buildings. Life-cycle assessment (LCA) has earlier proven (Lotteau et al. 2015; Anderson et al. 2015; Passer et al. 2016) to be an accepted scientific method for assessing environmental building performance, and its application is also evident in our literature study in which 10/20 papers apply LCA method for that purpose. On the other hand, only 2/20 papers consider certification tools for assessing environmental building performance of NRB.

LCA principles and the framework for life-cycle assessments are outlined by ISO 14040 and the requirements and guidelines are given in ISO 14044. In addition, the standard EN 15643 covers sustainability assessment of buildings (part 1-environmental, part 2-social, and part 3-economic). EN 15978 provides the calculations for the environmental assessment of buildings (Anderson et al. 2015).

There are two main approaches to data collection in LCA: process-based LCA and Input-Output LCA (IO-LCA). Process-based LCA is a bottom-up process analysis where the system is modelled by means of its specific information whereas IO-LCA uses economy or industry sector wide inventory data and break these down in a top-down process. A third approach, called hybrid-LCA consists in a combination of the two approaches (Lotteau et al. 2015).

4   DISCUSSION

The literature review has documented that the use phase of NRB is the most environmentally taxing life cycle phase. However, the literature itself is challenged when it comes to defining the lifetime of the building use phase. It is noted that the literature operates with different lifetimes for the use phase, and that these range between 30, 50 and up to 100 years (Cabeza et al. 2014). There is, of course, a relationship between material longevity, durability, and the natural differences between material assemblies and components (Grant & Ries 2012), but the use phase of NRB is also a variable highly depending on operation and maintenance (O&M) activities. A reliable building lifetime estimation is therefore an important prerequisite that needs to be considered when addressing environmental building performance of NRB.

Consequently, there is a need for a more dynamic LCA approach in practice that can illustrate the environmental impacts of different future scenarios and service lifetime of building materials and components, and not the conventional static LCA, as observed in most research published. However, the main barriers for applying dynamic LCA in practical building design include the perception that the LCA method is already highly data-demanding and work-intensive, and consequently costly. In addition, the use of LCA building tools is perceived to require a high degree of knowledge. Other barriers to the use of LCA in general include prejudices about the complexity, arbitrary results, accuracy and problems regarding the interpretation of results (Malmqvist et al. 2011). Furthermore, the application of the LCA method does not guarantee a reduction of emissions or energy consumption, but it allows highlighting the weak points of production process and identifying possible hotspots in the perspective of sustainable development (Proietti et al. 2013).

It is difficult to apply LCA to the construction industry because of difficulties in obtaining complete inventories for building components, tracking material flows and clearly defining system boundaries. Furthermore, Building Information Modelling (BIM) and FM software systems like Integrated Workplace Management Systems (IWMS) lack interoperability/interfacing with LCA and LCA software.

However, if the goal is to improve the environmental building performance of NRB, ALwaer & Clements-Croome (2010) argue that it is essential to design cohesive and coherent data management systems with a trusted format in order to ensure that the system performance is monitored properly, that reliable data is collected and that people are trained to analyse it for further use by decision makers, designers and facilities managers. It is advisable to think ahead so that data collected as part of a sustainability assessment can be reported as Key Performance Indicators (KPIs). The use of KPIs and benchmarking is fundamental to any improvement strategy and can be the right step in improving environmental performance of NRB. Combining actual FM data from FM systems like IWMS with LCA approach could provide improved system performance monitoring and deliver more realistic and reliable data on building performance, that later could be used for addressing and evaluating environmental building performance.

5   CONCLUSIONS

The literature reviewed states clearly that non-residential buildings have the highest environmental impact during their use phase. The operating energy accounts usually for 80-90%, while embodied energy requires 10-20% of the building total energy. Furthermore, the study notes that the use phase does not have a clear definition in the literature and that it ranges from 30 to 100 years, making the actual use phase period difficult to estimate.

Based on the results from our study, this paper suggests measuring following eight environmental indicator categories for non-residential buildings: Building materials, Energy management, GHG Emissions, Indoor environmental quality, Land use, Reuse/recycling potential, Waste management and Water management. The results also show that most research focuses on Energy management (16/20 papers) and GHG emissions (14/20 papers) categories, while there is less focus on Building materials (5/20 papers) and Reuse potential (4/20 papers).

Environmental performance for non-residential buildings can be quantified through two basic assessment methods: LCA models and criteria-based tools. Our study concludes that the LCA models are applied most (10/20 papers) to address environmental building performance of NRB. On the other hand, criteria-based tools are rarely considered in research (2/20 papers), while the research claims that they are popular in practice.

6   RECOMMANDATIONS FOR FURTHER RESEARCH AND PRACTICE

LCA and product system models can help facilities managers to choose more environmentally friendly solutions based on calculations taking the entire life time of buildings into account. However, further research is required to determine how LCA can be combined with FM in practice and to investigate which effects available FM data can have on optimization of environmental building performance. There is a need for mapping what kind of FM data is being used nowadays, its value and reliability, and how it can be collected, analysed and combined with LCA approach for optimizing environmental performance of non-residential buildings.

Based on the findings from this paper, we recommend the following for practice:

• Integrate environmental performance indicators with KPIs and FM systems for quantifying and managing building performance.
• Keep in mind that there are several environmental indicator categories to address.
• Consider how your FM data can be combined with the LCA approach to identify possible hotspots in facilities management for improving environmental building performance

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The Prioritisation and Satisfaction on Thai's Rating Energy and Environmental Sustainability Criteria: A Case study of Bangkok Green Condominium

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ABSTRACT

Purpose: The environmental performance of buildings can be measured by using an existing green building indicator system. In Thailand, the Thai's Rating Energy and Environmental Sustainability (TREES) has been applied to 70 buildings including condominiums. It is important to collect feedback from stakeholders in order to identify the criteria of green features that respond to the expectation of condominium's potential buyers as well as the satisfaction of current occupants. This research aims to examine the prioritised aspects of TREES criteria from potential buyers and the satisfaction of the criteria from occupants of a case study, a green condominium in Bangkok Thailand.

Design/methodology/approach: The case study was conducted at IDEO Mobi Sathorn in Bangkok, the only condominium certified with the TREES system so far. Research methods include interviews, field surveys, document analysis and the surveys from the condominium's potential buyers and current occupants.

Findings: The findings indicate that the condominium's potential buyers are more concerned about Site and landscape, Indoor environmental quality, and Energy and atmosphere whereas the current occupants are satisfied about Water conservation, Site and landscape, and Energy and atmosphere. The findings from the case study show that internal factors such as policy and cost saving demand have an impact on the satisfaction in Water conservation and Energy and atmosphere. Despite the features of green condominium, occupants are less satisfied about Green innovation as showed in the least satisfied percentage of TREES criteria. The findings also support the multi-unit residential project framework that was developed by Chotipanich (2001).

Practical implications: The findings and reflections upon the finding can help to understand the impact of green building aspects on the perception of different stakeholders. The recommendation is provided to develop, manage, and maintain green features in Thailand condominiums that not only achieve environmental quality aspects but also meet the expectation and satisfaction of stakeholders.

Originality/value: There has been no prior research in this area. The study provides better understanding with regard to prioritised aspects from the potential buyers and the occupant satisfaction of TREES criteria in Bangkok green condominium.

1   THE THAI'S RATING ENERGY AND ENVIRONMENTAL SUSTAINABILITY (TREES)

Various green building standards and certification systems are introduced and have been applied in several countries such as Leadership in Energy and Environmental Design (LEED) in the US, Building Research Establishment Environmental Assessment (BREEAM) in the UK, Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) in Japan, Green Star in Australia, Building Environment Performance (BEPAC) in Canada, Green Mark in Singapore, and Thai's rating of energy and environmental sustainability (TREES) in Thailand.   The common objectives of green building rating systems include (BREEAM, 2012; LEED, 2016):

1) to inform design process and to promote integrated design practices
2) to increase awareness among customers, owners, occupants, designers and operators
3) to establish standards of measurement
4) to allow organisations to demonstrate progress towards corporate environmental objectives

Thai Green Building Institute (TGBI) has been set up in 2008 under the collaboration between the Engineering Institute of Thailand and The Association of Siamese Architects to establish building and construction standard and provide understanding regarding the green building concept in Thailand. TREES is expected to help guiding construction industry to design and construct architecture that is environmental friendly and can increase occupant well-being and productivity comprehensively. TGBI expects that buildings using this rating system would consume less energy, reduce environmental impacts and reduce pollution while increase quality of life of the building occupants (TGBI, 2016).

In Thailand, the TREES standard has been widely accepted by both public and private sector building industries. Currently, there are 70 building projects registered and 7 certified buildings. TREES is based on the USGBC's LEED system specifically modified for Thailand in order to comply with Thailand context. Table 1 shows the comparison between TREES and LEED criteria. The first six criteria of TREES are similar to LEED criteria including: 1) Water conservation (Water efficiency in LEED), 2) Energy & atmosphere, 3) Materials & resources, 4) Indoor environmental quality, 5) Site & landscape, and 6) Green innovation (Innovation in LEED). The comparison between TREES and LEEDS show some differences regarding the assessment criteria. TREES offers points on Building management and Environmental protection whereas LEED includes Location and transport and Regional priority in the system.   There are four award levels of TREES that are identical to LEED including Platinum, Gold, Silver, and Certified.

TREES assessment process is divided into 3 main periods, starting with registering the project with TGBI, then submitting the documents in design stage when the drawings are completed and finally submitting the documents in construction stage when the construction is completed (TGBI, 2016). TREES assessment system includes: 1) points from prerequisite that buildings registered into the programme have to pass, and 2) points from the 8 criteria above. TREES system has been used to monitor environmental performance of various types of buildings including the multi-unit residential project. The implementation of TREES and

other green building rating systems is considered as the process of the added value of facility management (Sarasoja & Aaltonen, 2012).

Table 1 Comparison between TREES and LEED criteria

*TREES for New Construction and Major Renovation – Certified: 30–37 points, Silver: 38-45 points, Gold: 46-60 points, Platinum: more than 60 points

**LEED v4 for Building Design and Construction – Certified: 40-49 points, Silver: 50-59 points, Gold: 60-79, Platinum: 80-110 points

TREES criteria*		LEED criteria**	
Item	Points	Item	Points
1. Water Conservation	6	1. Water Efficiency	11
2. Energy & Atmosphere	20	2. Energy & Atmosphere	33
3. Materials & Resources	13	3. Materials & Resources	13
4. Indoor Environmental Quality	17	4. Indoor Environmental Quality	16
5. Site & Landscape	16	5. Sustainable Sites	10
6. Green innovation	5	6. Innovation	6
7. Building Management	3	Not mentioned	-
8. Environmental Protection	5	Not mentioned	-
Not mentioned	-	7. Location and Transport	16
Not mentioned	-	8. Regional Priority	4
Total points	**85**	**Total points**	**110**

2   FM IN MULTI-UNIT RESIDENTIAL PROJECT

Facility Management (FM) in multi-unit residential project has a different approach in comparison with FM in other building types. The practice of FM in multi-unit residential project consists of the management of common property and services (i.e. common services, residential services and community activities). The building operation and maintenance is provided to ensure that a building functions properly so as to create safe environment to the occupants. The scope of FM functions in multi-unit residential project include:

- Monitor, control and maintenance of buildings
- Facilities services
- Budget control
- Space management
- Energy management
- Safety, Health and Environment
- Data management for facilities
- Long range planning

The conceptual model in Figure 1 was developed by Chotipanich (2006) to explore the impact of influential factors on FM in multi-unit residential project. The conceptual model shows the influences of internal and external factors on scope & plan of the FM project. Internal factors include policy of condominium juristic person, occupants' needs and behaviours, occupant status, physical environment, and age of buildings. External factors are described as legislation, potential support of public facilities & resources, service & service pro-

viders, etc. Scope of project and plan of work impact on residential FM arrangement and implementation, which affect the evaluation of the project. The project evaluation includes stakeholder perception assessment, which will be introduced and discussed in the following sections.
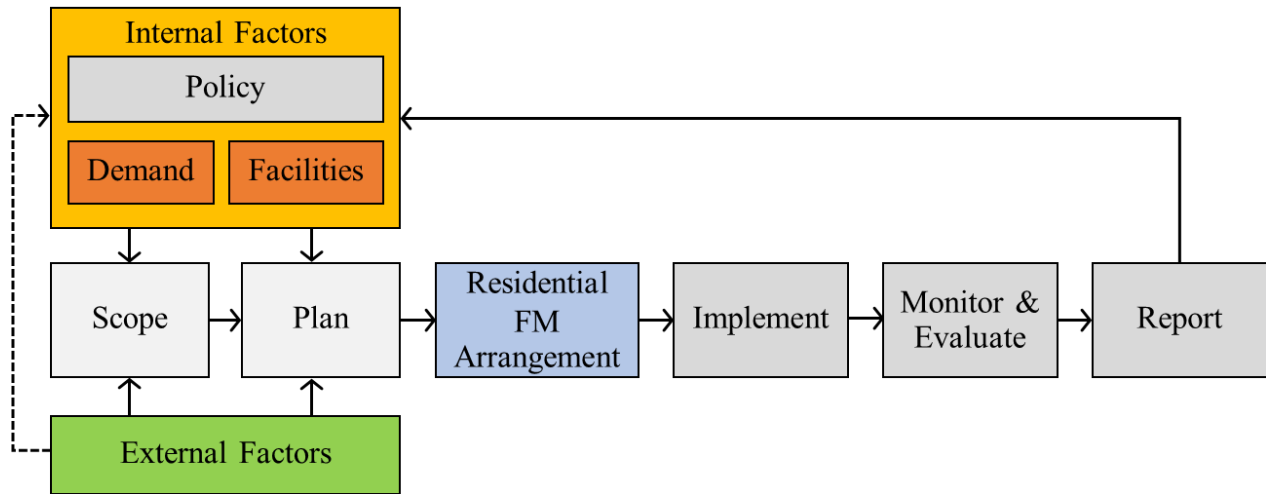
Figure 1 FM in Multi-unit residential project framework (Chotipanich, 2006)

3 STAKEHOLDER PERCEPTION

Several authors mentioned stakeholder perception as an area of the added value of FM (Den Heijer, 2011; Jensen, Van der Voordt, & Coenen, 2012; Lindholm, 2008; Nourse & Roulac, 1993; Van der Zwart & Van der Voordt, 2012; Van Meel, Martens, & Van Ree, 2010). Bradley (2002) proposed stakeholder perception as one of the six perspectives of performance measures based on the Balanced Scorecard. The six perspectives are:

1. stakeholder perception (customer perspective)
2. financial health (financial perspective)
3. organisational development (internal business process perspective)
4. productivity (learning and growth perspective)
5. environmental responsibility (internal business process perspective)
6. cost efficiency (financial perspective)

In this paper, the impact of Green Building design on stakeholders is measured by occupant satisfaction and prioritised aspects from potential buyers with regard to the TREES criteria.

3.1 Occupant satisfaction

It is widely accepted that the customer (client) plays an important role in many industries, particularly in the service business (Hui & Zheng, 2010). Customer satisfaction has been linked to higher profit margins, customer retention, and repeat purchases (Appiah-Adu & Singh, 1999; Berry & Parasuraman, 1992; Conrad, Brown, & Harmon, 1997; Jones & Sasser, 1995; Schneider & Bowen, 1995). Measures of performance for customers could include customer satisfaction surveys and a recording the number of complaints (Walters, 1999). Customer satisfaction with facilities can be measured by:

- survey rating (e.g. customer/tenant survey of the facilities, building, property management and corporate real estate services)
- number of complaints
- average call frequency and cost per square foot the help desk
- location success factors (e.g. access to customers, distance to other sites and businesses)

3.2   Prioritised aspects

Individuals prefer different environments to perform tasks depending on their personal factors. Preference is defined as priority in the right to demand and receive satisfaction of an obligation (Merriam-Webster, 2013). It is the thing that is preferred over another. The prioritised aspects of the built environment, therefore, are the items preferred over the others. User preferences are issues that cause happiness and satisfaction, but which are not necessary for performing a task (Rothe, Lindholm, Hyvonen, & Nenonen, 2012). Based on environment-behaviour research, the needs and preferences model proposed by Vischer (1985) addresses the users' demands and incorporates them primary assumptions:

- users' needs and preferences can be identified through questioning the users, or key informants who are spokesmen for the users
- appropriate design and manipulation of physical aspects of the environment do result in the users' needs being met
- meeting users' needs is a primary, if not the primary, objective of environmental design

Vischer (2008) further states that measuring the occupants' experience provides information both about the product – how spaces affect behaviour in different situations, the effects of building systems on comfort – and about psychological processes – how people feel about and respond to the spaces they occupy, as well as about process.

4   THE IDEO MOBI SATHORN CASE

Previous studies investigated occupant satisfaction of a building applied BREEAM assessment system (Sawyer, De Wilde, & Turpin-Brooks, 2008) and occupant satisfaction of a green multi-residential building (Zalejska-Jonsson, 2014). Their studies highlighted the importance of occupant feedback from green buildings. However, the assessment of the impact of green building on stakeholder perception has not yet been well-known in Thailand. The purpose of this study is to examine the potential buyers' prioritised aspects and occupant satisfaction of a green condominium on the TREES criteria. The paper aims to answer the following questions:

- What is the impact of TREES criteria on the potential buyers' prioritised aspects and occupant satisfaction of a green condominium?
- What is the implication of the TREES criteria on FM in multi-unit residential project?

To get a better understanding of the impact of green building aspects on the perception of different stakeholders, the Ideo Mobi Sathorn condominium has been selected to collect data. The Ideo Mobi Sathorn case was chosen because it is the only green condominium in Thailand that has been certified with TREES rating system. This project has been awarded with TREES Silver certification (please see table 1). The Ideo Mobi Sathorn is a condominium project, developed by Ananda Development, located at Krung Thon Buri road, Khlong San district, Bangkok. Construction of the Ideo Mobi Sathorn was completed in 2014. The condominium comprises of a single building, having 31 storeys and includes 529 units. The

condominium located within 930 metres or about 11 minutes walk from the Wong Wian Yai, a large roundabout in Thonburi province, and within 80 metres from Bangkok Sky Train. The nearest tollway entrance is located 2.4 kilometres by car from the condominium. The building comprises of residential units from 6th – 31st floor. Common facilities include elevator, parking, 24-hours security, CCTV, swimming pool, fitness, library, garden, laundry, and shop on the premises. There are restaurants, shops, schools, and office buildings nearby. The building has a gross floor area of 30,528 square metres and a total green space of 2,133 square metres.

Figure 2 Exterior of the Ideo Mobi Sathorn condominium
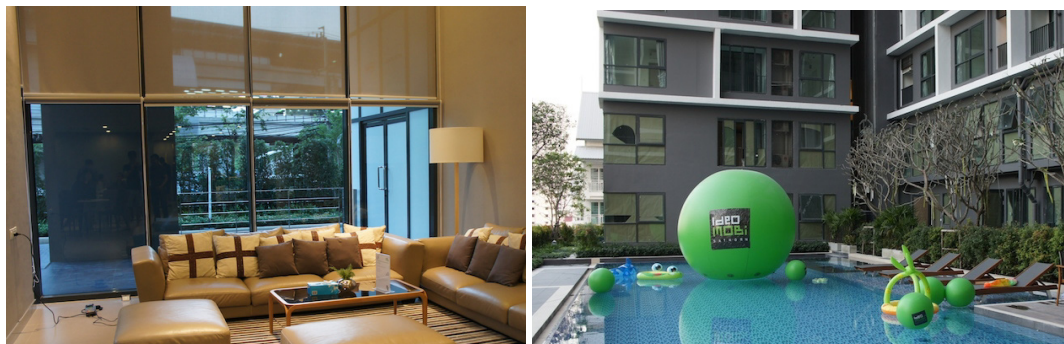
Figure 3 Common facilities: lounge (left) and swimming pool (right)

5   RESEARCH METHODS

Research methods included interviews, document analysis, observations and the use of two questionnaires. The impact of TREES criteria on stakeholder perception was examined through potential buyers' prioritisation and occupant satisfaction. The first questionnaire collected data on the prioritised aspects of TREES criteria from 222 participants of the potential buyers. The potential buyers are considered as the working age population (age between 15 and 64 years) who reside and work in Bangkok CBD, the area situated with a number of condominiums and office buildings. The second questionnaire collected data on occupant satisfaction from 222 occupants of the Ideo Mobi Sathorn condominium. The questionnaire surveys asked the participants how they prioritise and satisfy the following TRESS criteria: 1) Water conservation, 2) Energy and atmosphere, 3) Materials and resources, 4) Indoor environmental quality, 5) Site and landscape, 6) Green innovation, 7) Building management, and 8) Environmental protection.

A semi-structured interview was developed to be used for six participants interviews with the real estate developer, three potential buyers, and two current occupants. Interview questions referred to the overall understanding of green building concept, opinions regarding the results from the questionnaire surveys, the interests towards green building condominiums, and the suggestions for green condominium developers. Documents used for the analysis include the operating performance reports of the Ideo Mobi Sathorn.

The empirical study includes a collection and analysis made of reports on a case study including performance profile report 2012 and environmental impact assessment report during the construction. Observations were conducted by a walk through the condominium and recording the usage of facilities, common areas, and amenities of the project. The research took place from December 2015 till March 2016.

6 RESEARCH FINDINGS

6.1 Assessment from potential buyers

The assessment from potential buyers of green condominium focuses on the prioritised aspects of the TREES criteria. The questionnaire surveys were filled out by 222 participants, 112 male and 110 female. The participants were between 31 – 40 years old (49%), below 30 years old (39%), and over 40 years old (12%). More than half of the participants are single (71%), and the other 29% are married. Most of the participants are well educated with 70% holding a bachelor degree and 21% holding a degree above bachelor degree. The average percentage of participants that have income per month less than 30,000 Baht (38 Baht = 1 Euro) (48%) is slightly higher than those that have income between 30,000 and 60,000 Baht (41%). The majority of participants are office workers (87%). Most of the participants indicated the wish to buy green condominium (82%). The average percentage of participants that indicated the preference to buy condominium that has lower price than 2,000,000 Baht (46%) is slightly higher than the preference to buy with the price between 2,000,000 and 4,000,000 Baht (44%).

Table 2 Ranking of % score awarded by participants showing a particular aspect as being one of the three most important aspects of the TREES criteria (N=222)

TREES criteria	Percent
Site and landscape	62
Indoor environment quality	50
Energy and atmosphere	49
Green innovation	42
Environmental protection	32
Building management	28
Materials and resources	23
Water conservation	22

The participants found that the most important aspects of the TREES criteria to be Site and landscape (mentioned by 62% in their top 3 most important aspects, see table 2), Indoor environment (50%), and Energy and atmosphere (49%). The least prioritised aspects include Water conservation (22%), Materials and resources (23%), and Building management (28%).

6.2 Assessment from occupants

The assessment from occupants of the green condominium, the IDEO Mobi Sathorn, aims to collect occupant satisfaction on TREES criteria. The questionnaire surveys were completed by 222 participants, 170 male and 52 female. The participants were between 31 – 40 years old (50%), below 30 years old (46%), and over 40 years old (4%). Slightly more than half of the participants are single (51%), and the other 49% are married. Most of the participants are well educated with 99 % holding a bachelor degree and 1% holding a degree above bachelor degree. Slightly less than half of the participants have income ranging from 30,000 to 40,000 Baht (45%). The majority of participants are state enterprise employees (78%). The majority of the participants indicated the payment of current accommodation in monthly installments less than 15,000 Bath (79%).

Table 3 Percentages of satisfied participants (N=222)

TREES criteria	Percent
Water conservation	98
Site and landscape	97
Energy and atmosphere	96
Materials and resources	93
Indoor environment quality	89
Building management	84
Environmental protection	83
Green innovation	81

Criteria that occupants appreciate most are Water conservation (98%), Site and landscape (97%), Energy and atmosphere (96%), and Materials and resources (93%). The least satisfied aspects include Green innovation (81%), Environmental protection (83%), and Building management (84%).

6.3 Findings from the interviews

The findings show that all participants of the interviews understand the application of green building concept in a condominium project such as the environmental impact and energy efficiency aspects. With regard to the attitudes towards green building concept, the current occupants perceived that this concept helps improving environmental quality, occupants' health and well-being as well as reduce energy costs. All participants agreed with the findings of the prioritised and satisfied aspects, particularly in the satisfaction on Water conservation that helps in terms of the environmental impact using recycled water and the economic benefit from the decreased water cost.

When asked the participants' opinions about green building concept, most participants were interested in the development of green buildings. Both potential buyers and current occupants required the provision of knowledge and information on the green building concept from real estate developers. The information provided should describe the specific features of green buildings and show how the potential buyers and occupants will benefit from the investment in this type of building. On the other hand, the real estate developer considered the other factors relating to the development of green building in Thailand such as government policy, economic situation, location, size of the project, and competition in the market.

7   DISCUSSION

The findings show various factors influencing different responses from potential buyers and current occupants with regard to the prioritised aspects and satisfaction percentages on the TREES criteria. The potential buyers perceived Water conservation as the least important aspect (22 %), whereas this item is most satisfied from the current occupants (97%). Water conservation concerns water saving and water efficiency. Findings from the interview show that the potential buyers have not realised the link between water efficiency and cost saving benefits that resulted in the least prioritised aspect of this item. On the contrary, the occupants experienced cost savings from water efficiency that has had an effect on the high satisfaction percentage in Water conservation from the green building features. This item has rather low allocated points of the TREES assessment system (6 points; see table 1, p.3).

Materials and resources is less prioritised from the potential buyers (23%) in comparison with other TREES criteria, whereas this item showed to be higher satisfied than most criteria from the occupants (93%). Materials and resources concentrates on construction waste management, the use of recycled materials, the use of local or regional materials, and the use of materials with low pollution or low environmental impact. These items contribute to brand image of the Ideo Mobi Sathron, which resulted in the high average satisfaction rating of Materials and resources. This item also has high allocated points of the TRESS system (13 points).

Site and landscape focuses on the approaches to avoid inappropriate construction site, to reduce negative impact to green field areas, to reduce using private cars, to locate project on the developed land, and to allocate sustainable site planning. The issue of real estate sites relates to location success factors (i.e. proximity to required transportation, access to customers, distance to other sites and businesses) that are performance measures of customer satisfaction with facilities in stakeholder perception category (Bradley, 2002; Riratanaphong, 2014). This item showed to be both high satisfaction percentage from occupants and high priority from potential buyers. This item also has the high allocated points of the TREES system (16 points).

The highest allocated points of the TREES assessment system awarded to Energy and atmosphere (20 points). From the occupants' perspective, this aspect achieves high satisfaction percentage (96%). The potential buyers perceived this item as one of the top three most important aspects (49%). Energy and atmosphere concerns about building system commissioning, energy efficiency, renewable energy, and energy saving. According to the FM Value Map (Jensen et al., 2012), this item focuses on the use of organisation's resources that impacts stakeholders in terms of cost, environmental and satisfaction parameter. The assessment of resource use (i.e. energy consumption, number of energy audits) is an area of the proposed list of performance measures in environmental responsibility category (Bradley, 2002; Riratanaphong, 2014). This area concerns with the controllers' decisions that are strategically made in regard to minimising the resource use.

Environmental protection considers the reduction of pollution from construction, water management, and external glazing. The occupants are satisfied about this item (83 %), whereas the potential buyers perceived this item as less important than the other TREES criteria. This may result from the perception that Environmental protection is more concerned about environmental impact rather than the impact on particular stakeholders. In terms of the TREES assessment system, the allocated points of this item is much lower than the other TREES criteria (5 points).

Indoor environmental quality concerns about ventilation rate, illuminance in the building, reducing impact from pollution, low emitting materials, indoor lighting system control, and the use of natural light. These areas relate to occupant health, safety and well being. The indoor environmental quality achieves high satisfaction percentage from the occupants' perspective (89%). The potential buyers indicated this item as one of the top three most important aspects (50%). This item also has high allocated points of the TRESS system (17 points).

Building management focuses on green building preparation, promoting green building, building manual and building operation and maintenance training, and monitoring and evaluating green building activities. This item has the lowest allocated points of the TREES system (3 points). The occupants are satisfied with this aspect (84%), whereas the potential buyers perceived this item as less important than several aspects of the TREES criteria (28%). The focus more on the operational aspects of the building and less user involvement may result in the less significant rating from the potential buyers. The focus on improving existing accommodation is considered as an operational level of CREM and FM (Riratanaphong, 2014).

Green innovation is about techniques which are not specified in the rating system. This item has lower allocated points of the TREES system than the other aspects (5 points). From the interviews conducted with the occupants, it was concluded that there is no significant difference of building characteristics perceived between the green condominium case study and general buildings. Whereas the potential buyers perceived this item as higher priority (42%), the occupants are less satisfied about this aspect in comparison with most TREES criteria (81%).

Findings from the interviews show that the real estate developer concerns about external factors such as government policy, economic situation, and competition in the market. These factors influence internal factors including policy of condominium juristic person, occupant demand and building characteristics (i.e. location and building size). The internal and external factors impact on organisation's objectives, scope & planning for the development of the green condominium projects. The FM process includes the arranging of common facilities, monitoring, controlling and evaluating building performance, and conducting reports. Performance measurement information was gathered from the performance profile report 2012 and environmental impact assessment report during the construction. This is in line with the FM in multi-unit residential project framework proposed by Chotipanich (2006).

8   CONCLUSIONS AND RECOMMENDATIONS

The assessment of stakeholder perception on the TREES criteria helps real estate developers and facilities managers to understand different responses from potential buyers and current occupants in regard to the green building concept. Findings on the prioritised aspects from potential buyers and satisfaction from current occupants can be used to inform real estate developers and facilities managers on how to develop, manage and maintain green buildings that respond to different needs and preferences of stakeholders.

The internal factors including accommodation policy, occupant demand, and building characteristics impact on project scope & planning and FM arrangement that affect the perception of stakeholders. Feedback from stakeholders provides essential information that can be used to make judgments and to make decisions on policy and how to operate the facilities. From the real estate developers' perspective, the external factors including government policy, economic situation, and competition in the market have an influence on the development of green buildings.

Green buildings concern more than the design aspects. In terms of FM in multi-unit residential project, facility managers have to make a connection between green building design and FM functions such as facilities services, budget control, space management, data management, and long range planning.

Real estate developers and facility managers should get other stakeholders (i.e. potential buyers and occupants) involve in the green building development and management process in order to provide a better understanding of green building concept and to reduce negative impacts on the stakeholder perception assessment.

The comparison between TREES and LEED show the differences regarding the assessment criteria that reflect geographically specific contexts between countries and the different objectives of environmental performance assessment systems. The particular requirements in each TREES criterion impact differently on stakeholder perception and relate to performance measures in different managerial levels. Different criteria have different allocated points with regard to TREES assessment system. To develop green building based on the TREES system, the organisation has to set scope & planning of the project and prioritise the arrangement of organisation's resources in order to achieve points for the expected level certification.

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Linked Data for District-scale Energy Management: An Indicator-based Method

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ABSTRACT

Energy management (EM) is an important part of sustainable facility management, and the need to manage energy, from an individual building to the district scale, is increasing. District-scale EM requires an exchange and analysis of the information provided by different stakeholders, as stakeholders' engagement is the premise by which to promote EM. However, district-scale EM is a complex, multi-domain issue that generates a massive amount of information. The main question is how to extract and exchange the key information for an energy performance analysis that addresses stakeholders' performance goals. In this paper, a key performance indicator (KPI)-based, linked data method is proposed for extracting and exchanging the key performance information among stakeholders and enabling multi-level energy performance analysis. KPIs are used to extract key information and, subsequently, linked data to exchange them. The method is comprised of tasks such as identifying stakeholders, selecting KPIs, collecting master data, generating linked data and improvement analysis. A case study is carried out to demonstrate the methodology. A total of six groups of key stakeholders and 23 KPIs are identified. An EM-KPI ontology is developed to describe the KPIs and the identified cross-domain master data. The result of the linked data analysis of three representative KPIs shows that the district has the potential to save at least 12.7% of its energy cost. The findings demonstrate the feasibility of the method and its benefits to find performance problems and key areas for improvement.

Keywords: District-scale energy management, building energy efficiency, key performance indicator, ontology, linked data.

1   INTRODUCTION

Building is one of the main sectors in cities, accounting for 37% of energy consumption in the EU since 2004 (Pérez-Lombard et al. 2008). However, in European countries, a significant part of the building stock is designed or operated inefficiently (Balaras et al. 2007). Improving building energy efficiency could reduce the total energy consumption in the EU by

5%-6%, and CO_2 emissions by 5% (European Commission 2016). Energy management (EM), as an important part of sustainable facility management, is a critical factor to improve building energy efficiency. A lack of EM may cause the actual performance of a building to fail to meet the expected results indicated in the building's design. Moreover, improper EM will cause an additional waste of energy resources and extra costs (Rabinowitz 2014). Thus, effective EM is particularly essential for better building performance.

The modern need to manage energy, from an individual building to the district scale, is another imperative challenge. With the increasing use of information and communication technologies (ICTs), district-scale EM is realised by connecting the building demand-side with the district supply-side. However, district-scale EM is a complex, information-driven process (Aman et al. 2013). It requires an exchange of information from domains controlled by different stakeholders. Hence, stakeholders' involvement is necessary to facilitate information exchange and promote EM. Furthermore, a massive amount of cross-domain information and data may be generated because of the complexity of EM. A systematic method used to extract and exchange the key information that addresses the stakeholders' performance goals needs to be identified.

The key performance indicator (KPI) is a possible way to measure progress as regards reaching the stakeholders' goals. It can also represent critical pieces of actionable information (Van Gorp 2005). Currently, KPIs are commonly identified using methods such as literature reviews, stakeholders' validation and discussions with industry players and experts (González-Gil et al. 2015). Stakeholders' involvement in KPI selection from the beginning is especially important for underpinning their goals.

The information and data in district-scale EM are cross-domain and heterogeneous; thus, their interoperability problems need to be resolved. Linked data is a possible solution, and it has been broadly used in different fields. The linked data can set up query endpoints to access the data more conveniently through the SPARQL language, which facilitates data sharing and reuse on a massive scale (Heath & Bizer 2011). However, related studies regarding how the linked data can be enabled to exchange the key information in EM have not been conducted up to the present time.

In this paper, a KPI-based, linked data method is proposed to extract and exchange key information for multi-level energy performance analysis in district-scale EM. Section 2 illustrates the proposed methodology, including its tasks, such as identifying stakeholders, selecting KPIs that underpin their performance goals, collecting KPI-based master data, generating linked data and improvement analysis. In Section 3, a case study is conducted to demonstrate the feasibility of the methodology, and a linked data analysis of three representative KPIs is conducted to validate its benefits for finding key performance problems and achieving the stakeholders' performance goals.

2 METHODOLOGY

The KPI-based, linked data method for multi-level energy performance analysis is illustrated in Figure 1. The methodology is divided into 12 tasks. Tasks 1 to 3 involve the identification of stakeholders and a prioritisation analysis; the latter aims to find the key stakeholders. In Task 1, the concept of intervention points (Bourdic & Salat 2012) is introduced. The EM intervention points are where different stakeholders are involved. Typically, the points include urban morphology, building efficiency, system efficiency and individual behaviour (Bourdic & Salat 2012). However, energy managers can also identify their own points to describe the

intervention mechanism for their specific form of energy performance. Task 2 involves identifying stakeholders' roles instead of the specific people. The relevant stakeholders are those related to each role. They are classified into internal and external stakeholders, which are identified in Subtasks 2.1 and 2.2, respectively. Here, internal stakeholders are those who directly participate in the EM-related processes and intervene in different performance aspects, while external stakeholders are those who do not participate directly but have a specific interest in, and/or are affected by, the outcome of the EM. Not all of the identified stakeholders have the same importance. Therefore, a prioritisation analysis is carried out in Task 3 to determine the key stakeholders.
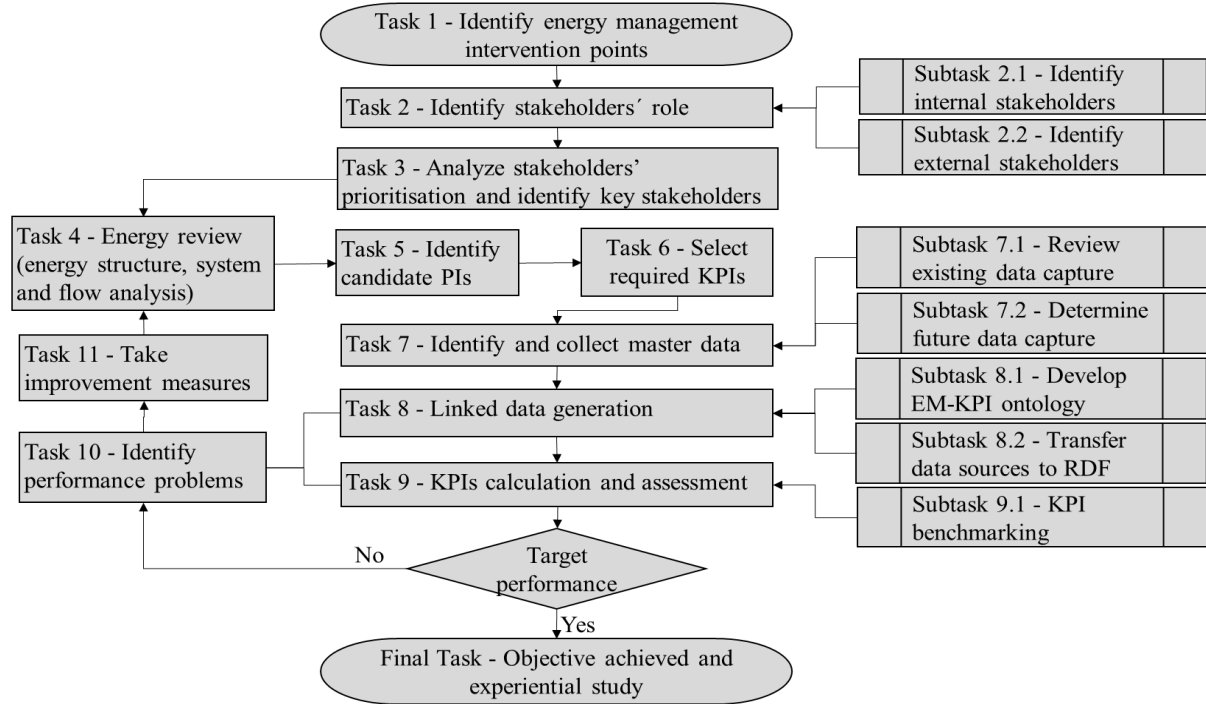
Figure 1 KPI-based, linked data method for district-scale energy management.

Tasks 4 to 6 consist of PI identification and KPI selection. KPIs convert the stakeholders' performance goals in a way that can be measured. Before selecting the KPIs, a pre-list of energy PIs is identified to facilitate KPI selection. The PIs are identified through district and building energy reviews in Task 4, which includes energy structure, systems and flow analysis (Wang & Chen 2012). The PIs identified in Task 5 reflect the basic performance concerns in a specific EM context. Then, KPIs are selected from this list in Task 6. KPIs are those PIs that represent the critical performance. They can be presented in a well-integrated hierarchy of three levels, namely the strategic, tactical and operational levels. Furthermore, each level can relate to different aggregation levels and scales (May et al. 2013). This hierarchy of KPIs helps to track multi-level energy performance.

Task 7 comprises the identification and collection of master data. The monitored data in EM are vast because of an upward trend in the use of ICTs. The concept of master data (Dreibelbis et al. 2008) is introduced to represent core, insightful data that provides valuable information. The master data are identified with KPIs to ensure that they underpin the stakeholders' goals and avoid unnecessary data analysis. This includes both the data for KPI calculation and the key data for performance analysis. To collect the master data, the existing data sources need to be reviewed, and further data collection needs to be performed when necessary.

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Task 8 involves the generation of linked data to integrate and exchange the master data and KPIs. Ontology is the foundation of linked data. Thus, in Subtask 8.1, an EM-KPI ontology should be developed. The target EM-KPI ontology should describe two parts, namely the EM master data part and the KPI part. The KPI part represents the key performance information and provides the basis for KPI calculation and energy performance tracking. The EM master data part integrates the master data domains and helps to exploit the knowledge and insights made available via the data for performance improvement. To generate the linked data, the data sources need to map to the ontology. The data sources may have different formats, and should be converted to the standard format, RDF (Resource Description Framework), in Subtask 8.2.

Task 9 consists of KPI calculation and evaluation. The benchmarking for KPIs is especially important to assess whether the performance targets have been achieved. Should this be the case, the final step should be performed. Otherwise, Tasks 10 and 11 must be conducted in order to identify the performance problems and implement improvement measures. The identification of performance problems in Task 10 is realised via the linked data analysis. Energy managers can query any piece of master data and use reasoning to determine a more implicit relationship between different data sources and to identify the performance problems. This methodology is a continuous improvement process until the final energy performance targets are achieved.

3   DEMONSTRATION

To demonstrate the feasibility of the methodology, a real scenario analysis was conducted. The scenario addressed here involved a small district called Villa Solar, located in Madrid, Spain, which was the site of Solar Decathlon Europe 2012 (Anon 2012). The village contains 18 solar houses and several public service buildings connected with a micro-grid in the district. Each solar house was equipped with photovoltaic panels, building energy management systems and other energy efficiency measures to ensure that the structures were zero-energy buildings. The solar houses and the micro-grid were monitored from September 17 to 28, 2012, but initially without information sharing among different domains.

In this section, the proposed methodology is used to extract and exchange the multi-domain key information and demonstrate its potential to improve energy efficiency. Sections 3.1 and 3.2 identify the stakeholders and the KPIs, while Sections 3.3 and 3.4 illustrate the EM-KPI ontology development and the linked data generation and analysis.

3.1   Stakeholder Identification and Prioritisation Analysis

To identify the stakeholders, the intervention points are firstly determined. These points are the district pattern, building performance, system efficiency, equipment efficiency and occupants' behaviour. The stakeholders' roles are found according to these intervention points and the different life cycle stages, as listed in Table 1. Some of the stakeholders' roles are simultaneously involved in several points.

The specific individuals or groups of stakeholders are identified according to these roles. At the district scale, the stakeholders are as follows: the district planning group, which serves as the district planner; the district energy engineers, who also act as district energy planners and managers; the micro-grid company, which acts as the system installation company and asset manager; the building owners, who also act as energy end users and financial beneficiaries; and the energy supplier of the main grid. On the building scale, the stakeholders include the architects of each building, the electrical and mechanical engineers, the construction compa-

ny, the equipment manufacturers, the building energy managers (in this case the facility managers) and the occupants. The external stakeholder includes the organising committee of the competition, and he/she plays the role of regulator.

Afterwards, the prioritisation analysis is conducted to identify the key stakeholders. The stakeholders who act as maintenance and operation staff, end users and financial beneficiaries are more significant than other stakeholders. The identified key stakeholders are the district energy engineers, the micro-grid company, the building owners, the building energy managers, the occupants and the organising committee.

Table 1 List of stakeholders' roles in different life cycle stages involved in different intervention points

	Intervention point / Life cycle stage	District pattern	Building performance and systems efficiency	Equipment efficiency and occupants' behaviour
Internal	Plan and design	District planner, energy planner, energy engineer	Architect, electrical and mechanical engineer, energy engineer	Electrical and mechanical engineer, energy engineer
	Construction and installation		Construction company, system installation company, equipment manufacturer	Equipment manufacturer
	Maintenance and operation	Energy supplier, distribution energy manager, asset manager	Building energy manager, facility manager, distribution energy manager, asset manager	Building energy manager, facility manager, asset manager
	Energy end use	Residential user, commercial user, office user	Occupant, building energy prosumer	Occupant, building energy prosumer
	Financial benefits	Energy supplier	Building owner, energy customer	Building owner, energy customer, energy supplier
External		Regulator		

3.2 PI Identification and KPI Selection

With the stakeholders identified, the next step is to select KPIs that underpin their performance goals. A pre-list of PIs is proposed to facilitate KPI selection, as shown in Figure 2. The PIs are identified using the energy review, together with a literature review of existing KPIs. They address different aspects of energy performance, such as energy saving, balance and cost. In the hierarchy, I01 to I04 are the hyper-aggregated PIs at the district level, I05 to I21 are disaggregated PIs at the building and system levels, and I22 and I35 are operational PIs at the zone and equipment levels. Given the spatial limitations of this paper, the PIs will not be introduced in detail.

Then, the stakeholders are involved in KPI selection, where they vote on each PI depending on their performance concerns. To prevent the stakeholders from maximising their own benefits at the expense of others, stakeholder prioritisation is also considered. The key stakeholders will take precedence over others. Hence, the selected KPIs can not only underpin the performance goals, but also balance the benefits of various stakeholders.

As a result, 23 KPIs are selected, including four strategic ones (I01, I02, I03, I04), 12 tactical ones (I05, I07, I09, I10, I11, I12, I15, I16, I17, I18, I19, I20) and seven operational ones (I26, I29, I30, I31, I32, I33, I34). The KPIs inherit the relationship of PIs, as shown in Figure 2.
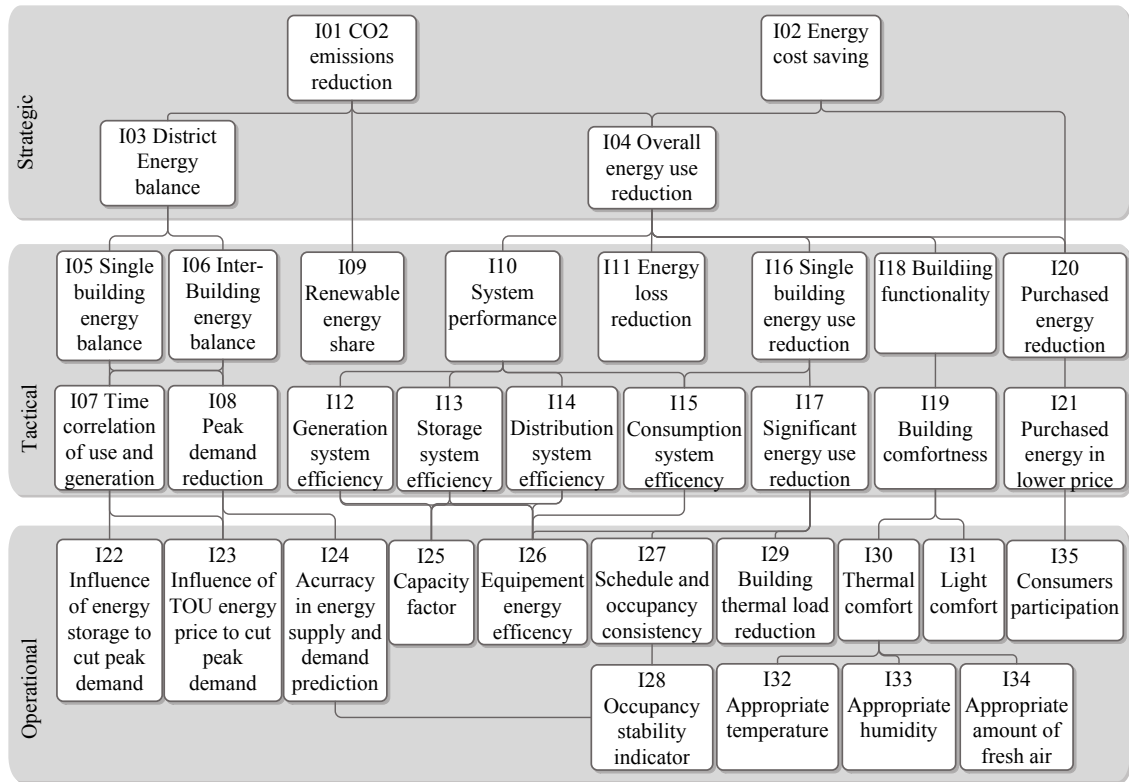
Figure 2 Hierarchy of the proposed PIs at strategic, tactical and operational levels.

3.3 Master Data Collection and Linked Data Generation

Master data are identified with the KPIs, and they contain the energy data, the building data, the facility data, the metre and sensor data, the occupancy data, the energy cost data and the external data, such as weather and location. The existing data include the energy production and demand data of each building and district substation, the sensor data regarding indoor temperature and humidity, the location data and the outdoor weather data. Further data about the system and equipment measurement also need to be collected.

To generate the linked data, an EM-KPI ontology is initially developed to describe the relationship between KPIs and master data. Its conceptual model is shown in Figure 3. The upper part, in red squares, is the KPI part, which describes the relationship between the KPI definition, the KPI calculation and its required datum sources, including the KPI evaluated objects, the stakeholders and their performance goals. The lower part is the EM master data part, where each colour indicates a different master data domain. This ontology provides a conceptual knowledge model that contains both the key performance information and the core insightful data. The implementation of the EM-KPI ontology is realised using the tool Protégé 5.1.

The ontology defines the classes, properties and axioms, and it is subsequently instantiated with the data sources to generate the linked data. The existing data sources are contained in the Microsoft Excel format. To map the data sources to the ontology, the tool OpenRefine 2.5 is used to convert them into the standard format RDF for data interchange.

3.4 Linked Data Analysis

With the generation of the linked data, and analysis of it is conducted. The linked data analysis aims to improve the multi-level energy performance. Taking energy balance indicators as an example, I03 district energy balance, I05 single building energy balance and I07 time correlation between generation and consumption are analysed.

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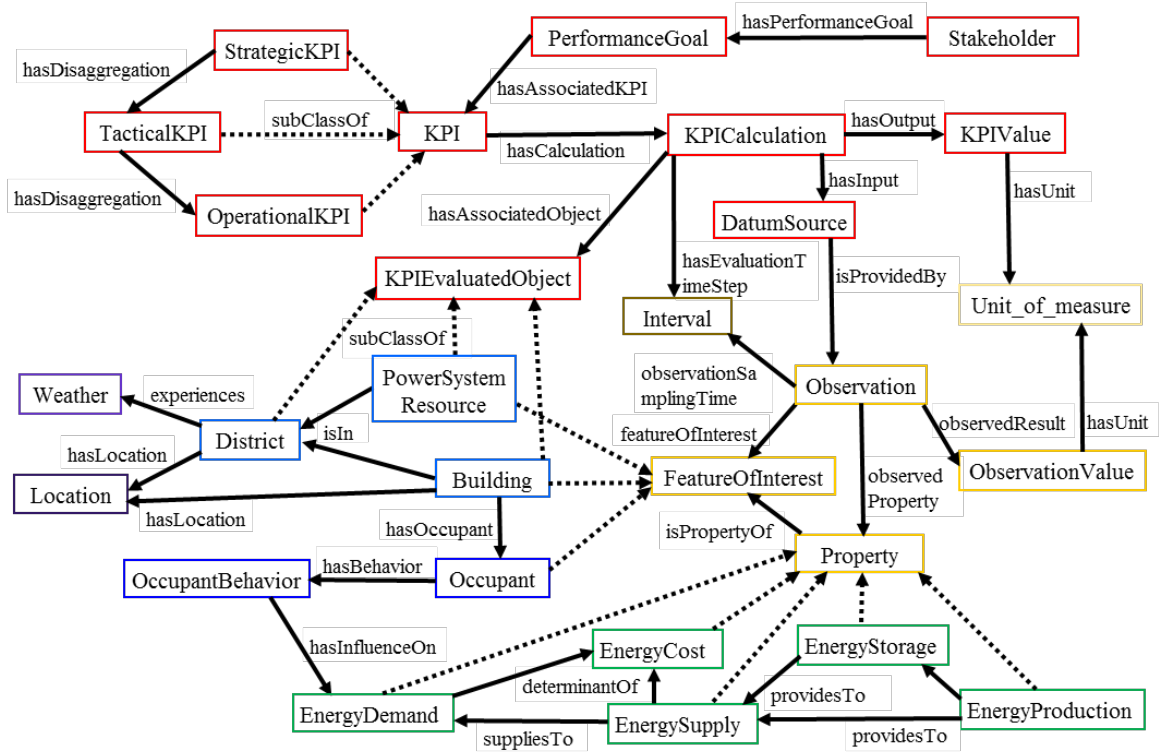
Figure 3 Conceptual model of the EM-KPI ontology.

Firstly, the calculation results of the KPIs are queried in the linked data using the SPARQL language. Figure 4 shows the example of querying the I03 values and its associated interval and unit. The prefix 'eko' is the prefix of the EM-KPI ontology, and 'ssn' and 'dul' are the prefix of the reused SSN (Semantic Sensor Network) ontology and DUL ontology, respectively.

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SPARQL ▼

1   PREFIX eko: <http://www.semanticweb.org/yehong/ontologies/2016/7/EM-KPI-Ontology#>
2   PREFIX ssn: <http://purl.oclc.org/NET/ssnx/ssn#>
3   PREFIX dul: <http://www.ontologydesignpatterns.org/ont/dul/DUL.owl#>
4   SELECT  ?Interval ?value_I03 ?Unit
5   WHERE
6 ▼ {  eko:I03 eko:hasCalculation ?I03Calculation.
7      ?I03Calculation eko:hasEvaluationTimeStep ?Interval.
8      ?I03Calculation ssn:hasOutput ?KPIValue.
9      ?KPIValue dul:hasValue ?value_I03.
10     ?KPIValue eko:hasUnit ?Unit. }
11  ORDER BY ?Interval
12
```

Figure 4 Query of the I03 values, and the associated interval and unit.

Given that 103 calculates the difference between the total energy production and consumption within the interval of one day, the performance target of energy balance is achieved only when the result is non-negative, which means that the total amount of energy production is higher than that of energy consumption.

The result of I03 is shown in Figure 5, which indicates that the district energy balance has not been achieved during the monitored days. To ascertain the reason behind the undesirable performance, the energy balance data of the 18 solar houses and the public service buildings are checked. The result shows that the district energy imbalance was mainly due to the higher energy consumption of public service buildings compared with the surplus energy generated by solar houses.
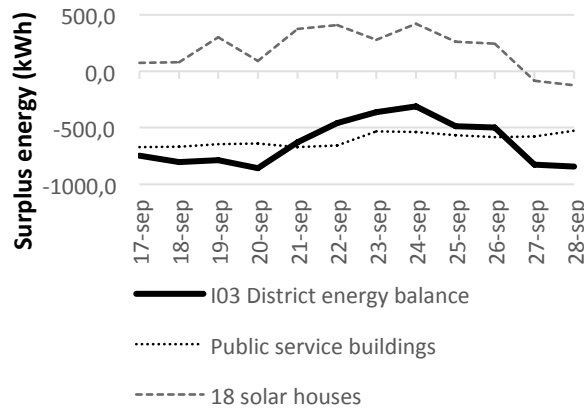
Figure 5 Result of I03 district energy balance, and its contrast with public service buildings and the 18 solar houses.
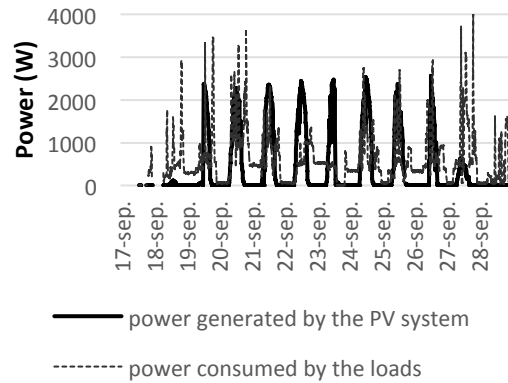
Figure 6 Global horizontal solar radiation [G(0)] and global inclined 41° solar radiation [G(41)] in Madrid.

The solar houses always had surplus energy, with the exception of two days: September 27 and 28. Through a query of the factors influencing it in the linked data, the weather data are found, as shown in Figure 6. The intensity of solar radiation on September 27 and 28 was much lower than that on the other days, with the intensity being lower than 300 W/m^2.

Then, the disaggregated indicator I05 of each solar house is analysed. The result shows that solar houses 2 and 14 had unsatisfactory performance in regard to energy balance. To determine the cause of this situation, the data concerning their generated and consumed power are checked, as shown in Figure 7(a) and 7(b). The findings indicate that Solar House 2 experienced problems with its PV system, as its energy generation was so low that it could almost be ignored, while the PV system of Solar House 14 ran inefficiently, because its installed generating capacity was 8.8 kW, but the power output was less than 2.5 kW, which was not enough to cover its energy demand.

Lastly, the indicator I07 is analysed to evaluate whether the energy generation is consumed in situ, because I03 and I05 consider only the total amount of energy generation and consumption. The result of I07 shows that, even though most of the solar houses had surplus energy, some power still needed to be imported from the external grid, because they did not achieve the time correlation between energy generation and use. Solar House 13 is given as an example; it imported 162 kWh of energy from the external grid but had 123.4 kWh of surplus energy as a result of I05. Figure 8 shows its generated and consumed power from September 21st to 25th; most of the energy consumption occurred during times involving no energy generation. Therefore, the occupants' behaviour would need to be adjusted in order to improve the energy performance in this case.
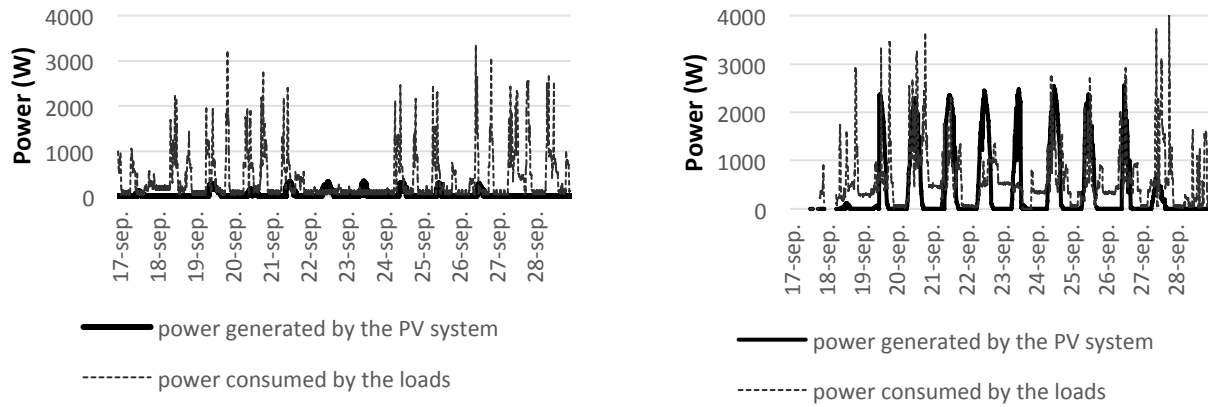
Figure 7 Power generated and consumed in Solar Houses 2 and 14 during the monitored days. (a) Power generated and consumed in Solar House 2 (b) Power generated and consumed in Solar House 14.

An adjustment of the occupants' behaviour, without accounting for the improvement of problematic and inefficient systems, could enable the solar houses to save 1645 kWh in the external energy supply during the 12 days, or 7.6 kwh per house per day, on average. The solar houses will not have to spend to purchase external energy, and they can export 2317.9 kWh surplus energy to the external grid.
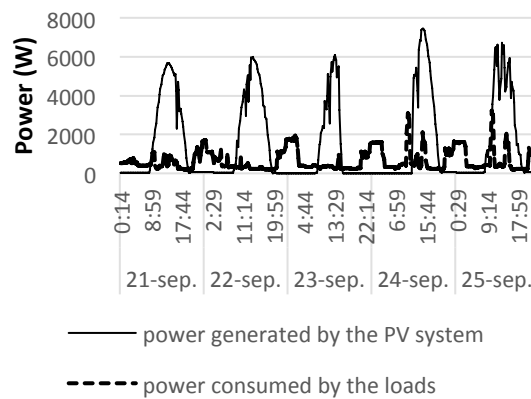
Figure 8 Power generated and consumed in Solar House 13 from September 21st to 25th.

In the entire district, given that the consumption of the public service buildings during the day occurred consistently with the generation of surplus energy in the solar houses, the service buildings consumed part of the surplus energy to meet their demand. However, an 1104.2 kWh external energy supply could still be saved by effectively using the site production and adjusting the synergies between the public service buildings and the solar houses; that is, 12.7% of the total energy cost in the district could be saved only by adjusting the time correlation. The results of the indicators I03, I05 and I07 demonstrate the advantages of the linked data analysis for identifying performance problems and conducting improvement analysis.

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4   CONCLUSION

District-scale EM helps to improve multi-level energy efficiency. For this purpose, district-scale EM needs to share and analyse the energy information from different stakeholders. Moreover, it must help the stakeholders achieve their performance goals to motivate their engagement. However, EM is a complex multi-domain issue that involves a vast amount of cross-domain information. Therefore, the key information needs to be extracted, exchanged and analysed to address the stakeholders' goals.

This paper proposed a KPI-based, linked data method to retrieve and exchange the key information for the multi-level energy performance analysis. This methodology includes 12 tasks: stakeholder identification and prioritisation analysis (Tasks 1 to 3); PI identification and KPI selection (Tasks 4 to 6); master data identification and collection (Task 7); linked data generation (Task 8); KPI calculation and assessment (Task 9); the identification of performance problems (Task 10); improvement in decision-making (Task 11); and an experience study (final task).

The proposed methodology was demonstrated using the Solar Decathlon Europe 2012 case study. We identified six groups of key stakeholders and selected 23 KPIs. A linked data analysis involving indicators I03 (district energy balance), I05 (single building energy balance) and I07 (time correlation in generation and consumption) was conducted. The result shows that adjusting the occupants' behaviour ensures that the solar houses will not spend any amount to purchase external energy, and that they will export 2317.9 kWh of surplus energy to the external grid. The effective use of the site production and the adjustment of the synergies between the public service buildings and the solar houses will allow the district to save 12.7% of its energy cost, not accounting for system improvement measures. The case study demonstrates the feasibility of the methodology and its benefits for finding the performance problems and helping the stakeholders to achieve their goals.

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Does modularity trump usability? Assessing modular facility solutions for the public sector

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ABSTRACT

Purpose: Western societies are currently facing major demographic changes, due to mega-trends such as urbanization, ageing of the population, and migration. These disruptions place a lot of pressure on public services, and consequently on municipal facilities including schools, day-care centres, and hospitals. The purpose of this study is to examine the potential of modular facility solutions to respond to these demographic changes and related facility needs in municipalities.

Design/methodology/approach: The study focuses on a case study of one Finnish hospital campus, where leased, modular facilities are in use. The facilities are analysed from the perspective of usability. The primary research data comprises semi-structured interviews of producer representatives and end-users. Observations during site and factory visits are utilized as complimentary data.

Findings: Based on the findings, the prefabrication of the modules imposes some functional limitations, although the facilities were found usable in their current use. In addition to dimensional and technical limitations, short lease periods and the recuse of the leased facilities limit customization. Interestingly, issues such as architectural quality or poor image, were irrelevant to the users. Instead, the users valued workplace comfort and support of work activities, which the modular facilities did provide.

Originality/value: The findings are useful to municipal real estate managers and decision makers in their quest to provide the right facilities, in the right place, at the right time. Modular facilities could well replace a portion of municipal facilities, making the building stock more adaptable to fast-paced demographic changes. Still, more collaboration between module producers, end-users, and decision makers, is encouraged to further enhance the usability of the modular facilities. This includes introducing an adequate level of customization, even if that led to longer delivery time for the modules.

Keywords: Adaptability, Facilities, Flexibility, Modularity, Usability

1   INTRODUCTION

In recent years, Finland, like many other Western countries, has faced major demographic changes, due to phenomena such as urbanization, ageing of the population, and migration. The changes place a lot of pressure on public services, and consequently on facilities including schools, day-care centres, hospitals, and homes for the elderly. While many rural municipalities bear the burden of under-utilized facilities, urban municipalities may be in a hurry to develop new ones. All municipalities with uncertain demographic forecasts would benefit from adaptable solutions; facilities that may be adjusted in volume and scale based on the changing population needs. Besides demographic changes, many public facilities in Finland suffer from indoor air quality issues. A significant percentage of schools and healthcare facilities developed in the 1960-70s have moisture damage. As a result, school children, teachers and medical staff have been forced to relocate to temporary facilities. For these challenges, high quality facilities that may be developed rapidly, and near the previous location are much needed. Prefabricated modular solutions, with transferable characteristics, have been offered as one potential solution.

Transferable building modules may be easily and rapidly assembled on existing school, hospital, or other sites based on demand. This transferability is enabled by carefully designed and loose interfaces between modules. The risk to municipalities is significantly reduced as there is no initial capital cost for the leased facilities, and the producer takes care of any major maintenance and retrofitting. Adaptability is a key benefit in these modular, transferable solutions, as they are able to provide the right amount of space in the right place at the right time. When space is no longer needed, the modules can be hauled off to another location. Similarly, if space demand increases as a result of demographic changes, more modules may be added to the same location.

Instead of adaptability, Arge (2005) uses the term elasticity for the ability of a building to be extended with changing space demands. Further, Arge (2005) states that flexibility is the possibility to make minor modifications to a building, such as adding wall partitions, whereas generalizability is the potential of the building to fulfil different types of needs without making any layout changes. For the purpose of this study, both flexibility and generalizability are referred to as adaptability. The significance of post-construction operations is emerging, and facility solutions should support lifecycle performance. Better lifecycle performance may be achieved through replaceable and transferable solutions, which increase adaptability. Previous research has suggested that better integration and collaboration between designers, producers and operators is needed to enhance the usability of modular products (Gosling et al. 2016).

Usability may be defined as perceived support of work activities; control over work environment; control over individual workspaces; or comfort (Windlinger et al. 2016). Workplace comfort is typically seen to include such items as indoor air quality, lighting, daylight and views, interior design including the use of colour. Alexander (2006) defines functionality as the technical and physical properties of a facility that support its theoretical performance potential. Usability on the other hand, only occurs in the real world, and depends on the context of use, time and personal values of the users.

Regardless of the known benefits of modular and transferable solutions, questions about the usability remain. Based on previous literature, the rigidness of modules and their interfaces (Da Rocha et al. 2015; Edelman et al. 2016) may affect the usability of the facility, and therefore diminish user satisfaction. Modular, temporary solutions also suffer from image issues,

as they may be perceived to be of poorer quality than permanent buildings. Moreover, prefabricated modules are restricted in height, width, and length, and bearing capacity (Doran and Giannakis 2011; Edelman et al. 2016), which set limits to architectural design, and may also limit their use for specialized facilities.

This study explores the case of a Finnish hospital campus, which has responded to changing facility needs by leasing transferable modular facilities. Stakeholder interviews are used to determine the different interests of the producer and user side. The focus of study is on the usability of transferable, prefabricated modular facilities.

The remainder article is structured, as follows. Next, Section 2 introduces the theoretical framework used for analysis. The following Section 3 details the study design, and describes the case study, and one Finnish modular solution producer. Findings are presented and discussed in Section 4. Finally, Section 5 concludes the article with ideas for further research.

2 THEORETICAL FRAMEWORK

The framework of analysis for the study is based on benefits and challenges identified in previous literature on modular construction and transferable buildings. The general benefits and challenges of modularity have been explored in several previous studies (Pasquire and Gibb 2002; Jaillon and Poon 2010; Doran and Giannakis 2011; Choi and Song 2014; Da Rocha et al 2015; Nahmens and Bindroo 2011).

One clear challenge discussed in earlier literature is related to the ability to customize mass produced buildings, (Da Rocha et al 2015). Additional challenges include dimensional restrictions (height, volume, weight) due to prefabrication on the one hand, and road transport on the other (Doran and Giannakis 2011). Several studies indicate large initial investment to producer (Gosling et al 2016; Jaillon and Poon 2010; Choi & Song 2015), as a disadvantage of modular construction. However, for an established producer with existing production facilities, this does not present an issue. Meanwhile, prefabrication saves considerable amount of time and cost during the onsite construction phase.

The commonly listed advantages of prefabrication include better quality control, resource efficiency (including construction waste and materials), improved health and safety, more efficient labour and management, and less disruption in the construction phase (Jaillon and Poon (2010; Pasquire and Gibb 2002). Gosling (2016) also notes better quality through standard solutions and better worker safety as benefits of modular prefabrication. Nahmens and Bindroo (2011) report that industrialized construction reduces labour cost on the one hand, and improves employee satisfaction and quality on the other.

Other scholars have focused on the sustainability benefits of prefabrication. Modularity reportedly supports sustainability through reducing construction waste, reducing employee commuting and associated greenhouse gases, creating less construction site noise and other disruption, as well as improving insulation and therefore energy efficiency and acoustic quality (Nahmens and Ikuma 2012; Lawson et al. 2012, Quale et al. 2012).

In addition to the general literature on modularity and prefabrication, two previous studies from Finland address the business model of leasing transferable modular facilities. These two studies find the modules to be inherently adaptable as they are leased for a certain period and may be reused in another location (Edelman et al. 2016; Vihola et al. 2016). Furthermore, Edelman et al. (2016) identify many benefits related to leasing, where the producer obtains

risk for any repair of maintenance. Vihola et al. (2016), focus on the lifecycle costing of the facilities, and find the leasing alternative to be beneficial to the client in case the facility is operational less than 40 years. Edelman et al (2016) notes the poor image of the temporary facilities is often a concern to the clients.

Table 1 summarizes the theoretical framework formed based on previous research on the benefits and challenges related to modular facilities. Benefits and challenges clearly related to the factory prefabrication phase with no implications to the use phase (investments by producer, occupational health and safety issues and productivity, or management) are excluded.

Table 1 Framework for analysis

	BENEFITS	CHALLENGES
MODULARITY	Quality (Gosling et al. 2016; Jaillon and Poon 2010; Choi and Song 2014; Nahmens and Bindroo 2011; Lawson et al. 2012; Pasquire and Gibb 2002)	Lack of customisation (Da Rocha et al. 2015)
	Sustainability (Nahmens and Ikuma 2012; Lawson et al. 2012, Quale et al. 2012)	Dimensional restrictions (Doran and Giannakis 2011)
TRANSFERABILITY	Adaptability (Edelman et al. 2016; Vihola et al. 2016)	Poor image (Edelman et al. 2016)
	Low risk (Vihola et al. 2016)	

In the framework, benefits and challenges are first divided based on whether they are related to modularity and pre-fabrication, or to the business model of leasing transferable modular facilities. Within these categories, benefits are further grouped into *Quality* (incl. standardized quality), and *Sustainability* (incl. resource and energy efficiency), *Adaptability* (possibility to add or remove modules), and *Low risk* (from leasing, instead of owning the modular facilities). The challenges are grouped under *Lack of customisation* (of mass-produced modules), *Dimensional restrictions* (due to factory prefabrication and road transport), as well as *Poor image* (due to the temporary nature of the facilities).

3   STUDY DESIGN

This paper presents a qualitative case study (Yin 2013) of a hospital campus in Hyvinkää, Southern Finland. The hospital is undergoing major redevelopment and retrofitting. The existing buildings, dating from the 1960-70s, have suffered from indoor air quality issues, and have become too small and outdated for the current use. The hospital has therefore introduced two modular facilities to respond to contemporary healthcare practices. Both facilities are leased and have been on site for approximately 5 years. Both will soon have their lease period extended for another 5 years. The temporary facilities follow a 'satellite model', namely, they are connected to the main building of the hospital via corridors. Figure 1 shows the two facilities, hereinafter referred to as Facility A and Facility B.

The main data source for the study comprises 9 semi-structured interviews. Five users of the two temporary modular facilities were interviewed. The user interviewees include a real estate manager (1 interview) as well as doctors and nurses (4 interviews, 2 from each facility). All informants, including the real estate manager, use the modular facilities on a daily basis.

The User interviews comprised questions about end-user participation, workplace comfort and satisfaction, and general usability.

Figure 1 Facility A (in the background left) and Facility B (in front right)

For the purpose of comparing different stakeholder interests, producer representatives were also interviewed. The producer interviewees comprise representatives of one of the modular facilities on site, hereinafter, 'the Producer' (4 interviews). The semi-structured interviews focused on basic information about the modular solution, its usability for different purposes, and possibilities for participatory methods in the design phase. The Producer and their business model are introduced in brief in the following subsection.

All interviews have been recorded and transcribed for analysis purposes. The interviews vary between 30 min and 75 min, and 3-4 researchers were present at each interview. The observations made by three researchers during the site visit comprise another important data source. Furthermore, observation during a visit to the building module factory, as well as commercial data such as product feature documents were utilized as complimentary data sources. The different data sources provided data triangulation, while the presence of several researchers in the interviews and visits offer researcher triangulation. Validity was further increased through conducting data analysis collectively with the authors of this paper. Utilizing the framework presented in the previous section, one author manually coded the User interviews, while another focused on the Producer interviews.

3.1 The Producer
The Producer pre-fabricates and leases transferable building modules for municipalities and other public actors in Finland and Sweden. Their solution offers the possibility to modify the size of the facility based on changes in demography or operations. Most of the modules produced annually replace older buildings from the 1960-70s with indoor air quality issues. The fully equipped, load-bearing and volumetric building modules include all structural elements, doors, windows and finishes, even cabinets and other fittings. The throughput time to produce a module in the factory is around 9-12 days, and assembly typically takes three weeks. Only

the foundation works have to be performed onsite. The modules are hauled to the site and connected with cranes or hoists. Figure 1 illustrates how the Producer's module facility (Facility B) is designed to be of similar architectural quality as a permanent building, with the quality of façade, pitched roof and plinth. The difference is clear compared to the other transferable facility in the background, which resembles a traditional 'barrack' solution.

The Producer's business model is based on leasing, rather than selling the facilities. The lease period for the modules is 3-7 years, making the solution suitable for shorter-term use, and allowing for reacting to changes in space needs. The Producer takes full responsibility for the repair and maintenance of the buildings, which are included in the monthly lease. At the end of the lease period, the building and its parts may be leased to the next customer for another purpose, and relocated. In fact, whenever possible, the Producer offers existing modules, either transferred from another site or new ones that are ready in stock at the factory. The calculated lifecycle of the modules is 20 years, even though they are generally expected to sustain 25-30 years. Currently, around a quarter of all the Producer's modules are in their second or third location and use.

From the perspective of municipal real estate management, the most interesting characteristics of these modular facilities include the low risk associated with leasing, and the possibility to add or remove building modules as needed. Good indoor comfort and energy efficiency, as well as the possibility to customize the module based on the planned function (school, day care, healthcare) would also be of interest to the municipal real estate manager.

4   FINDINGS AND DISCUSSION

This subsection presents the findings from User and Producer interviews, supported by observations during site and factory visits. The framework presented in Table 1 was utilized in the analysis, but the analysis revealed many additional, different issues. Moreover, some issues that were evaluated to be of importance based on previous literature, did not come up in the interviews. The following Table 2 shows an adjusted categorization of the identified benefits and challenges from both User and Producer perspectives. Explanations with descriptive evidence, including direct quotes from informants, are enclosed.

Table 2 Findings

Issue	User View	Producer View	Explanation
Benefits			
Adaptability: Possibility to remove or add interior walls	*"It is easy to remove walls here. You take one wall down and make it bigger, or you divide the booth in half, depending on the size." – User 2*	*"…The client can visit the former client; So this is the facility, will this do for us? They can see whether it is good as is, no need to do anything, or that we need to take out that wall."* *- Producer 1*	From the Producer perspective, the possibility to take down or add walls is crucial when the facilities are relocated. For Facility A, several changes had been made already during the use phase, as some walls had been taken down in order to allow for different uses.

Adaptability: Expanding existing buildings with attached modular facilities	*"You could add these modules, to bring more floors, what a benefit that would be, for example to healthcare districts"* – User 5 *"It is really peaceful here. There is not a lot of pass through traffic."* – User 3	*"…We have used the satellite model in many locations and effectively. So there is a small corridor and you do not have to touch the structure of the existing building at all."* - Producer 1	Modules may be added or removed as the hospital campus retrofitting proceeds. In the satellite model, the modules are connected to the main hospital building via a long corridor. The isolated location allowed for more privacy from the patients and a calmer work environment.
Quality: Indoor Comfort	*"These are one of our best facilities because we have cooling, and ventilation is working."* - User 1 *"And we have good views and a lot of light."* – User 3	*"They are light, there is new technology, they are warm, no draft, there is no mildew"* – Producer 1	Particularly daylight and views, and indoor air quality were complimented. Facility A had first suffered from temperature fluctuations, but after the installation of a new air conditioning unit, the problems ended.
Quality: Standardized solutions	*"I think, based on our experience, this space works perfectly, no complaints."* – User 5 *"Everything is thought through, using these lean principles, that there is this and that in every cabinet."* – User 3	*"So functionality, we make a lot of facilities so we know what spaces should be next to which space, so that the interior space is in the right order"* – Producer 1	Every room had the same equipment in the same place, making it possible for any nurse of doctor to operate in the room. This was said to make medical work a lot easier.
Challenges			
Dimensional restrictions	*"The current facilities are excellent for the use, but they are way too big, if we knew there were so much space we would have divided into three, instead of two spaces. But is has something to do with the modular solution."* - User 4	*"Yes, there is a maximum height to fit through the factory door, about 5.6 meters"* - Producer 1 *"Well in Finland you can transport a six-meters-by-six-meters cube pretty well to pretty much anywhere"* - Producer 1	The size of the modules is limited by both factory capacity and regulations for road transport. The height and width have to be adjusted to the prefabrication conditions inside the factory. The Users see the standard size as a challenge from another perspective: the modularity created excess space and consequently increased the rent.
Other technical limitations	*"It soon came apparent what type of electronic medical equipment we cannot use here"* - User 3	*"The biggest challenge are the technical limitations we have [...] so that the client's and user's wishes are fulfilled in a way that they accept the*	Customization of the module facilities is always possible within the technical (framework depth, bearing

		compromises" - Producer 3	capacity) limits of the module. However, the bearing functionality and electricity capacity are limited, which limits the use of e.g. heavy hospital equipment.
	"In practice, a CT scan weighs a few hundred kilos, that might be possible… if we planned that, but there needs to be led walls all around" – User 4		
Lack of Customization: Reuse of modules	"*Well I think you need to consider how long t will be in use, there is no point, if it is like 5 years, does it make sense to invest.*" – User 1	*"So what do we do after 5 years when it is no longer needed? Will it be easily transformed into an office? Due to the wide corridors, etc. they* [*healthcare facilities*] *create a lot of excess space"* – Producer 1 *"We can do a lot in terms of customization, but then the lease period has to be longer."* – Producer 5	The reuse of the module in another location has to be considered, and therefore high-level customization may not be feasible for the Producer. For the User, it is also a question of lifecycle costing.
Lack of Customization: Schedule	*"Well, there was a gap; there was not enough communication or user participation"* – User 4	*"So if the client's preferred schedule is 'last week', then there is not that much talk of* [user participation] *"* - Producer 3 *"A really large portion [of orders] are ones, when there is no way to use any extra time on changes"* - Producer 3	The procurement of temporary facilities typically under strict time pressure, and there is no time to use participatory methods. This has created some unfortunate mishaps, such as the excess space in Facility B.
Safety: Expanding existing buildings with attached modular facilities	*"There is a safety issue, because the security guard is in the main building, next to the ER. And the doors open automatically until 5 pm."* –User 3	n/a	For the Users, distance to hospital security staff was in the main building was a security risk. Furthermore, patients and staff need to walk through the same corridors to the temporary facilities, which was seen as privacy risk. Typically, in hospital environments, the staff have their own private routes, isolated from the patients.

The identified benefits may be categorized under Adaptability and Quality. Adaptability was familiar from the previous literature, but are here further divided under possibility to remove or add interior walls and expanding existing buildings with attached modular facilities. Likewise expected based on previous literature, Quality here is grouped into benefits to indoor comfort and advantages from utilising standard solutions. However, Low risk, associated with a leased facility, which bears no capital or renovation costs, was not reflected in any way in the User interviews. Low risk is more a benefit to the municipal real estate managers, and the end-users are not necessary even aware or interested in this advantage. Similarly, the end-users did not even mention resource efficiency, or any other sustainability related benefits, that the modular facilities are expected to deliver. The operational energy-efficiency of the modules was only discussed in passing in one of the Producer interviews.

As expected, the dimensional restrictions from the factory prefabrication and road transport limited the potential uses of the facilities. However, the facilities were found usable in their current use. Most identified challenges may be categorized under the theme Lack of customisation, whether related to reuse of modules, lifecycle costing, or schedule. However, the lack of customization was seen as an issue from a functional, not architectural perspective. As for poor image, the Users did not see any problems with their temporary facilities.

Finally, the Users raised an unexpected issue related to the satellite model: the long distance and narrow corridors to the main building were perceived as an issue of 'Safety'. This finding was unexpected, as location within existing urban structure and onsite was in previous literature and based on Producer interviews seen as merely a positive thing.

This study set out to examine the usability of temporary, transferable, modular buildings. Some key issues arise from the findings. First, it should be noted that while some benefits and challenges relate to the modularity and prefabrication of modules, others are a direct result of the business model, where modular facilities are leased and may be removed or added on demand. Second, it appears that the modular facilities face the same challenges as permanent buildings, namely, the lack of communication between client and user and producer. Third, while the modular solutions are incredibly quick to assembly, if customization is needed, the delivery times become longer. In other words, modularity in itself is not able to deliver both a customized solution and a rapid delivery. Customization, with the appropriate participatory methods, takes time, exactly like participatory design in traditional facility projects.

One final word from the Users is worth noting. The Users stated that as long as there are walls around you and a roof over your head and you get to do what you love, it does not really matter what your workplace is like. When asking about flexibility, one interviewee actually referred to the flexibility of co-workers as the most pivotal thing. Another interviewee stated that interesting patient cases were the most crucial element for workplace comfort.

5   CONCLUSIONS AND FUTURE RESEARCH

Based on this study, the temporary, modular facilities function well in their intended use and users consider the facilities flexible, adaptable, and of good quality. Modular buildings could well replace a portion of municipal facilities, making the building stock more adaptable to fast-paced demographic changes. Ultimately, modular facilities suffer from similar challenges than any other facility project: the end-user is rarely the client, which results in lack of

communication and collaboration in the design phase, and the design phase decisions are then reflected in the use phase. The lack of communication also hinders exploiting some of the benefits of the leased facilities. More collaboration between module producers, end-users, and decision makers, is encouraged to further enhance the usability of modular facilities. This includes ensuring an adequate level of customization, even if that led to longer delivery time for the modules.

This study compared the perceptions of two different stakeholders, users and producers, but failed to include one very important stakeholder group, namely, municipal decision makers. Next steps will include looking into the perceptions of these decision makers, 'the Clients'. Future research will focus on identifying the problematic areas in the communication between the different stakeholders, as early as in the planning and design phase. Specifically, it would be of interest to determine the level of end-user participation in the design required to achieve even better solutions for the use phase.

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Taking off: Conceptual Model for FM in airports

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ABSTRACT

After different models had been developed for the FM in Healthcare context, the goal was to find out how the developed service allocation model could be used as a basis for structuring service provision of FM in a standardized way to be able to carry out expedient benchmarking for FM across industries with complex and high demanding conditions in the future. By doing so, it is expected that ponderous industries like healthcare can learn from more dynamic environments. To start with, the complex and dynamic environment of airports, causing specific needs for the provision of FM in partially extreme conditions, was chosen as the research subject. Similarities between specific characteristics of and differences between the two industries were investigated and transferred into the principle of the existing model. The adaptation and development of the model was conducted with the Design Science Research approach [DSR]. To develop the model as an artefact, the generally accepted modelling principles were followed. The service allocation model for support services in airports presented provides not only a basis for benchmarking between hospitals, airports and other industries with high demanding conditions, but also findings about developing conceptual approaches for further initiatives to benchmark FM across different industries in the future.

Keywords: FM in special environments, FM in airports, FM in Healthcare, FM models, conceptual model

1   INTRODUCTION

For Facility Management in Healthcare [FM in HC], several standardization initiatives were started in order to provide systematic, empirical, complexity-reducing bases for optimizing the non-medical support services in hospitals and thus to establish FM in HC as a driving force in the development of the healthcare sector. Reasons for choosing the healthcare industry as a field of research were first of all its extensiveness and complexity, which call for systematic approaches in order to reach comprehensive findings, and secondly, the topicality of the development of the healthcare industry worldwide. The norm for Taxonomy, Classification and Structures in Facility Management (SN EN 15221-4: 2011-12) specifically encourages the development of branch specific definitions of FM. Soon after setting up FM in HC

standards for key performance indicators [KPIs] and processes, the need for comparing and benchmarking not only amongst national and international hospitals, but also amongst FM in other (comparable) industries became evident.

2   RESEARCH OBJECTIVE

The objective was therefore to find the comparable aspects for FM in industries other than HC and to develop a conceptual model as a basis to compare and benchmark FM in different complex environments in the future, starting with airports. As for the HC context, the goal was to show the greatest possible scope – bigger sized enterprises are thus represented in total, smaller sized enterprises will be able to leave out services not provided.

3   METHODOLOGY

As the goal is to set up a (conceptual) model as a visualization basis for further discussions, the methodology of Design Science Research [DSR] according to Hevner et al. (2004), Hevner and Chatterjee (2014), Peffers et al. (2007) and Vaishnavi and Kuechler (2008) was applied. Based on the DSR principle illustrated in Figure 1, an iterative approach combining explorative elements and expert interviews was chosen.
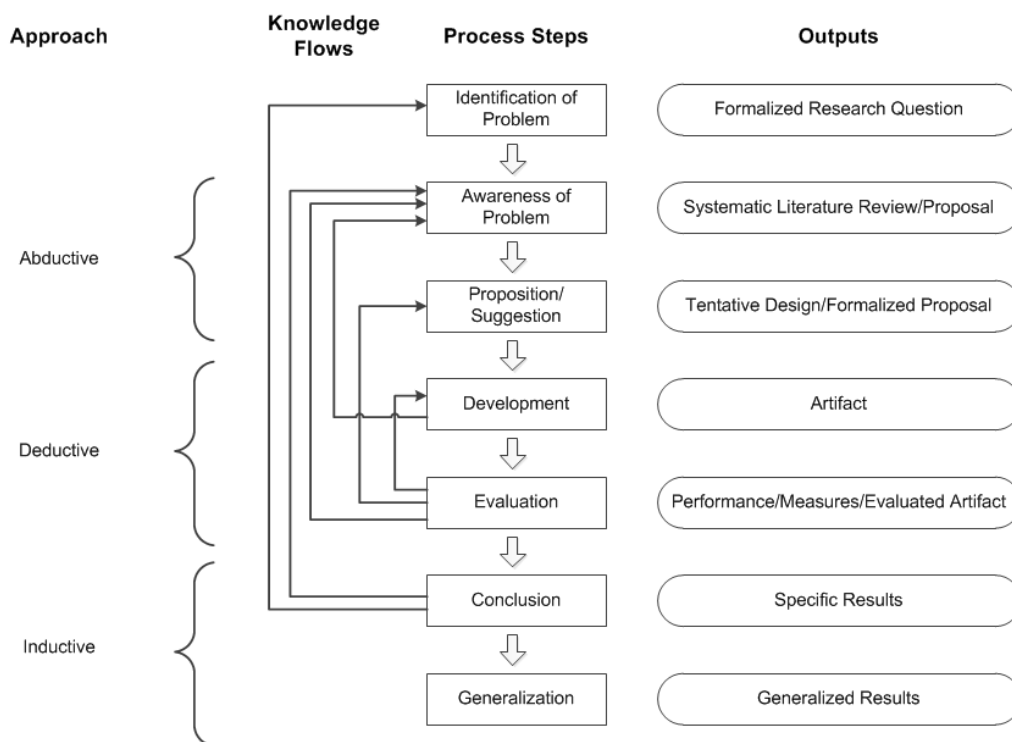
Figure 1 The general methodology of design science
(based on Vaishnavi & Kuechler, 2008 and Dresch et al., 2015)

The *Identification of the Problem* and formulating the *Research Question* was derived from on-going research and development projects and previous publications. The *Awareness of the Problem* was underpinned by a *Literature Review* on the subjects of FM in Healthcare and (FM in) Airports. As a *Proposition*, modelling was suggested as a *Tentative Design*. In the *Development* phase, the model as an *Artifact* was developed using a concurrent exploratory

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approach combining design and empirical principles according to Huysmans & Verelst (2012). To ensure for the choice of the services listed in the model to be systematic, first a list was created where the hospital specific services listed in LemoS 3.0 (Gerber, 2016) such as sterilization and maintenance of medical technology were excluded, leaving all services that are not exclusive to the hospital environment. In a next step, information found in airport-specific literature was added to this list. Then the services were – where possible – allocated to the four domains of LemoS (Gerber, 2016): Infrastructure, Facility Services, Hotel Services and Logistics. Since there are many airport-specific services which cannot be allocated to one of these pre-defined fields, a fifth field – Airport-Specific Services – was created. In addition the areas were divided into Airside and Landside where applicable. The continuation of the further development is two-fold. Firstly, the model has to go through an *Evaluation* by more specialists of FM in HC and FM in Airports. Secondly, the inclusion of specialists of FM in other complex environments might raise more specific *Awareness of more Problems* and will thus lead to more iterations (illustrated by the upward directed arrows in Figure 1) before final *Conclusion* and *Generalization* can occur.

The conceptual bases for developing the model was the Service Allocation Model for non-medical Support Services in Hospitals [LemoS] (Gerber, 2016) as depicted in Figure 2.

Figure 2 Service Allocation Model [LemoS] (Gerber, 2016)

4   DEFINING COMPLEX INDUSTRY CONDITIONS BASED ON HOSPITALS AND AIRPORT CONTEXTS

To start with, the definition of complex conditions for FM based on the environments of hospitals and airports are shown based on literature reviews. Then, a derived general definition of complex conditions will be presented.

4.1 Complex Conditions in HC

The provision of the services in a hospital requires **hybrid collaboration** between the immobile and mobile infrastructure with their inherent highly complex (information)systems (e.g. medical device and their integration in the information system) and humans of very different disciplines. This causes not only technical, but also human and techno-human **interfaces** operating within limited availability of resources. (cf. Angerer, et al., 2012; Braun von Reinersdorff & Rasche, 2014; Burwitz, et al, 2013; Kriegel, 2012)

The **provision of the service(s) is complex and can only partially be planned**, as the need for a medical treatment can be sudden and the course of healing might vary (Bornewasser, 2013; Fritsche & Hermann, 2009; Marsolek & Friesdorf, 2009).

In the healthcare context, **many different internal and external stakeholders** can be identified. To name a few according to Abel (2009), DIN 13080:1999, Fritsche & Hermann (2009) and Kriegel (2012):

- Patients (insured or not) receive medical treatment
- Different medical and care specialists provide medical treatment
- Non-medical support entities provide services for staff, patients and external visitors
- Governmental and private health insurers decide upon financial streams and regulations
- Politicians and governmental institutions regulate conditions, prices and degree of subsidizing
- Owners of the hospital require shareholder value

The healthcare industry is subject to **rapid medical/technological and socio-cultural change** (Abel, 2009; Busse et al., 2009; Fischlein & Pfänder, 2008; Marsolek & Friesdorf, 2009). Medical treatment processes themselves are becoming increasingly complex due to developments in medicine, pharmacology, care and medical engineering. At the same time, a request for more service quality prevails on the patient side.

Hygiene is a very important (quality) aspect in hospitals which has to be treated with high sensitivity not only during medical operations, but also when running technical installations like ventilation systems or while conducting cleaning (Abel, 2009; sanaCERT suisse, 2011).

The politically motivated supply of the population with healthcare leads to a specific market situation which implies **many regulations** (Abel, 2009; Kriegel, 2012; Rasche et al., 2010).

Digitalisation leads to a high demand for investment in IT within the healthcare industry, where IT has not been treated with high priority in the past. The penetration of information technology is additionally hampered by many **data-protection requirements** due to sensitive patient records and the lack of IT competence amongst staff who up until recently have been highly focused on medical issues instead of business administration aspects (cf Bornewasser, 2013; Günther & Hartmann, 2007; Hartmann & Günther, 2015).

Requirements for **logistics** in HC are complex because for procurement, storage, transport and disposal & recycling, many different kinds of material, food and pharmaceuticals have to be handled, some of which are subject to strict regulations and have to be handled with specific care and/or accommodated in specially conditioned areas. In addition, transportation has

to be provided for different kinds of goods as well as for people – sick or healthy. (cf. Bornewasser, 2013; Kriegel, 2012; Walther, 2005).

4.2 Complex conditions in Airports

Within an airport, **many stakeholders** are involved, e.g. airlines, handling agents, government agencies, concessionaires, retailers, providers of food and beverages, entertainment, tourism, business localities or internet access as well as passengers and visitors (Ashford et al., 2013; Graham, 2014; Young & Wells, 2011)

According to Graham (2014), airports face a high demand for air transport and are therefore undergoing **rapid growth.**

Security is a very important aspect for airports and aviation in general. Airport security includes badge regimes, protecting staff restricted areas, checks of passengers, visitors, staff, baggage and cargo, terrorism prevention, armed protection, parked aircraft protection, video supervision, perimeter fencing and lighting, barriers, road inspections Graham (2014), Kazda & Caves (2015), Young & Wells (2011) and are provided by the government (inspection of passengers and cabin baggage), by the airport (security for areas behind the security check and the airport premises) and airlines (passenger baggage and ground equipment) (Kazda & Caves, 2015).

According to Kazda, & Caves (2015), several **technical interfaces** for navigation aids are necessary such as instrument, microwave or transponder landing systems, global navigation satellite systems, VHF omnidirectional radio ranges, non-directional radio beacons, UHF distance measuring equipment, precision approach, surveillance and surface movement radars and advanced surface movement, and guidance and control systems.

For special cargos like live organs, human remains, livestock, dangerous or radioactive goods, meat, flowers or plants, **special accommodations or hygienic standards** have to be guaranteed (Kazda, & Caves, 2015).

Kazda & Caves (2015) also emphasize the **impact on the environment** is important for airports in different respects: noise, air pollution, contamination of water and soil, wildlife control, waste, construction and possible accidents or incidents.

According to Young & Wells (2011) and Richter (2013), an airport is a **transportation** facility with high complexity because people, goods and information have to be delivered in the correct state, at the right time at the correct place and different kinds of service receivers with different needs like aircrafts, passengers, cargo and surface vehicles have to be served.

In airports, a number of **regulations** like transportation security regulations, airport tenant security programs, airport safety rules or local, regional, national and international regulations and agreements have to be considered (Young & Wells, 2011; Ashford, et al., 2013). According to Ashford, et al. (2013), the local interrelationships between the governmental institutions or quasi-governmental bodies and the airport influence the operation of an airport tremendously.

According to Ashford et al. (2013), the **size** of the airport indicates the complexity factor of an airport. While small airports are easier to handle, medium- or large scale airports become very complex.

4.3 Definition of Complex Conditions

From the findings of the above chapters, the following factors for defining complex conditions for industries can be derived:

- Hybrid collaboration between humans, technology and humans with technology and complex processes with high interdisciplinary interactions and numerous technical interfaces
- Many different internal and external stakeholders of different disciplines and/or cultures
- Rapid change of framework conditions or rapid growth
- Only partially plannable service provision
- High degree of (data) security requirements
- Many regulations and/or high degree regarding hygienic standards
- High need for transportation of people and goods
- Size of the enterprise
- These definitions have to be taken in consideration and discussed when thinking about conducting benchmarking between industries in the future and when comparing figures.

5   FM IN HC AND FM IN AIRPORTS

As a basis for the development of the model, an attempt to set the scope for FM in HC and FM in Airports has been undertaken.

5.1   FM in HC

For the definition of FM in HC, the holistic approach described in LemoS 3.0 (Gerber, 2016), which is bases on the norm EN 15221-4, was used as depicted in Figure 1. It comprises the subject areas Procurement, Inventory Management, Transport & Distribution, Disposal & Recycling, Maintenance, Space Management, Energy, Safety, Security, Cleaning, Sterilisation, Catering, Textiles, Accommodation Administration & Operation of Properties and Hotel Various.

5.2   FM in Airports

According to Young and Wells (2011), airports are gradually coming to rely on the private sector in order to cut costs and improve quality. This results in most facilities and services being provided by organizations other than the airport operator itself (Graham, 2014). Graham (2014) points out that therefore the identity of each airport operator is different, but still they have the overall control and responsibility. As stated by Ashford et al. (2013), an ideal one-size fits all solution regarding the administrative structure of airport operations does not exist and it becomes clear that a holistic definition of FM in Airports had not been undertaken. The conceptual model in Chapter 6 will provide a systematic basis.

6   CONCEPTUAL MODEL FOR FM IN AIRPORTS

The service allocation model for support services is a conceptual model illustrated in Figure 3 and was developed through the adaption of LemoS 3.0 (Gerber, 2016), applying information from airport-specific literature (ACRP, 2015; Ashford et al., 2013; de Nuefville & Odoni, 2013; Graham, 2014; Kazda & Caves, 2015; Richter, 2013; Young & Wells, 2011) and subject experts like managers of FM in airports.

The model follows the same main structure as LemoS 3.0 (Gerber, 2015) with a division into three levels: the Strategic Management Services level, the Business Support/Management Support level and the industry specific Support Level, which in this industry is also named Aviation/Non-Aviation Support Services. The first and second level both integrate all services listed in the first two levels of LemoS 3.0, adding airport-specific services, such as Public Safety as a strategic management service or Public & Government affairs for business and management support.

Figure 3 Service allocation model for support services in Airports

Strategic Management Services

IT management	Identity	Sustainability	Asset & portfolio management	Quality management
IT-strategy definition	Innovation facilitation	Life cycle planning	Management of investments, portfolio & multiprojects	Standards & guidelines
Risk management	Resources & sourcing strategy	Environmental management system		Process management
Risk policy definition		Energy strategy definition	Financing management	
	Public safety	Project consult	Aviation planning & development	Aviation operation design & construction

Business Support/Management Support

Finance & controlling	HRM	Legal services	Administration	Marketing & communication	IT-Services
Infrastructure & environmental affairs	Public & government affairs	Information services	Real estate & development		Planning

Aviation/Non-Aviation Support Services

Airport-Specific Services

Airside Operations	Landside Passenger Operations
FOD inspection & self-inspection	Parking management
Ground-vehicle control	Information services
Airport-wide communications	Baggage services
Gate allocation & apron control	**Landside Traffic Handling**
Airside Construction (development)	Passenger handling
Airside Capacity Management	Assistance of disabled & elderly
Airside Emergency Services	passengers
Fire fighting	Baggage handling
Rescue	Executive lounge/club operation
Airside Ramp Handling	**Landside Cargo Handling**
Baggage handling & sorting	Processing of cargo export/import
Operation of load equipment	Cargo handling
Boarding & deplaning	Quarantine
Catering loading/unloading	
Cleaning & servicing of aircrafts	
Routine & non-routine inspection/	
maintenance of aircrafts	
Aircraft marshalling & push back	
Communication/aircraft dispatch	
Airside Cargo Handling	
Cargo handling & sorting	

Hotel Services

Landside Commercial
Retail & duty free
Food & beverages
 (incl. vending machines)
Essential & leisure services
Event management
Car rental
Advertising

Facility Services

Airside Safety	Landside Safety
Occupational safety	Occupational safety
Health protection	Health protection
Ramp safety	**Landside Security**
No hazards on board /	Passenger screening
runway	Immigration, customs & health inspection
Airside Security	Baggage screening & reconciliation
Ramp security	Cargo & airmail screening/ agricultural
Airside barriers	inspection
Access control	Employee identification
Armed protection	Armed protection
Protection on parked	Landside barriers
aircrafts	Personal security
Fire detection & protection	Fire detection & protection
Lightning protection	Protection of property
	Technical protection of information
	Landside Cleaning
	Areas for employees with granted access
	Areas for checked passengers &
	employees with granted access
	Public areas

Tactical Resource Management

Infrastructure

Airside Maintenance	Landside Maintenance
Maintenance of ramp	Maintenance of spaces
equipment & vehicles	Parking lot maintenance
Infield maintenance	Building maintenance & technical building
Wildlife management	management
Winter operation	Operational technology/ tenants specification
FOD	Fittings & furnishings maintenance
Minor servicing & alteration of	Maintenance of internet facilities/kiosks/
cabin fittings/seats	workstations
Airside Energy	Facility improvement
Ground power supply	**Landside Space Management**
Fuel & oil	Internal rental & space management
Compressed air	Property administration
	Landside Energy

Logistics

Airside Procurement	Landside Procurement
Tactical & operational	Tactical & operational procurement
procurement	Incoming goods control
Incoming goods control	**Landside Inventory Management**
Airside Inventory Management	**Landside Transport & Distribution**
Airside Transport & Distribution	Catering transport
Catering transport	Passenger transport
Passenger transport	Baggage/cargo transport
Baggage/cargo transport	Fleet management
Airside Waste Management	Mail/courier services
Disposal & recycling	Relocation
Airside Environmental Control	Ground transportation desks
	Landside Waste Management
	Disposal & recycling

The third level covers five domains. The domains known from LemoS 3.0 are Infrastructure, Facility Services, Logistics and Hotel Services. In the airport context, the field Airport-Specific Services had to be added. Moreover, each subject area contains clustered services which were matched with the services in LemoS 3.0 and completed with services named in airport-specific literature and by FM in airport experts. With respect to the airport industry's customary division, a distinction between landside and airside services was made (exception: Hotel Services).

The Infrastructure domain on the airside consists of Maintenance and Energy, and of Maintenance, Space management and Energy on the landside.

The domain of Facility Services comprises Safety and Security on the airside and on the landside Safety, Security and Cleaning.

Under Logistics as domain Procurement, Inventory Management, Transport & Distribution, Waste management and Environmental Control are listed on the airside, and on the landside Procurement, Inventory management, Transport & distribution and Waste management.

Hotel Services as domain consists of Landside Commercial - there is no commercial department on the airside.

Airport-Specific Services include Operations, Construction (development), Capacity Management, Emergency Services, Ramp Handling and Cargo Handling on the airside, and on the landside Passenger Operations, Traffic Handling and Cargo Handling.

Tactical Resource Management is placed in the middle to indicate that it is involved in all five fields.

7   CONCLUSION, LIMITATIONS AND OUTLOOK

It is becoming clear that hospitals and airports as industries have several analogies: both have many different internal and external stakeholders which leads to a multi-layered collaboration and a great number of (technical) interfaces. Both environments are subject to numerous regulations and they both rely on specific transportation systems and sophisticated logistics. In addition, both environments can partially plan the service e provision but are subject to changes due to emergencies or weather conditions. Several aspects are similar but have different characteristics due to varying surroundings; both industries need to focus on security, on hygiene aspects and on data-protection, however security is a much more compelling aspect in airports while hygiene and data-protection requirements are much more prevalent in hospitals. Finally, there are also some differences: while airports are going through a period of rapid growth, HC is currently heavily influenced by medical/technological and socio-cultural changes. The size of the enterprise seems to have a much greater impact on the complexity of airports than on hospitals and environmental impacts have been a strongly present topic within the airport context but so far very little in HC.

Focusing on the support services context, similarities are that the domain Logistics with the subject areas Procurement, Inventory, Transport & Distribution and Waste Management, the domain Infrastructure with the subject areas Maintenance, Space Management and Energy, the domain Facility Services with the subject areas Safety, Security and Cleaning and the domain Hotel Services are provided in both environments.

Hospital-specific is the subject area Sterilization; airport specific is the clear division of the service provision in Airside and Landside and the domain Airport-Specific-Services with the subject areas Airside Operations, Airside Construction, Airside Capacity Management, Airside Emergency Services, Airside Ramp Handling, Airside Cargo Handling, Landside Passenger Operations, Landside Traffic Handling, and Landside Cargo Handling. As safety & security as well as environmental aspects have a higher prioritization in airports, this is also represented in the model.

However, the clear and generally applicable division between core services and support services in HC by Gerber (2016) could not yet be identified in the airport context. As depicted in Figure 1, another iteration will have to be conducted before the model can undergo final evaluation and generalization for other industries, like for example the production of pharmaceu-

ticals with their numerous regulations and need for strict hygiene, or event management with their high degree of unplanned occurrences.

For the future, at least three superordinate benefits should result from these developments. Firstly, the ponderous industries like healthcare should be able to learn from dynamic industries like airports in order to become more efficient and effective and to develop a better focus on the patient as a customer and thus increase the medical and non-medical service quality. Secondly, the basis for benchmarking of FM across different industries pointing out similarities and differences between the different contexts will be given. Thirdly, once specific results can be presented in different industries, it should be possible to refine the context of the EN 15221-4 norm by defining more clearly the common FM service provision and the industry specific areas, possibly adding several industry-specific issues. By doing so, FM will benefit as a discipline and as an industry.

ACKNOWLEDGMENTS

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2 FM and knowledge management

2.1 Knowledge transfer from building operation to construction
Per Anker Jensen and Stamatia Chatzilazarou

2.2 Risk management of water systems in residential homes: The 'process' of Legionella prevention
Thomas W. Leiblein, Hans Peter Füchslin, Hans Anton Keserue, Matthew Tucker and Susanne Hofer

2.3 Swiss-COBie: Development of a design for information exchange between planners, constructors and FM in Switzerland
Marc El-Arousy, Simon Ashworth and Carsten Druhmann

2.4 Co-creation of campus by using Virtual Reality
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2.5 Employer's Information Requirements (EIR): A BIM case study to meet client and facility manager needs
Simon Ashworth, Mathew Tucker and Carsten Druhmann

Knowledge Transfer from Building Operation to Construction

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ABSTRACT

Purpose: To investigate how knowledge that derives from operation and maintenance of buildings can be stored and transferred in order to be reused in a future building project?

Design/methodology/approach: The paper is theoretically based on knowledge management with a particular focus on interdepartmental knowledge transfer between departments responsible for operation and management and departments responsible for building projects in organisations with large and fast changing building portfolios. The paper includes a case study of the FM organisation of the Technical University of Denmark with data collection mainly by interviews with managers and staff in the relevant departments in this organisation.

Findings: The case organisation seems to be aware of the importance of sharing and transferring their organisational knowledge. Over the last five years, the organisation has developed different tools and adopted several processes, aiming to the integration of the knowledge they possess from many years of operation and maintenance of the existing buildings. However, there are many situations, where the tools and processes do not work efficiently, and therefore the knowledge transfer is not sufficiently effective. It is apparent that the best results can be achieved only if the different actors involved in a construction project collaborate aiming towards the same objectives.

Originality/value: The paper presents and evaluates a case of interdepartmental knowledge transfer in an organisation, which has a strong focus on improving the interconnections between building operation and planning new building projects.

Keywords: Building Operation, Knowledge Management, Project Management, Construction projects, University Campus

1 INTRODUCTION

This paper concerns a challenging topic within the construction industry and the Knowledge Management (KM) discipline. The issue that is examined is knowledge transfer (KT) between building operation and project management of construction projects to ensure appropriate performance of new facilities.

According to literature, the involvement of Facilities Management (FM) expertise in a construction project from its early phases is of great importance (Jaunzens et al, 2001; Jensen, 2009; Hansen et al., 2010; Meng, 2013). Although it might be assumed that knowledge trans-

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fer could be approached in the same way as it is in other kind of industries, the nature of the construction industry makes it difficult. Construction firms move from one building project to another, which usually differs substantially from the previous one. The lack of distinct similarities between these building projects makes the project management team more reluctant to consider, extract and reuse knowledge that has been acquired during past projects.

The purpose of the paper is to answer the following research question: How knowledge that derives from operation and maintenance (O&M) of buildings can be stored and transferred in order to be used in a future building project? Besides, the paper aims to clarify the benefits that occur from this, the barriers that are preventing KT between these two parties, as well as the KS and KT tools and processes that have been developed and are being used within the organisation.

The paper is based on a case study of the FM organisation of the Technical University of Denmark (DTU) called DTU Campus Service (CAS). They are in charge of management, operation and development of all the existing facilities of the university as well as a huge construction program of new buildings at its main campus, following a number of fusions with former independent institutions. The case study examines the intradepartmental knowledge sharing (KS) in, as well as the interdepartmental KT between, the building O&M department and the department responsible for new construction projects – the Real Estate Project Management Office (PMO). The methodology of the study is described in section 2 followed by a literature review on KM in section 3. The case study is presented in section 4 and followed by discussion and recommendations in section 5 and conclusion in section 6.

2   METHODOLOGY

CAS was chosen for the case study, because they are one of the largest building clients in Denmark at the moment, they have a large in-house departments responsible for O&M of buildings, and earlier research (Rasmussen et al., 2014) has shown that CAS as an organisation is deliberately aiming at increasing knowledge transfer from building operation to building projects. The methodological approach used during the research was divided into three stages.

In the first stage a broad literature review was conducted sub-divided into two parts. Initially the field of KM was examined thoroughly, giving weight to the aspects that are useful and assist the understanding of the importance of KM within an organisation. Secondly, research regarding KS and KT in construction industry and particularly in KT between FM and building design was conducted.

The second stage focused on data collection, using semi-structured interviews, which took place during spring 2015. As the research is qualitative, interviews were considered to be the most suitable method of data collection. Ten interviews were conducted. Two of these were external experts, while the remaining eight were with people from CAS, see the case study section below.

The third stage included analysis and categorization of the data that were gathered during the interviews. The categories in which the data were placed were regarding the KS and KT behaviour and activities that CAS uses at the moment and were used in the past as well as KS and KT activities that are being developed at the moment to be used in the future.

3   LITERATURE REVIEW

KM is a relatively new management field, established on the argument that it is a challenging task for an organisation to fully utilize the knowledge that they create or possess. The information technology revolution is one of the crucial reasons, why increased access to knowledge has become possible. It is of great importance to discriminate between data, information and knowledge. A collection of data is not information, and a collection of information is not knowledge. Therefore, KM can be described as the strategy that aims at development of organisational knowledge through accumulation of data and information, along with past experience derived from the human resources (Dubey and Kalwale, 2010).

A common way to distinguish knowledge is into two fundamentally different categories; explicit and tacit. The explicit knowledge is useful technical knowledge, which comes from the employees and can be explained by them; thus can easily be codified. Once codified and stored, this explicit knowledge can be distributed within the organisation and reused. Examples of explicit knowledge are templates, patents, reports and copyrights. Tacit knowledge is non-articulated knowledge and thus inherently personal, which makes it difficult to be extracted out of human minds, formalized and disclosed in manuals in order to be shared or transferred. Another difference compared to explicit knowledge is that tacit knowledge consists of a technical and a cognitive dimension. While explicit knowledge has a solely technical dimension, tacit includes individual experience along with personal belief, perspective and values. This feature constitutes an obstacle to the transferability of tacit knowledge (Lundvall, 2004).

Knowledge codification is an important part of the knowledge refinement process, which includes the techniques that extract, filter, clean and reform the new knowledge in order to enter the various knowledge repositories. Such repositories hold both organisational knowledge and information, either in an electronic form (i.e. knowledge databases), or in a documented form (Davenport et al., 1998).

Technology has a crucial role in the acquirement and codification of organisational knowledge as it can store large amounts of knowledge, allowing its smooth distribution and re-use. Therefore, a robust Information and Communication Technology (ICT) infrastructure to support both the codification and storage of the organisational knowledge is necessary. The selection of appropriate technology should be aligned with different organisational aspects. The most important aspect is organisational culture as it is the one that affects internal communication and KS, with operational, technical and cost aspects being significant as well (Smith, 2001).

In order for knowledge to be spread and affect the organisation, it has to be either transferred or shared. In KT, knowledge is communicated from a sender to a known receiver, having a specific focus and purpose (King, 2009). On the other hand, in KS knowledge is exchanged among individuals, groups or organisational units and usually does not serve any specific purposes, thus it can be either focused or not (Paulin and Suneson, 2012). Therefore, in this paper KS refers to knowledge that is shared between the participants of the same group, network or organisational unit, while KT refers to knowledge that is transferred from a group, a network or an organisational unit, to another.

The success of KS is heavily based on the existence of cooperative behaviour between the participants. Appel-Meulenbroek (2014) distinguished cooperative behaviour into two main

types; interaction and collaboration. Interaction adds structure to how departments interrelate and describes a more formal kind of cooperation with routine activities, such as scheduled meetings and teleconferences, routine calls or standardized documentation. On the other hand, collaboration represents the unstructured, affective nature of intradepartmental relationships portrayed by more informal processes and mutual understanding between the different parties which work together sharing a common vision and a same objective.

KT mechanisms are currently a hot topic in the KM field (Zuo et al., 2013). The initiation mechanisms of KT can be categorized into push, pull and fixed (or symmetric) mechanisms. Knowledge push represents an initiation mechanism where the sender provides knowledge without any particular demand for it, knowledge pull is a mechanism where the receiver is the one that requests the knowledge, while a fixed KT initiation mechanism depicts the scheduled KT activities, such as regular meetings, where both sender and receiver play an active role through established interaction activities (Ahmed-Kristensen and Vianello, 2015). Another type of categorization of the KT mechanisms, in respect to the strategies for capturing and transferring knowledge, is the distinction between personalization or codification strategies (Lê, 2007; Jensen, 2012; Ahmed-Kristensen and Vianello, 2015). The personalization strategies represent a more informal communication between the participants and can be related to the collaboration KS activities. Usually through these strategies new knowledge is generated and existing tacit knowledge becomes available to the receiver. On the other hand, the codification strategies refer to the transfer of the explicit knowledge that is captured into knowledge repositories, related more to the interaction activities.

4   CASE STUDY

The main purpose of DTU CAS is to ensure that all students and personnel are provided with the best possible physical working conditions in all DTU's 17 different locations around Denmark and Greenland. CAS is headed by a campus director with reference to the university director and is subdivided into three different departments, each headed by a director, see Figure 1.
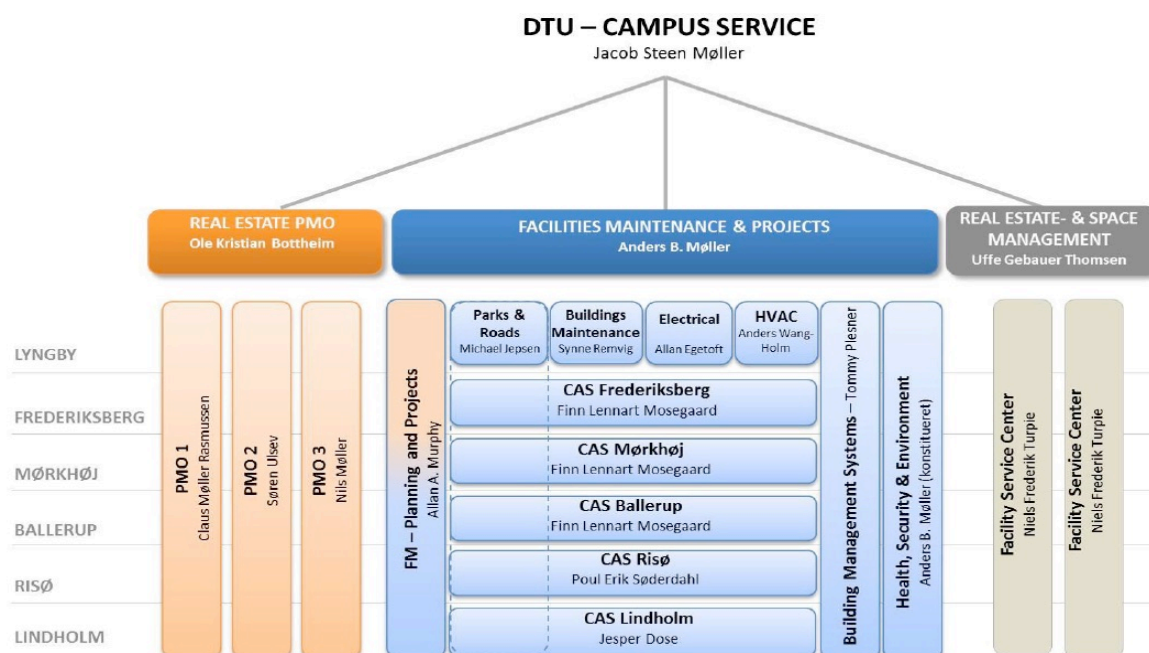
Figure 1 Organisation of CAS

These departments represent the core activity areas of the organisation; Real Estate PMO, Facilities Maintenance and Projects (O&M), and Real Estate and Space Management. The organisation is physically distributed on 6 locations, employs approximately 180 employees and has its headquarters at the main campus in Lyngby, north of Copenhagen. The case study concerns the main campus, owned by DTU, as it is currently expanding in order to support the centralisation of the external research institutions, currently placed in rented buildings elsewhere, as well as the future demands deriving from the increase of students and staff.

The eight interviewees from CAS included the heads of the three departments as well as section leaders and project managers from the O&M and PMO departments, whose interaction was examined.

4.1   KM in CAS generally

According to the literature review interaction as a cooperative behaviour for KM is more structured and formal than collaboration. Interaction in CAS is established on a phase-gate model that has been developed based on the principles of PRINCE2 project management model in order to support every new construction project, in which all the departments of CAS along with external actors, are involved. A building project in CAS is divided into four main stages; Conceive, Design, Implement, and Operate (CDIO). Each of these stages is subdivided into different phases, representing the activities that take place during the project execution. All CAS departments are involved in a building project, depending on the phase that the project is in. Each phase is followed by a gate-point, where activities that support the interaction of the involved in the project parties, occur. These activities are usually scheduled meetings or exchange of documented information for review or approval from CAS units or other project participants.

Collaboration as a type of cooperative behaviour for KM includes unstructured and informal organisational processes, as mentioned above. Although CAS has a structured cooperative behaviour in terms of interaction, when it comes to collaboration, they have not yet achieved an adequate level within the whole organisation. A clear common goal regarding KS has not been defined. Employees in CAS know that they have to share knowledge between them and transfer knowledge to another department when necessary, but there has not been formally stated a strategy that clarifies, why and how it should be done. On the other hand, the heads of CAS departments collaborate to a higher degree than their employees do. At the moment the three departments are placed in three different buildings at the campus, which in many cases may result in the development of subcultures within the organisation. Even though subcultures can be considered as a positive consequence, because employees feel as a part of a community and therefore may collaborate and perform better, it can prevent the development of a common organisational culture. However a new building is constructed in order to gather CAS departments during 2016, aiming as well to the development of a strong universal organisational culture.

As mentioned in the literature review, KM depends heavily on ICT-based tools. Since CAS is moving to a direction where the knowledge that has arisen from previous projects will be shared in order to be reused, they invest in ICT systems to assure competent and efficient KS throughout the organisation. Two such systems are the Building Information Modelling (BIM) for 3D models of buildings and a Computer-Aided FM (CAFM) system, which will be used among other things for maintenance management. However, both systems are not fully developed and updated with data of all buildings and projects yet.

4.2   KT from O&M to PMO

The main activities in O&M are the amendment of the faults that are reported through a helpdesk system, and the management of planned maintenance projects. However, its responsibilities include also the transfer of the knowledge created during building operation and maintenance to PMO, assisting this way the reuse of this knowledge by the project managers during their projects.

DTU's main campus has a distinctive architecture that it is important to preserve. One of the main focuses of O&M is the conservation of the campus architectural harmony as well as the avoidance of having buildings that is difficult or expensive to maintain. However, sometimes external architects in order to leave their footprints by designing a building that will differentiate from the existing, tend to ignore the original architecture and the general aesthetics of the buildings. Hence, it is essential for O&M to set some requirements, by using their knowledge from operation and maintenance of existing buildings, and transfer it into the new projects.

The type of KT from O&M to PMO can be described both as knowledge push and as knowledge pull depending on the phase of the project. During the first meetings in the design brief phase of a project, O&M section leaders 'push' knowledge, through the design specifications that they pass on to the project team, setting in this way the requirements that assure the efficient future maintenance and the preservation of the original DTU architecture. On the other hand, PMO project managers call meetings with O&M section leaders and try to involve them in every project phase, in order to 'pull' knowledge useful for the project, through the O&M section leaders' feedback.

A critical issue that has an impact on several KT activities of O&M is the lack of human resources. The main responsibility of the O&M section leaders is to coordinate basic operation and maintenance activities and define the new maintenance projects they are in charge of, with respect to the future needs of the buildings. Additionally, after each phase of a PMO project, they have as an extra duty to participate in meetings with the project managers and provide the project team with feedback by commenting on project drawings and documents. These tasks are time-consuming processes and sometimes O&M section leaders cannot attend the meetings or give feedback on the projects on time. In order to improve the efficiency of the O&M sections and support the O&M section leaders, CAS employed extra personnel over the last years.

A rather new method that O&M has started to use extensively in the recent past, in order to assist the KT from their department, is codification of their departmental knowledge. This codification is based on production of documents that standardize specifications or solutions and are applicable in both new construction and refurbishment projects. The main standardization method used by CAS is the development of design standards. The development of these standards started on the request of a PMO project manager, who wanted to simplify the facilitation of KT from O&M. They define the design requirements that have been set by O&M, having as main para meters design consistency, level of complexity and cost of maintenance. For instance, a toilet standard aims to prevent designing different toilets around the campus, while saving time during design.

The standards are distributed to the project team by the O&M section leaders in the design brief phase of each project; thus, the KT through the design standards can be described as knowledge push as shown in Figure 2.
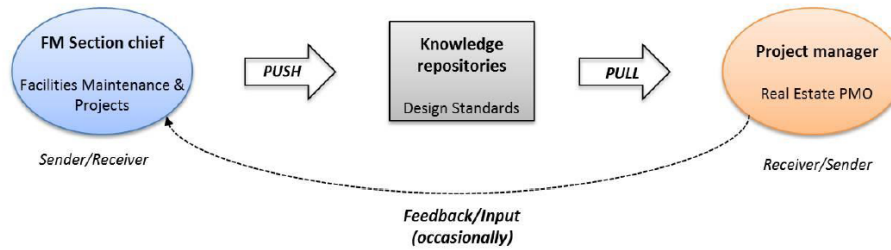
Figure 2 KT from O&M to PMO through design standards

From this moment the responsibility regarding their implementation on the design of the project passes to the project managers. However, often O&M section leaders discover that the decisions that have been made during the project phases are not compatible with the standards' requirements. This can happen either because the requirements set in the standards could not be applied to the specific project or because the project team disagrees with them. In this instance, O&M section leaders need to remind the project team about the implementation of the standards or, in case of disagreement, try to find a common ground.

4.3   KT from PMO to O&M

PMO is in charge of all the new building projects of DTU. The project managers in PMO comprehend fully that after the completion of a project, O&M personnel will inherit and be responsible for the operation and maintenance of the building; therefore the O&M personnel needs to be familiar with the building and know how its technical systems function. The head of PMO uses what he calls the "gift metaphor", where the new building is seen as a gift that PMO is wrapping up in order to give it to O&M. When the people in the latter department unwraps the gift, they should be able to use it; hence PMO should provide them with all the necessary knowledge and instructions. To achieve this, PMO uses processes which facilitate transfer of the knowledge that is created during the different project phases. The knowledge that arises from PMO and could be beneficial for O&M is mainly associated with new processes, technologies or materials that can substitute the currently used. Usually, project managers try to push this knowledge to the O&M section leaders, during their meetings after each project phase.

However, according to the interviewed O&M section leaders, KT from the PMO project managers is not an often occurring phenomenon; thus the knowledge distribution can be characterized as asymmetric. Moreover, the knowledge that is transferred is not always considered relevant or useful for the O&M section leaders because these two participants "look at the project with different eyes". The O&M section leaders are more concerned about buildings which maintenance does not require too much effort and expenses, while the project managers are more focused on delivering an original, innovative and less conventional building, ignoring the future maintenance difficulties. Therefore, most of the times the knowledge that PMO tries to transfer to O&M, is not being used.

The time that O&M usually devotes to KT activities is limited due to their lack of human resources. Hence, KT from PMO to O&M can be described as knowledge push, supported by the use of ICT-based systems. Project managers push the information and knowledge that arise during a project into the ICT-based systems that serve as knowledge repositories – including a project-web called iBinder. Following, it depends on the availability of the O&M section leaders to pull and use this knowledge, as shown in Figure 3. The same knowledge push from the project managers is happening also during their meetings with O&M section

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leaders after each project phase. There, the project managers are 'pushing' information and knowledge regarding the project to the FM section leaders, requesting their comments.
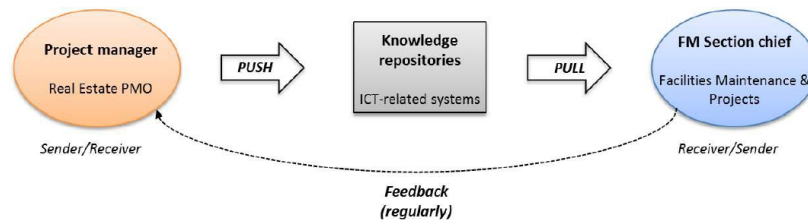
Figure 3 KT from PMO to O&M

On the other hand, project managers in PMO are also engaged with tasks related to their projects, thus sometimes their work overload does not allow them to hold discussions and give feedback to the comments that they receive from both O&M section leaders and user groups. Therefore, some of the decisions are not made in common and this can cause tensions or disappointment between the participants.

5 DISCUSSION AND RECOMMENDATIONS

The discussion and recommendations in this section are structured according to a management tool called POKI – Process, Organisation, Knowledge and tools, and Information and communication (Due and Stephensen, 2011), which was developed as part of a project about best practice in implementation of FM knowledge in construction projects. It aims to assist an organisation in overcoming the usual barriers that are met during the integration of FM expertise into new construction projects.

5.1 Process
This POKI element concerns the revolving process of a construction project divided in phases, from feasibility study to handover of the finish building. The phase-gate model that CAS has developed is being used in every construction project and is enriched with interaction activities, so that O&M, end users and other important stakeholders will be involved in the project from its early beginning. This model seems to be best applicable to large and complicated building projects, but for smaller and not so complicated projects it appears less suitable. Therefore, the development of simpler versions of the model is recommended, so that it is decided before the beginning of a new project, whether a simple, medium or comprehensive model should be applied.

A critical parameter in the 'process' element is the assurance that all project participants are aware of the common goal of achieving a user- and FM-friendly building. The interviews revealed that the PMO department is gradually becoming more aware of this parameter. For instance, the "gift metaphor", that the head of PMO used, shows how important is for him the development of FM-friendly buildings that fulfil the O&M and user requirements. However, part of the project managers in the PMO department and all the specialists, that constitute the project teams, are external consultants; thus, they do not feel part of the organisational culture and they do not hold responsibility after the delivery of a building project.

5.2 Organisation
The 'organisation' element of the POKI management tool underlines the importance of including the right persons into the KT processes. The involvement of representatives of future

users, FM personnel and technical consultants is considered to be essential. As described in the previous section, CAS involves all these actors in its construction projects through the phase-gate model. However, during the interviews the heads of the departments of CAS seemed to doubt the personnel's competences regarding using the existing ICT-based tools that assist the facilitation of KT between and within its departments. A suggestion that could help CAS to improve personnel's skills and ensure that everyone involved in the KT is competent enough to work effectively with the existing tools, is to provide them with the appropriate training.

5.3 Knowledge and tools

As described in the previous section, over the last years CAS has developed – and is still developing – various ICT-based tools. Even though the amount of the existing tools and techniques might be sufficient, their effectiveness is often in dispute. The ICT systems are not fully developed and updated, which means that they cannot fulfil their role as knowledge repositories. Therefore, it is suggested that the O&M department assign a small group (2-3 employees) of each O&M section for a short period of time, which after being trained can fulfil this task.

Another tool that could be adopted by CAS is checklists that will assure that the most critical demands for each project phase have been satisfied. Maintenance checklists have been developed and have been more popular over the last years within the construction industry. For instance, during their study, Hassanain et al. (2015; 2016) developed maintainability design review checklists about electrical and water supply and drainage systems for campus maintenance departments in universities in Saudi Arabia. These checklists were developed to be used by design teams in order to reduce the occurrence of the most frequent defects.

A third tool, that could benefit CAS, is Life Cycle Costing (LCC) – also called Whole Life Costing (ISO, 2002). LCC is a tool which provides economical overview of a building over its lifetime, including both initial investments in the construction project and ongoing expenditures to building operation etc., helping to achieve the right balance between investments and operational expenses.

5.4 Information and communication

The establishment of an effective KM strategy (KMS) can assist an organisation in order to benefit as much as possible from the existing organisational knowledge. However, usually the management of an FM organisation does not realize the necessity of forming a KMS. In CAS, even though there is no established KMS, some of the interviewees have noticed a change in the organisational culture regarding KS over the last years. In an organisation like CAS, where both construction projects and FM activities take place, two different mind-sets are met; 'hunters' and 'farmers'. According to Johnstone et al. (2007), a hunter's mind-set is orientated towards the successful development and execution of high-profile projects within the provided time frame. In CAS this mind-set describes the PMO project managers, as according to the heads of the departments they are described as 'butterflies' that after the completion of a project fly away to the next one. On the other hand, a farmer's mind-set represents a long-term focus, where continuous improvement and benefit through sharing knowledge deriving from past experience, are main goals. This mind-set can be linked to the O&M department's mind-set, as they are more concerned about the operation of the facilities in long-term.

The co-existence of these two kinds of mind-sets within an organisation and the development of a common KS-oriented culture is not dependent on the replacement of the hunters' mind-set with a farmers' mind-set. The most effective way to combine them both in the same organisational culture is to find a balance between them. The development of a KMS can assist this effort and therefore can assist the development of a common organisational KS culture. An effective KMS is tailored to a specific context of use; hence, it should be able to answer the questions 'What knowledge to share?', 'Whom to share with?', 'Why should knowledge be shared?' and 'How will knowledge be shared?' In the case of CAS, the CLEVER (Cross-sectoral Learning in the Virtual Enterprise) framework, which was developed to support the establishment of a KMS addressing a specific KM issue within an organisation (Anumba et al., 2005), is suggested to be applied.

Besides, it is essential to develop an organisational culture, which is built on mutual trust among the participants and is based on collaboration processes. The two different units of CAS, which have been analysed in this paper, need to develop a more holistic point of view, without focusing exclusively on their own success. The establishment of an organisational culture in CAS could include the use of incentive systems that will keep the staff motivated. The development of a KT incentive system within an organisation is a rather tough process, as it usually involves the study of the factors that motivate the participants to share or transfer the organisational knowledge. Pemsel and Blomé (2011) conducted a research on real estate organisations in Sweden, which tried to identify what motivates the employees in the construction industry to perform successfully in their job, and proposed appropriate incentive systems. Their study revealed that the two fundamental motives of the employees are their eagerness to develop a construction project that will satisfy the client, and to undertake more challenging projects. What is interesting in this study is that the employees are seldom motivated by improving their relationships with their colleagues or their consultants, while a possible increase of their salary does not constitute a motive at all. It is suggested that CAS follow a similar procedure by first identifying the motives of the main participants in the KT activities, and then develop suitable incentive systems.

6   CONCLUSION

This paper aimed to examine the knowledge transfer from building operations units to the construction project management in FM organisations to ensure appropriate performance of new facilities. The type of knowledge that has been examined, derives from the O&M of existing buildings and is either shared or transferred. According to the literature, the involvement of FM in a construction project from its early phases is crucial. In a new construction project FM units can provide the project team in charge, with valuable knowledge that supports the decision-making, ensuring that decisions with long-term benefits are made. For the facilitation of this knowledge transfer from the FM units to the project team, several tools and frameworks have been developed. ICT-based tools, such as intranet, project-webs, BIM and CAFM systems, play a key role in the facilitation of this knowledge transfer. However, these systems just serve as knowledge repositories that can store huge amount of data, information and knowledge.

The case organisation DTU Campus Service is an organisation that has been taking care of the operation and maintenance of campuses for many years; therefore, it possesses huge amounts of knowledge that can be used in the new construction projects. Over the last years the importance of utilizing the existing FM knowledge has become apparent. For this reason, the management of the organisation has developed and established different tools and pro-

cesses that facilitate the sharing of the existing knowledge throughout the organisation or within the departments, as well as the interdepartmental transfer of knowledge, from the FM unit to the project management of the new constructions. However, during the research it has been discovered that the case organisation has given more attention to the interaction activities, through the formation of a phase-gate project model and the development of several ICT-based systems, without focusing much on the collaboration activities within the organisation. This lack of collaboration and universal objectives within the case organisation creates several issues that lead to inefficient KT and frustration between the participants and impose the formation of a KM strategy.

Knowledge transfer within the case organisation has improved over the last years, and the personnel are becoming aware of the importance of the knowledge transfer activities. The FM section leaders have created design standards to facilitate knowledge transfer from O&M department to the new constructions, which ensure that the FM requirements regarding the new projects are set for the project team to consider during the design phases. On the other hand, project managers ensure that all the available data and information that derive throughout every project phase are communicated to the FM sections, through the use of an ICT-based project-web. However, there is still plenty of room for improvement and the previous section includes a number of specific recommendations of relevance for the case organisation, but also for other FM organisations.

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Risk management of water systems in residential homes: The 'process' of *Legionella* prevention

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ABSTRACT

In the present study data was collect and analysed to gain evidence for the present situation of *Legionella* risk management and prevention of water systems in different buildings in the Canton of Zurich, Switzerland. These buildings comprise retirement homes, care homes and dwellings for people with a disability. According to given legislation, standards and technical rules, duty holders are liable for the quality of drinking water distributed by the water system in a building. Showers represent a frequently used, aerosol-generating device in the domestic setting and have been proposed as a source of Legionnaires' disease, caused by *Legionella* bacteria. This study investigated the prevalence of *Legionella* in showers which are recognised as a potential source of risk of contamination for users. During a field campaign, data from ten buildings were collected. Water was sampled from showers and analysed with reproducible sampling procedures. As a second source of data, information concerning technical specifications and operating parameters of the (hot) water systems and shower facilities was collected from the operating manager through a semi-structured questionnaire. Based on the microbiological results provided by the classical culture method, a *Legionella* contamination was detected in two objects. Three additional care facilities showed raised results according to a different method applied. Evaluation of the responses given in the questionnaire revealed that control functions and documentation seem to be either unsatisfactory within the institutions, or are missing completely. Although the small size of the sample in this study does not permit generalizable statements, the results provide a solid foundation upon which further investigations can be based.

Keywords: Risk management, process, prevention, water system, *Legionella*

1 INTRODUCTION

1.1 Facility management in healthcare

In this article, risk management and *Legionella* prevention is discussed and reflected from a practice-oriented point of view. It can be assigned to facility management in healthcare (FM in HC). The topic of *Legionella* in water systems in HC settings has a clear link to FM and prevention, which can be regarded as part of an active risk management (Shohet & Lavy, 2004; Leiblein *et al.*, 2016).

Legionellae are causative agents of Legionnaires' disease (LD) and can cause a potentially fatal pneumonia (Phin *et al.*, 2014). Species of *Legionella* (*Legionella* spp.) are ubiquitous in aqueous environments but favour growth in man-made water systems operating between 20°C and 45°C (Fields *et al.*, 2002). One species of *Legionella*, *L. pneumophila*, seems to cause approximately 90% of all reported cases of legionellosis (R.E. Besser cited in Fields *et al.*, 2002: 507). Among 15 serogroups (Sg) of *L. pneumophila* almost 80% of all culture-confirmed cases are caused by *L. pneumophila* Sg1 (Marston *et al.*, 1994).

1.2 Duty holder

Water systems in facilities contaminated with *Legionella* is just one example but a serious and a topical issue of hygienic risks which needs to be addressed. Besides the threat of economic or image loss to the facility, the risk to people is undeniable. Potentially affected are people being exposed to open water systems or the apertures of water systems, e.g. showers (Collins *et al.*, 2016). Hazards arise from contaminated small-size water droplets, termed aerosols. Awareness of the potential contamination risks from environmental sources is relevant in FM contexts where managers (e.g. operators or any other duty holders) may be responsible for building-associated facilities such as water systems (*"Legionella* - stay vigilant"*, 2015). Understanding the context and the environment is the first step towards precisely defining actions against hazards such as *Legionella* (Arvand *et al.*, 2011).

When talking about the management of processes, we must not forget about the key personnel responsible. On closer examination, however, who are those who are responsible?

In their 'Guide to *Legionella* Risk Assessment' the Water Management Society (WMSoc, n. d., p. 11) differs between four types of key personnel with respect to the responsibility for processes of water safety. These are 'duty holder', 'responsible person', 'deputy responsible person' and 'other key persons'. Each represents a different level of hierarchy. The 'duty holder' characterises as follows: *"Described in L8 (the Approved Code of Practice, 4th edition 2013) as the employer, the self-employed person or the person in control of the premises. [...] in cases of shared accommodation, there may well be a shared responsibility. The duty holder cannot delegate his duty, but he can delegate managerial responsibility to the responsible person [...]"*

The responsible person for the building is liable for maintaining the hygienic quality of drinking water throughout the building.

1.3 Protective goals

According to legislation and to generally accepted engineering standards (norms, recommendations, technical and guidance documents) there can be undeniable aspects of water hygiene that enforce criminal and civil law obligations (Gollnisch & Gollnisch, 2016). The maxim of the operating manager should therefore also be aligned according to defined "protective

goals" of his own organization, which go beyond the liabilities created by law. This is to ensure the highest possible contribution to the protection of drinking water hygiene for the building users. Where health or even human life is endangered at the end of a process chain, there is no tolerance for gross deficits, e.g. seen in the lack of objective control mechanisms.

1.4 Norms, legislation, recommendations
WHO
Drinking water distribution networks harbour the risk of *Legionella* formation. Due to the optimal temperatures, the proliferation of *Legionella* occurs mainly in DHW (drinking hot water) distribution networks. Based on the WHO (2007, p. 32), certain components have to be examined for safe drinking water distribution, of which were taken into account in the present paper. In addition, the WHO (2007, p. 62) has published a list of risk factors that could lead to legionellosis associated with water systems. The list mentions stagnation, pipe materials, water temperature between 25 and 50°C, and the presence of biofilms or the potential of outlets generating aerosols.

Food Legislation
In Switzerland, the 2016 VQWmK regulation of the Federal Office for Food Safety and Veterinary Affairs on the quality of water, "intended for human consumption and contact with the human body" regulates the use, treatment and disinfection of drinking water as an object of use or as food. This regulation applies only to non-private installations. Until now, there has been no legal basis for hygiene standards of shower and bathing water (related to *Legionella*) in Switzerland. This will change with the revision of the Food Act in mid-2017. From there *Legionella* spp. (all species of the genus *Legionella*) in shower water should not exceed 1000 CFU/l (unit: Colony forming units per litre) in the warm water cycle.

Recommendations of the Federal Office of Public Health
In a step-by-step list of measures, a publication by the Federal Office of Public Health (from here onwards 'FOPH recommendations') describes the measures to be taken in case of presence of *Legionella* in the water pipeline system (FOPH, 2009). Contamination with *Legionella pneumophila* is differentiated into three levels. If a value of 1000 CFU/l is not exceeded, there is only a low risk of legionellosis according to the FOPH. The FOPH also assigned three different risk categories to various building types. Residential / nursing homes are assigned to the medium risk level. Corresponding measures for exceeding concentrations include flushing with hot water. Sanitary installation must be designed in such a way that the temperature in the heated part of the distribution network is always above 55°C. If the temperature recommendations are not adhered to or cannot be adhered to bacteriological checks must be carried out.

1.5 Risk management
For the future, it is important to define effective and, in practice, viable self-control of drinking water systems and water systems in buildings. Various national guidelines and standards can be used for guidance. Merely complying with existing legislation and guidance, however, does not necessarily mean that a system is safe or operates reliably. Particularly for buildings with water systems serving third parties (Dyck *et al*., 2007), and a variation in water consumption, water-associated hazards and associated measures are to be considered carefully and closely scrutinised ("Facility-borne illness", 2013).

As part of self-control it is necessary to limit appropriately, and to establish appropriate control and intervention measures, according to hazard potentials (Freije, 2005). At the begin-

ning of preventive measures (as regards *Legionella*), an individual risk assessment of the building's water systems should be performed (Kruse *et al.*, 2016; Völker *et al.*, 2016).

1.6 Hygiene and water safety

The discipline of FM is confronted with issues which differ in their complexity regarding hygiene in healthcare settings (Freije, 2005; Gamage *et al*., 2016; Liyanage & Egbu, 2005). Thus, hygiene-related issues must be understood as an interdisciplinary task. However, the responsibility for the effectiveness of the quality management, to which the rate of hygiene makes an essential contribution, is also assigned to the management level. Top management is obliged to take managerial responsibility. In the present article, one of the various possible areas of responsibility will be scrutinised, in which special demands on hygiene, water safety and risk management arise. These are not solely important to the FM (Hübner *et al.*, 2012). In terms of hygiene for water systems in buildings, there is a risk of contamination of drinking water in the final meters before reaching the consumers (WHO, 2011). *Legionella* and *Pseudomonas* are the most prominent pathogens which can become a problem in water systems (Völker *et al.*, 2010). This study focuses on *Legionella*.

Temperature of drinking water
According to the WHO (2007), the DHW water should leave the hot water reservoir with a temperature of at least 60°C. Furthermore, the WHO states that the return temperature should not be less than 50°C for a circulating line. According to the Swiss Association of Gas and Water, the hot water temperature in distribution and riser ducts in residential / nursing homes should be at least 50°C.

Hydrodynamic conditions
Kistemann (2014) argues the dynamics of the water movement in the drinking water installation is of great importance from the point of view of drinking water hygiene. So-called "dead lines", in which the water stagnates, must be avoided.

1.7 Legionnaires' Disease and showers

Worldwide, the occurrence of LD is increasing, with the highest number of cases ever reported in Europe in 2014 (ECDC, 2016). *Legionella* infections are particularly dangerous for immobile and elderly persons. According to BAG statistics, the number of reported cases of legionellosis has increased considerably in recent years. Household potable water systems have been shown to be a potential source of sporadic LD (Straus *et al.*, 1996). Exposure to *Legionella* contaminated showers is a recognised risk factor for legionellosis (Muhlenberg, 1993) and previous exposure assessment has ranked showers second in a relative ranking of *Legionella* exposure pathways from common household water uses (Hines *et al*., 2014). However, there is limited information on the prevalence of *Legionella* in household showers and the associated risk to users. With aging and increasingly immunocompromised populations (Chan *et al.*, 2016), a better understanding of opportunistic pathogens, including *Legionella* in household water systems, will become more important.

1.8 Research-driven field campaign

Based on the theoretical framework described above, a field campaign was conducted to explore the current state of residential homes and their present situation with respect to FM, risk management, water safety and *Legionella* prevention.

2 MATERIALS AND METHODS

2.1 Mixed methods design

The aim of the study is to associate microbiological results with building-specific parameters. This requires a mixed-method research design, since there are quantitative and qualitative instruments of data collection. In principle, the research complies with knowledge-oriented research methodology. Due to the non-representative sample size of ten organisations, no generalised statements can be made about the total population of all the residential homes of the Canton of Zurich. Results are discussed with reference to current research on this topic.

2.2 Instruments for data collection

Different microbiological analysis methods represent one of the two data sources. Overall-data collection is carried out using two different instruments. A questionnaire differentiates the results in their content quality and is therefore a qualitative survey instrument. A questionnaire from the United Kingdom, which is used as part of risk assessments for drinking water installations (WMSoc, n.d.) was used as a basis. For the purposes of this project, the questionnaire was translated, abridged, and adapted to Swiss water system standards and terms, and supplemented where considered necessary.

2.3 Sampling sites

According to the Federal Statistical Office there exist 1552 residential/care homes in Switzerland. Of a total amount of 238 such homes in the Canton of Zurich, 10 were randomly selected for this study.

2.4 Water sampling

Samples were collected by experienced water sampling stuff from the local health authority according to a defined sampling scheme, transported to the laboratories and processed within 24 hours. Places for sampling had been defined prior to sampling. Sampling included points furthest from and nearest to the rising pipe.

2.5 Microbiology: Detection of *Legionella*

In this study, the classical cultural method and a novel one were applied for microbiological analysis of water samples. Different measurement methods yield different data on *Legionella*. This can be related to different sensitivity and specificity. There may also be non-culturable cells of *Legionella*, so-called VBNC state, which means 'viable but not culturable'. Inaccuracies such as this may represent a potential hazard for 'water-consumers' and are unsatisfactory for decision makers. Thus, it is essential to employ a reliable, specific analytical method for the detection (Keserue *et al.*, 2013).

Classical culture method
The classical cultivation method carried out by the Official Food Control Authority of the Canton of Zurich within this field campaign is based on ISO standard 11731. This method represents the currently recognized valid reference method.

Immunomagnetic separation with FCM-detection (FCM-IS)
According to Hammes and Steinberg (2012), single cells suspended in aqueous solution are passed through a laser beam during flow cytometry in a flow chamber. Keserue *et al.* (2013) state that a large proportion of the *Legionella* cannot be detected with the classical cultivation method, and might lead to inaccurate results. The advantages of the immunomagnetic separa-

tion are described in Füchslin *et al.* (2010) as a shortened examination period (1h), as well as the differentiation into living and dead cells.

2.6 Questionnaire to duty holders

A total of 10 questionnaires were filled and returned by operating managers with a 100% response rate. The questionnaire consisted of a larger set of questions (items) of which we present a selection.

2.7 Data analysis

Microbiology

Results are presented with descriptive statistical analysis, where characters A – J indicate the ten different institutions. Within each institution, 6 water samples were collected. Water samples indicated with odd numbers mean 'direct sampling without water forerun', even numbers 'with water forerun'. This is relevant for the interpretation of the results (Figure 1). Thus, a sampling location is characterised by two samples of water.

Classical culture method

Water sample analysis was carried out by the Official Food Control Authority of the Canton of Zurich. The detection limit of a sample is 1000 CFU/l. The samples were tested for *Legionella* spp. (species), which comprises all species of the generic group *Legionella*.

Immunomagnetic separation with FCM-detection (FCM-IS)

Water sample analysis by means of FCM-IS method was carried out by an independent laboratory. The FCM-IS method provides the total number of *L. pneumophila* Sg1 detected in the water samples. One of two analyses includes viable but not culturable cells (total *L. pneumophila* Sg1). The second analysis contains only the number of *L. pneumophila* Sg1 (viable cells). The detection limit of the FCM-IS up to the level "single cell" of a sample.

Questionnaire

A semi-structured questionnaire was used, containing scaled and open questions. The questions were answered by the operating manager or the person who fulfils the jobs of an operating manager. For reasons of clarity, the results were grouped into five main groups: 'general questions', 'system properties', 'hygiene / maintenance', 'monitoring / recording', and 'showers'. The results are tabulated for these groups (Tables 1-5). The ten residential homes are each designated a letter (columns A-J).

2.8 Objectivity, validity, reliability

In this study, the three scientific quality criteria 'objectivity', 'validity', 'reliability' are taken into account. Objectivity is ensured by an objective, non-interpretive but descriptive evaluation of the data. The microbiological analysis methods are scientifically common methods, which are carried out by specialist departments, ensuring the reliability of the findings. The reliability of the questionnaire is ensured by the fact that a verified questionnaire of the Water Management Society has been used as a basis in practice. All presented survey instruments are used in practice in the examination of *Legionella*. Therefore, the validity can be considered fulfilled.

3 RESULTS

The results of microbiological detection and temperature of water samples are illustrated in figure 1. Threshold values are taken from the FOPH recommendations.

3.1 Microbiological detection of *Legionella*

Classical culture method

Of 60 analysed water samples, 52 are below the detection limit. In all water samples of homes B, C, G, H and J, less than 1000 CFU/l were determined by the classical method. The largest value is from home A. The second sample of the same shower shows 2000 CFU/l. The water sample from the third shower in this home (sample A5) also shows an increased value with 5000 CFU/l. In home I, a high *Legionella* spp. concentration was also detected at the last two sampling sites, I5 and I6. The result of the analysis of water without water forerun is 50,000 CFU/l, and those of water with water forerun 40,000 CFU/l. Further values, which are above the limit value, were observed for water samples D1, 4000 CFU/l, E4 and F1, 2000 CFU/l each.

Immunomagnetic separation with FCM-detection (FCM-IS)

The results of 47 water samples were below the threshold level of 1000 CFU/l. In 13 water samples, total *L. pneumophila* Sg1 detected succeeded the threshold level. More than 10,000 CFU/l had been detected in samples C1, C4, C6, D5, E1, E6. In seven water samples total viable *L. pneumophila* Sg1 detected succeeded the threshold level of 1000 CFU/l.

3.2 Temperature of water samples

No values were recorded for A1, A3 and A5.

Figure 3 Microbiological results. Samples indicated succeeding the threshold level of 1000 CFU/l (red boxes for rows 'culture method' and 'FCM-IS method'). The threshold level is relevant for *Legionella* spp. FCM-IS method yielded results for *L. pneumophila* Sg1. Therefore the interpretation must be considered carefully. Temperature of water samples smaller than 55°C indicated by red box (row 'Temperature').

3.3 Questionnaire

General questions

Table 2 Results questionnaire: Items of category 'general questions' (FOPH=FOPH recommendations; QMS=Quality Management System; PHI=experienced plumbing and heating installer; n=no; y=yes; n/a=not available; a.=annually; m.=monthly; w.=weekly; * = Building A+O: 2008, Building B+C: 2009; ** = Main building: 1997, new building: 2013)

Question	Object									
	A	B	C	D	E	F	G	H	I	J
Guidance for keeping the water system hygienic quality?	FOPH	QMS	n/a	FOPH	n/a	n/a	n/a	n/a	n/a	PHI
Controls and frequencies conducted on the water system?	*[This question was answered with a very wide variation of control measures and frequencies. It requires a separate, in-depth discussion from an operative perspective.]*									
Installation date of the drinking water system in the building?	1974	2013	n/a	2010	2004	1993	1993	2011	*	**
Parts of the water system that have been replaced or reconstructed?	y	y	n/a	n/a	y	y	y	n	y	n/a
Problems of water quality in past?	y	n	y	n	y	n/a	n	n	n	n/a
Dead lines in water system?	y	n	n/a	n	y	n/a	n/a	n	n/a	n

System properties

System characteristics are the technical characteristics and their condition characteristics in connection with the water systems of the objects.

Table 3 Results questionnaire: Items of category 'system properties' (*=groundwater 61%, surfaces waters, spring water 21%, others: lake water 11%; ci=cast iron; c=copper; p=plastic; ss=stainless steel; gs=galvanized steel n=no; y=yes; n/a=not available; y**=yes, for selected lines; r=recirculating; nr=non-recirculating; ***=combined system of recirculating, non-recirculating and point of use; mp=mains pressure)

Question	Object									
	A	B	C	D	E	F	G	H	I	J
Sources of the water?	mains	mains	mains	mains	*	n/a	mains	mains	mains	mains
Materials of construction?	ci	ss	n/a	ci	gs, ss	ss	ci, c, p	n/a	gs, ss, p	ss, p
Does the mains supply serve a water softener?	y	y	y	y	y	y	n	y	y	y**
Is water softener system maintained periodically?	y	y	y	y	y	y	n	y	y	y
Calorifier / hot water storage outlet temperature?	92°C	60-65°C	n/a	n/a	45°C	70-80°C	72°C	n/a	65°C	54°C
Return temperature?	62°C	58-60°C	n/a	n/a	42°C	40-50°C	70°C	n/a	20-45°C	48°C
Type of system?	r	r	n/a	r	r	r	r	nr	***	mp

Hygiene / maintenance

In this category, answers are presented which refer to procedures supporting the maintenance of hygienic level of the DHW distribution system.

Table 4 Results questionnaire: Items of category 'hygiene / maintenance' (n=no; y=yes; n/a=not available)

Question	Object									
	A	B	C	D	E	F	G	H	I	J
System regularly cleaned and disinfected?	n	n	n/a	y	n/a	n/a	n	y	n/a	n
Is there a weekly flushing regime in place?	n	n	n/a	n	n/a	n	n/a	n	n	n

Monitoring / Recording

The 'monitoring / recording' cluster contains questions relating to internal routine monitoring and recording of the drinking water system. Answers can provide information about the organisation or quality standards of the institutions.

Table 5 Results questionnaire: Items of category 'monitoring / recording' (n=no; y=yes; n/a=not available; *=partly)

Question	Object									
	A	B	C	D	E	F	G	H	I	J
Is there a site logbook?	n	y	n	y	y	y	n	n	y	n
Evidence of regular audits/reviews by management?	n	y	n	n/a	n	n	y	n	n/a	n
Are incoming temperatures checked regularly?	n	n	y	y	n	n/a	n/a	n	n	n
Are calorifier / hot water storage outlet and return temperatures checked & recorded monthly?	y	y	n/a	n/a	y	*	y	n/a	y	n
Are supply water temperatures of furthest/nearest tap from incoming supply checked & recorded monthly?	n	n	n/a	n	n	n	n	n	y	n
A representative number of taps checked annually?	y	n	n/a	n	n	y	n	n	y	n

Showers

Table 6 Results questionnaire: Items of category 'showers' (n=no; y=yes; n/a=not available; *=partly)

Question	Object									
	A	B	C	D	E	F	G	H	I	J
Number of shower outlets?	38	n/a	n/a	n/a	32	>60	15	n/a	~50	4
Is scale evident on shower head?	y	n	n/a	*	n	n	y	y	y	y
How often is shower used?	n/a	n/a	n/a	daily	daily	daily	daily	daily	n/a	daily
If the shower is used less than weekly, is there a flushing regime in place?	n	n	n/a	y	n/a	y	n/a	n/a	y	n/a
Shower head fitted to a flexible hose?	y	n	n/a	y	y	y	y	y	y	y

3.4 Limitations

A number of limitations have been identified for this study. This work focuses on the presence of *Legionella* spp. in drinking water systems, which includes shower installations. The questionnaire used required a relatively large amount of expertise. Not all questions were completed by the participants. The classical cultivation method was used as a reference in the evaluations since it is currently the legal reference method. The small sample of ten homes does not allow any generalizable conclusions on the totality of all homes in Switzerland.

4 DISCUSSION

4.1 Microbiological detection methods

Within this field campaign, the results of the classical cultivation method were used as a reference. On the basis of the available results, it can be said that the *Legionella* concentrations are significantly above the limit value for at least two care homes.

4.2 Questionnaire

From 26 preselected items, the most striking are discussed briefly. Implications to operations and thus, risk management procedures and demands for duty holders are pointed out.

General questions

Two of the ten residential homes are concerned with drinking water hygiene, referring to relevant documents (FOPH recommendations). Three homes indicated past problems with water quality. Two respondents affirmed the presence of dead lines. However, in one home, supplementary information provided that these lines were disconnected from the pipe work. This would defuse the problem from a hygienic point of view.

System properties

Nine of the ten care homes operate a water softening system which is serviced regularly. A water softening system bears the advantage that the pipes and fittings do not calcify so quickly. However, as an additional technical device, this system must also be serviced regularly and faultless function must be ensured. The flow and return temperatures of the hot water storage vary greatly between the homes. A circulating DHW distribution system is installed in seven care centres. In non-circulating installations, such exist in homes H and I, the water stagnates. It can cool down and thus fall into the critical temperature range where *Legionella* grow.

Hygiene / maintenance

None of the ten homes are running a weekly flushing regime applied on the DHW system. In the case of consumption points, which are not used or are irregularly used, a weekly flushing may be recommended to prevent stagnation. Other technical solutions may be conceivable.

Monitoring / recording

Half of the residential care homes indicated the existence of a building logbook. Plant components of the drinking water supply network should also be considered. Inspections indicate the existence of an internal quality control, even if this does not allow any statement on its contemporary quality. Regular audits are carried out by the management at two homes. For the other institutions this suggests that the quality of drinking water is subject to the operating managers, and that higher management is not concerned with this issue, although it serves with responsibility for it. In half of the institutions the flow and return temperatures in the DHW distribution system are measured monthly. Only one home checks the hot water temperature at the point of consumption. Three institutions carry out annual checks of water taps (points of consumption).

Showers

50% answered the question of regular flushing of showers used less than once a week. Regular flushing is considered an important preventive measure when the shower is not used or not used regularly.

4.3 Linking results from microbiological analysis and questionnaires

After assessing the results of the classical cultivation method, a high *Legionella* infestation was found for two institutions. The institutions C, D and E also showed high numbers according to the FCM-IS method. This should be given further attention, due to building-specific indices (e.g. water temperatures in the system). The FCM-IS method is an interesting, specific, rapid detection method (analysis result after 1 h) which can differentiate between living and inactive cells. It may be useful for decision-makers who have to act quickly and cannot wait up to 10-14 days for results (as required by the cultivation method).

The control function and documentation in homes might require optimisation. The orientation towards recommendations for drinking water hygiene, such as those of the FOPH recommendations, would contribute to a greater awareness of the operating managers.

Although the FOPH recommendations provide valuable information, it does not appear to be a suitable medium for operating managers. Two of the ten institutions refer to this recommendation. It suggests that not enough is known about the recommendation. Preference is probably given to a different way of available information, holding the most important principles for safeguarding drinking water hygiene and procedures in cases of contamination.

5 CONCLUSION

To counteract potential threats caused by *Legionella* contamination, organisations should consider a mandatory scope statement as part of their risk management. However, the legal framework or potential threats are not always sufficiently identified. Duty holders may fail to determine appropriate strategies to counteract *Legionella* (Gollnisch *et al.*, 2003). Considering parameters specific to the organisation must be an inclusive part of the risk assessment. An infected water system is something which is lacking in a building and reduces the value of

a facility. Foremost the hazard to people and the liability of duty holders may be two even stronger arguments. Professionals with operator duties must bear this in mind.

Apart from the challenges of historically grown building structures and changing infrastructure, hygiene-related issues are perceived and discussed from different perspectives. According to the de-facto existing requirement of an organisation, the scope of action aligns itself in the competitive tension of those who are responsible. Not only classic microbiological topics play a role in the prevention process, but also activities serving the building which are specific to the building and which are people-related. The subject of functioning (water-) hygiene is often dependent on and influenced by a variety of protagonists (Gamage *et al.*, 2016; Spagnolo *et al.*, 2013).

FM can synergistically support where there is a perceived and recognized need by decision-makers. Building age, materials, proper handling, compliance and consistency along defined process chains with conjunct objectives and their implementation are just as authoritative as an appropriate, forward-looking (re)view and adjustment of protective goals. These need to be incorporated strategically. Demands must be 'translated' into process logic according to existing requirements A common and mutual understanding at the operational and strategic levels between different disciplines is essential to achieve mandatory objectives.

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Swiss-COBie: Development of a Design for Information Exchange Between Planners, Contractors and FM in Switzerland

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ABSTRACT

Purpose: To develop a prototype Swiss Construction Operations Building Information Exchange (COBie) suitable for information exchange between planners, construction and facility managers (FMs) in Switzerland. To support this aim three questions were investigated: 1) what information relating to assets/buildings do users need most? 2) when does, information need to be exchanged during the planning and construction process? and 3) how can facility management (FM) benefit from a Swiss-COBie?

Design/methodology/approach: Triangulation including; review of literature, Building Information Modelling (BIM) standards and industry best-practice in Switzerland, an analysis of data from three different company's Computer Aided Facility Management (CAFM) systems to establish the most common/important data and semi-structured interviews with the responsible FMs.

Findings: BIM for constructing new buildings is developing fast in Switzerland. However, there is a lack of established Swiss BIM standards and FMs have little or no BIM experience. Analysis of CAFM data highlighted essential COBie schema data fields and how existing COBie schema could be adapted to Swiss construction standards. FMs will benefit from improved handover of asset information from construction to operation helping to prevent long-term issues during the operational phase.

Practical implications: A Swiss-COBie will help FMs transfer relevant BIM data localised to the Swiss market for transfer into their CAFM systems.

Originality/value: This paper represents a first step in establishing a system for digital information exchange in Switzerland that could be trialled in practice.

Keywords
Facility Management (FM), Building Information Modelling (BIM), Computer Aided Facility Management (CAFM), Construction Operations Building Information Exchange (COBie), Switzerland

1   INTRODUCTION

The increasing trend towards digital planning and construction in Switzerland offers FMs new opportunities to improve the quality of building documentation at handover from construction to operation. Traditionally FMs receive information at the point of handover from construction to operation related to buildings, like room lists or technical facilities. This is a mix of digital and hard format but customers have still demanded hard copies. With the introduction of BIM, the trend is towards digitising all information with the aim of making the transfer to other systems such as CAFM more effective and efficient.

Today CAFM and BIM software tools are largely considered as separate systems with different functions. BIM software tools are used during the planning and construction phase of creating assets. while CAFM work-process management tools are used in the operation phase to manage the assets. In the near future, such systems will probably become much more integrated to allow a seamless transfer of data between construction and operation but for now a mechanism such as COBie is required to transfer data between the two. The BIM process enables the capture of a wealth of information, however, there are often difficulties to transfer the relevant information from BIM into a CAFM system. One possible reason is the different data formats of BIM and CAFM. For example, some software such as the BIM Revit software from Autodesk uses Industry Foundation Classes (IFC) or Portable Document Format (PDF) as an open data format, while CAFM systems mostly support excel spreadsheets (XLS) and 2D drawings. Although this is starting to change as CAFM suppliers see the potential benefits of systems which support IFC and PDF. Another key issue is that clients and FMs working in BIM projects need to consider if their CAFM tools can presently accept data from a schema such as COBie or if they are limited in this respect and can only partly take over BIM models and data from the planning and construction phase.

If there is lack of communication between planners, contractors, FMs and users without adequate planning with respect to the data transfer many of the advantages of BIM and COBie may not be realised. In Switzerland, today's many systems cannot transfer information easily to one another without a significant manual effort which can be costly and time consuming. There are currently no standardized procedures in Switzerland to regulate the information transfer between the planning, construction and operation phases of an asset. The aim of this paper was to create a first design of a standardized information exchange between planners, contractors and FMs/users in Switzerland. The design is based on existing COBie systems and the authors refer to it as "Swiss-COBie". A COBie is basically a digital tool (often an excel spreadsheet) which can be used to exchange data from one software to another.

2   LITERATURE REVIEW

BIM is increasingly used in Switzerland with respect to the construction of new buildings. Six years ago, only contractors of large buildings used BIM as their planning and construction tool. However, nowadays even small flats are being built with BIM (Hart, 2016). BIM is a method used during the planning and construction phase that works with a 3D model of the planned building. According to Abdullah, et al. (2013, p. 2), BIM can "enhance the cooperation between the various disciplines of work", such as architects, facilities managers, engineers, etc. while providing a working "platform" for everyone. They came to the conclusion that BIM can support FMs "successful and outstanding" creating a synergy between the planning and construction phase as well as the operational phase. However, the so called success-

ful support from the BIM process will only work properly, if FMs get the information needed for operating a building as early as possible.

Kassem et al. (2015) argue FM should be involved in the planning process from an early stage, or better, from the beginning, otherwise, FMs will not benefit from BIM for the operational phase. In addition, the information exchange between BIM and FM can be "incomplete and inaccurate" (Kassem. 2015, p. 5). Liu, et al. (2013) note that a BIM model "should hold information for different stakeholders at different phases of the facility's life cycle" (p.7) whilst Parsanezhad, et al. (2014) note that "insufficient interoperability issues among information systems in the building industry" result in a "considerable financial loss" (p.2). For BIM to be successful it needs to work with already established systems, like CAFM currently used by the FM industry.

Often there are issues between BIM and CAFM due to difficulties in exchanging data due to different data formats. It is possible to transfer the data from one system to the other but it comes with additional manual workload. To solve the information exchange problem, Patacas et al. (2014) suggest using COBie as an exchange tool. COBie was first developed by the US Army Corps of Engineers to help structure data of facilities and assets. It is compatible with several approved data standards, e.g. IFC and XLS. According to East (2016) before COBie FMs had to type in and review the data given by the contractors manually. This step could take months to complete. By using COBie the data can be filled up at every stage of the project, making sure that information is regularly updated and data transfer errors are addressed as they occur. Because COBie can use several data formats, CAFM systems need to be able to recognise and map data for transfer into the CAFM system.

The British Standards Institution (BSi) launched a Code of Practice BS 1192-4 (BSi, 2014) in which the use and structure of a COBie spreadsheet is described. The Swiss Society of Engineers and Architects (SIA) is aware of the increasing use of BIM and has held several national congresses for informational purposes to investigate BIM in Switzerland (SIA, 2013). In addition, they have initiated the production of the Swiss BIM guideline SIA 2051 "Building Information Modelling (BIM) – Grundlagen zur Anwendung der BIM-Methode" (basics for appliance of BIM method) as they recognise the need for BIM standardisation in Switzerland. However, there is a gap in knowledge with respect to the possible use of COBie. This research gap should be investigated to establish if a Swiss-COBie could help planners, construction, FMs and users in Switzerland.

3   METHODOLOGY

The methodology included; 1) a review of literature/industry best-practice in Switzerland with respect to BIM, 2) an analysis of data from three different company's CAFM systems to establish the most common/important data and 3) semi-structured interviews with the facility managers responsible for these CAFM systems.

Five organisations were invited to take part and 3 accepted. Two of the organisations declined the offer as they did not want to share their data due to confidentiality reasons. The CAFM data analysis was carried out in partnership with the IC Information AG Company[1] in Switzerland who are CAFM systems specialists. Data sets were analysed from three different types of organisation; 1) a hospital set in the north-west part of Switzerland with over 400

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[1] The IC Information Company website is https://www.ic-information.com/en

beds and 2000 employees, 2) a FM service provider with focus on energy solutions set in the west part of Switzerland featuring 20 locations and over 1400 employees and 3) a FM provider with focus on cleaning set in central Switzerland with 6'000 employees. An analysis was undertaken to try and understand which types of information were accessed and used most regularly by the organisations. (This helped to identify the degree of use of certain types of information). However, use is not necessarily a clear indicator of importance and so semi-structured interviews were held with the responsible facility managers to try and establish which data also was seen as useful and important.

To help understand how a Swiss-COBie might work in Switzerland three research questions were investigated: 1) what information relating to assets/buildings do the users need most in operation? 2) when does, the information need to be exchanged during the planning and construction process? and 3) how can FM benefit from a Swiss-COBie?

4   RESULTS

The following results address the first research question: "what information relating to assets/buildings do the users need most in operation."

All data sets provided by the companies were last updated in May 2016. Because the newest system was implemented in 2011 and to get data from complete years, the research timeline was set between 2011 and 2015. In total, 767'698 data entry records were analysed. The data was categorised into two sections: 1) classes and 2) attributes. For the purposes of this paper, classes refer to categories of equipment, e.g. HVAC facilities, sanitary facilities, etc. Attributes are descriptions related to a specific facility in a category. So, for example building facilities, such as elevators or doors are categorised into different classes. The class structure is based on the Swiss construction costs standard BKP 2001.

The top 10 classes used by all companies are shown ranked in terms of usage in figure 1. The HVAC facilities, with 21.3%, were the most used class followed by the electric supply (e.g. high voltage facilities, power supply) with 20.4%. IT facilities and devices were ranked 3[rd] with 17.9% and sanitary facilities 4[th] with 8.8% to. The top four ranked classes combined equate to 68.4% of the total data. The following classes had less than 5%; electrical medical devices, transport facilities, shell 2 (windows, doors, outer façade), monitors for patients, medical devices and devices for extended care.
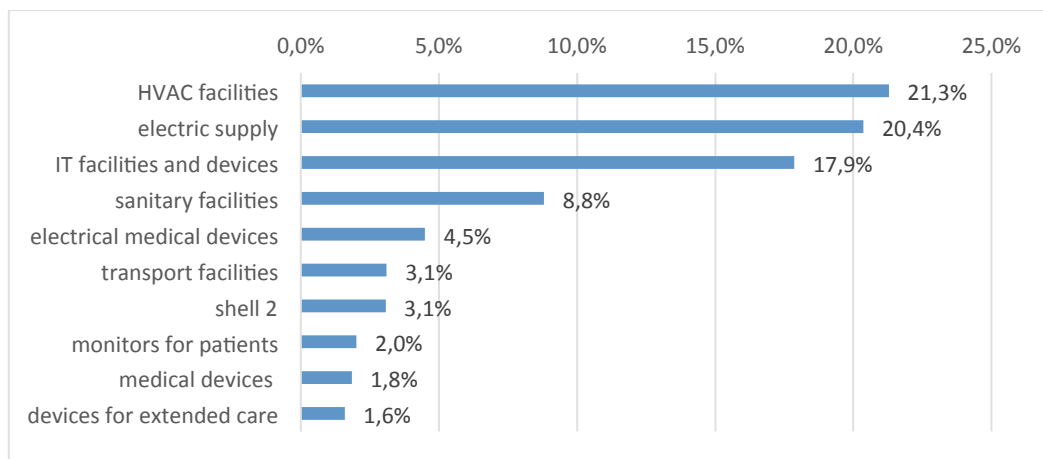

Figure 4 The top ten categories for class in terms of percentage

The top 10 most used attributes are shown in figure 2 combined are equal to 33% of the total data. Compared to the classes, the differences are significantly smaller. The most used attribute was "project contract" followed by "service level". Both were used more than 30'000 times during the 5-year period. Third goes to "facility usage status". All three were used only by the FM service providers. The forth most used attribute "description" was the first one used by all 3 investigated companies as well the remaining six "serial number", "client facility number", "supplier", "location", "BKP sub-group" and "status".
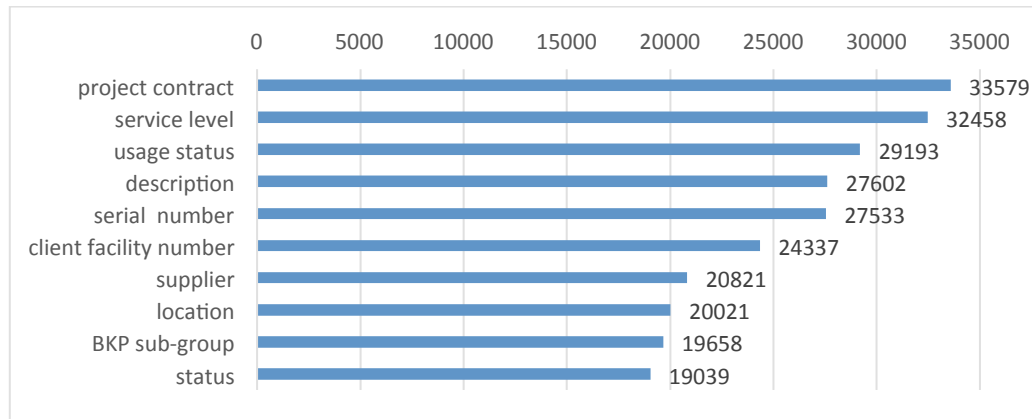

Figure 5 The top ten most used attributes

The following paragraphs summarize the key findings from the interviews to help try and answer the research questions 2) when does, the information need to be exchanged during the planning and construction process? and 3) how can FM benefit from a Swiss-COBie?

The interviewees were all aware of and commented on the general lack of standardisation with respect to BIM in Switzerland. They noted also the lack of a standardised information exchange process which could be used in Switzerland such as COBie. They were in agreement that such a system would be very useful not only for FMs but also during the whole planning and construction process. However, they were of the view that market demand will finally decide, if digital construction and thus the use of tools such as COBie will become the norm as they felt many people would resist change.

They all agreed it is the responsibility of FMs to better inform themselves about BIM and to try and make the contractors aware of the importance of good quality information exchange and how this might have a significant affect during the operational phase of assets. However, during the interviews and research as it was very difficult to establish a clear answer to question 2 as there are not currently few well documented BIM case studies in Switzerland and none of the interviewees had any direct experience of BIM. At present the authors felt unable to answer the question in detail based on the interviews other than to note a given answer was that information was normally exchanged in line with the current requirements as laid out in the Swiss standard SIA 112 *Nachhaltiges Bauen – Hochbau* which addresses sustainable building and the stages for the planning, construction and handover of assets.

Both of the FM providers had a high level of request for information related especially to their technical assets, while the hospital prioritises the medical equipment and the non-medical processes. All of the interviewees agreed that if digital planning and construction is used increasingly to construct new assets then the associated data management will become one of the most important issues. They indicated that they believe most companies in Switzerland are not cur-

rently adequately prepared for the increased digitisation of asset data. Although they could provide feedback of what data was needed (which was broadly in line with CAFM analysis) they were not able to provide detail on when data should be exchanged other than shortly before the point of handover. Although an exact answer to the "what information, and when" was difficult to answer they made reference to the Swiss standard SIA 113 *FM-gerechte Bauplanung und Realisierung* which addresses FM-compliant construction planning and realisation.

With respect to question 3 all the interviewees felt FM stood to gain from the introduction of a Swiss-COBie aligned with the Swiss construction standards. However, they could not quantify or qualify specifically in what way. An interesting finding was that although the responsible FMs work with their CAFM system every day, they knew little about the CAFM's structure, functionality and how the data is organised. When asked about the possible structure of a Swiss-COBie, they were in agreement that it should be based on the new Swiss construction costs standard e-BKP-H which takes the structure of the old (BKP2001) but goes into more detail. However, legacy issues exist and many companies still work with the old BKP system.

They noted a key general issue with the introduction of BIM in Switzerland is the current total lack of specific Swiss BIM standards. This leaves most people unsure of what to expect from a BIM project and they are not sure how to engage with a project that intends to use the BIM process. They believed the new SIA 20151 standard will be a big step in the right direction and indicated that a specific Swiss-COBie might be a valuable addition and help improve transfer information into their CAFM systems, especially within large assets.

5   DISCUSSION OF RESULTS

It was not a surprise that HVAC was seen as the most important of the classes as most commercial buildings are equipped with HVAC, water supply and electric supplies as part of their mechanical and electrical (M&E) systems and these systems make up a significant element of the capital and operational cost of assets. Therefore, it was expected that these classes would be often used by FMs in practice. The class IT facilities was also used often by FM when compared to other classes. The authors believe this reflects the increasing importance of IT in the workplace over the last couple years. As mentioned in the methodology section, the results do not necessarily tell us, why this information was used most. Therefore, the responsible FMs were asked during the interviews to provide some answers that might help explain the findings in more detail. Surprisingly, the interviewees could not give answers to most of the author's questions in this respect. Many general aspects, like COBie or attribute description remained unknown by the responsible FMs. The BIM process requires COBie to transfer data from BIM to CAFM, however, although FMs may have heard of the term COBie they were not aware of how this would work in practice which caused some difficulty in answering questions during the interviews. They understood the need but the knowledge of how COBie could be implemented was unclear, as it has barely been used in Switzerland according to their knowledge.

Based on the findings from the data analysis and interviews, the authors concluded that a proposed Swiss-COBie needs to be based on the local standards common to Swiss market, e.g. eBKP-H. A proposed system might be influenced by guidance from other international COBie standards such as BS 1192-4:2014 (BSi, 2014). However, the BSi is almost over-detailed to be implemented directly in Switzerland. A key issue is how the costs are structured in Swiss construction projects. These are not directly compatible with those stated in the BS 1192-4 as the sheet system gives the user a good orientation but there are a lot of separate sheets. The eBKP-

H gives a better overview without neglecting the details and is an accepted standard in Switzerland. The challenge for the authors was therefore, to find a "good mix". Even a brief look at the design of the spreadsheet can be daunting to those not used to COBie. It can also become more complex if the complexity of a building demands it. To conclude, the Swiss-COBie should be viewed as a standard but also give contractors and FMs the freedom to adjust it according to their needs. One project/building is not the same as another and the same goes for the attributes because operators may have very different needs, buildings and different attributes for their specific CAFM systems. This explains why the medical classes are in the top 10 even though only one company uses them. Therefore, it should be up to the planners and facilities managers to decide which attributes they consider important. But the whole information exchange process using the Swiss-COBie will only work if the facilities managers are active in the planning and construction process. Due to the size of the Swiss-COBie the authors cannot implement it into the paper. Below is a schematic view of its structure:
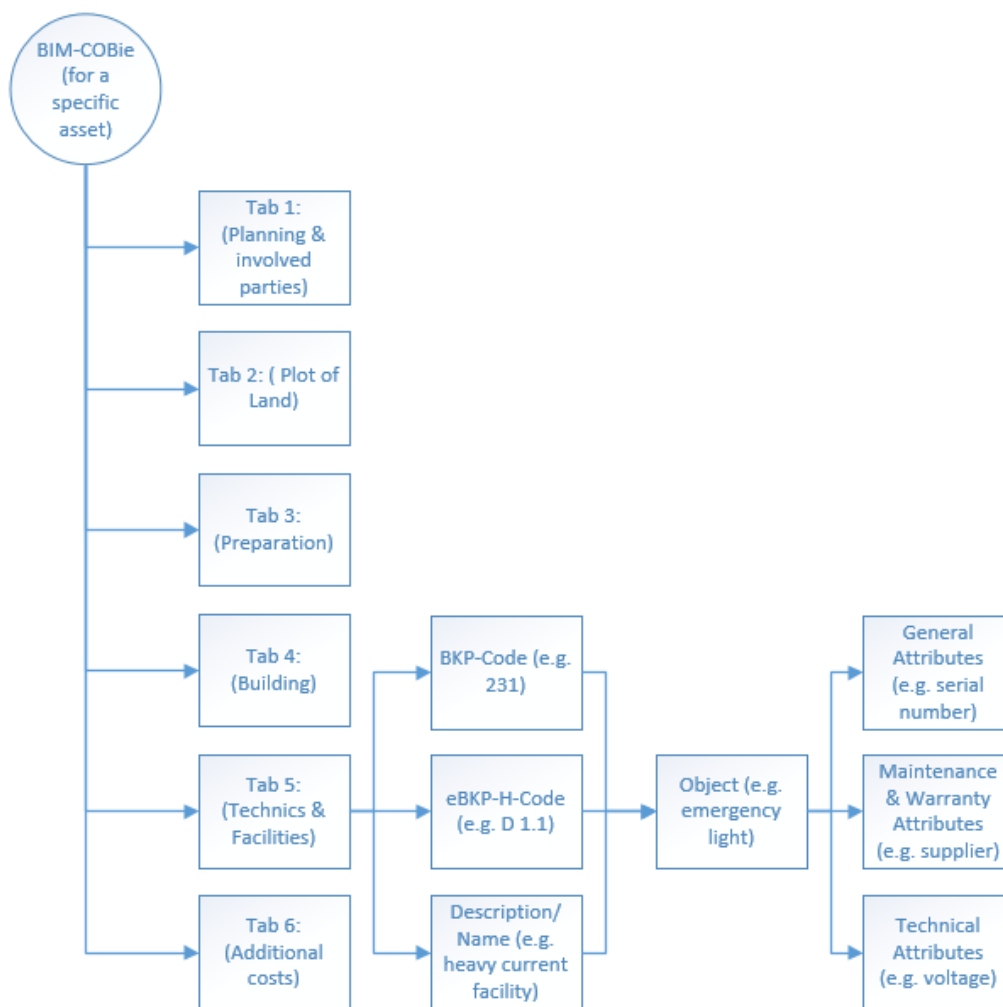

Figure 6 Structure of the Swiss-COBie

6   CONCLUSION

According to the interviewees, the local Swiss FM industry should be more engaged or as one of the them said, "pushier" towards the planners to drive them to produce information that meets the end needs of clients and FMs.

Today a lot of information related to assets during construction is maintained in spreadsheets. The information contains the same sort of attributes as that in a COBie although the intention of the manufacturers is not to exchange information but to keep control of the information correctness and costs. However, these could be easily implemented into a COBie by simply copying the data or by combining all the spreadsheets into one COBie. Based on the interviews, there are currently no standards for spreadsheets but a COBie can replace them and let manufacturers work better together based on the same standard. However, this will only be possible if the Swiss-COBie gets accepted by the leading Swiss construction institutions.

Even though the analysis and interviews could not answer directly the research question *when does the information need to be exchanged during the planning and construction process?* literature review showed that the exchange should happen regularly and not at a single point. If this is the case, FM will undoubtedly benefit from a Swiss-COBie by getting the data they really need and having a smooth transition from the planning and construction process to the operational phase. For that, FMs need to make sure that they get the most useful information by the users, according to the results as early and accurately as possible. The conclusion answers the question *How can FM benefit from a Swiss-COBie?* The results of the analysis show the most used information and the interviewees confirmed its importance. Both answer the first research question *what information relating to assets/buildings do the users need most?*

7   FURTHER ANALYSIS

The research could be extended to include more companies' data for analysis which would give a better picture of the current information FMs need most. In addition, a collaboration between recognised Swiss institutions should be conducted to look deeper into the Swiss construction market and clarify the need for a Swiss-COBie and what it might take to implement it as a standard.

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Co-creation of Campus by Using Virtual Reality

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ABSTRACT

Purpose: The purpose of this paper is to demonstrate how advanced visualisation technologies and Unity3D game engine can serve as an inspiring and easily accessible tool for campus co-creation processes.

Theory: University campuses are complex entities consisting of simultaneous processes of design, construction and maintenance. Large volumes of information and essential maintenance is stored to Building Information Models (BIM) and it can be traced, updated and reported in schedules in order to support the performance of Facilities Management (FM). So far the accessibility of the heavy BIM-systems has been a threshold for agile user-centric co-creation by using virtual reality.

Design/methodology/approach: The research is based on case study and includes two campus co-creation demonstrations where the creative use of game engine in campus development was tested. The experiences of users are investigated in order to understand how the users found the co-creation experiences.

Findings: The demonstrations provide examples how the elements of virtual reality can be an essential part of digitalisation strategy of campus and its Facilities Management and how the end-user can contribute to campus development. The experiments indicate that such tools provide potential for co-creation and user-centric approach in campus development, which is supporting also the performance of Facilities Management (FM).

Originality/Value: The originality of the research is in increasing the accessibility of Building Information Modelling by using advanced technologies.

Keywords: Building Information Modelling (BIM), Computer game engine, Co-creation, Demonstrations, Campus development

1   INTRODUCTION

University campuses are complex entities consisting of simultaneous processes of design, construction and maintenance. According to den Heijer (2008) managing the university cam-

pus has gradually changed from monitoring the technical condition of campus buildings and reducing costs to effectively supporting education and research processes and adding value to university goals. In this cumulative development process functional and organisational aspects have been added to technical and financial aspects. In practice, FM is not only about managing facilities, but the essence of it is merely about managing the processes of human actors' engagement with these facilities (Cairns 2012). Rytkönen (2015) discusses about the spatial transformation of expands the roles of the campus managers e.g. in engaging users to campus development. Co-creation is the process during which consumers take an active role and co-create value together with the company (Prahalad and Ramaswamy 2004). Information and communication technologies (ICT) provide the opportunity for consumers to engage in an organization's innovation process (Di Gangi et al 2009).

This paper discusses the use of virtual reality (VR) in co-creation as one opportunity for facilities management to engage users in campus development. The purpose of this paper is to demonstrate how advanced visualisation technologies and Unity3D game engine can serve as an inspiring and easily accessible tool for campus co-creation processes. The aim is achieved by finding a response to a research question: What is the potential to use Virtual Reality (VR) in facilities management? The subquestion is: How the end-user can contribute to campus development by using virtual reality and advanced visualisation technologies.

The paper begins with overview of the latest studies about computer aided facilities management (CAFM), BIM in facilities management, user experience and co-creation. It then presents the study desing, method and case study. The results are described in the chapter 4 and the conslusions are drawn.

2 FACILITIES MANAGEMENT, VIRTUAL REALITY AND CO-CREATION

2.1 Facilities Management and digital information

As the world is becoming increasingly digitalized, the amount of information that exsists is growing exponentially. In 2012, the amount of information online exceeded 2.8 Zetabytes. By 2020 it is expected that this number will be 50 times greater (Hagstroem 2015). One big contributor to this is IOT (Internet of Things) as our physical world is becoming increasingly connected to the internet. The data in and of its self is of little value, but when it is analyzed and structured, usefull information can be extracted which allows for areas to be identified that need attention or improvement, to clarify which factors influence users behavior, to help understand where to place products in their environment, and to predict future sales.

Being able to effectively interpret and understand these increasing amounts of data is becoming more challenging by using traditional methods of Computer-aided facility management (CAFM). Basicly CAFM is the support of facility management by information technology. The supply of information about the facilities is the center of attention. According to Madritsch and May (2009) CAFM has provided efficient information technology (IT) tools for mapping, evaluation and control of facilities management (FM) structures and processes since the 1990s. Using diverse softwares is still in the progress in many user organisations.

The effective use of big data is also a question of visualization of the data. Data is currently shown in tables and graphs, but as the complexity and volume of information grows, we will need new methods of visualization. This is where BIM (Building Information Modelling) comes in. Building Information Modeling is the latest software technology with a complete 3D digital representation of a building system or subsystem. This sophisticated technology is

both a visually accurate model of a building and a database for recording the breadth of information developed and associated with building components. Beyond being a drawing and documentation tool, BIM offers a platform for enhanced interdisciplinary collaboration, the capability to manage change, and the ability to extend information support throughout the building lifecycle (Sabol 2008).

Facilities management (FM) encompasses and requires multidisciplinary activities, and thus has extensive information requirements. While some of these needs are addressed by several existing FM information systems, building information modeling (BIM), which is becoming widely adopted by the construction industry, holds undeveloped possibilities for providing and supporting FM practices with its functionalities of visualization, analysis, control, and so on. There is research how BIM can be a beneficial platform for supplementing FM practices (Burcin Becerik-Gerber, 2012). The case studies e.g. in the Atlantic College emphasis sustainability (Gillard et al 2008). Case study about Sydney Opera House provide an apporoach to ingrated collaborative approach (Morris et al. 2006). There is a research about BIM and its implementation in lean architectural practice (Arayici et al 2011), in interaction between diverse stakeholders within construction projects (Azhar et al 2008; Kymell, 2008) as well as in lifecycle management (Jordani, 2008; Jordani, 2010). According to Arayici et al. (2012) facilities managers have to acquire, integrate and update diverse facility management information ranging from building elements, facbric data, operational costs, contract types, room allocation, logistics, maintanence. BIM that seeks to integrade the building lifecycle, can support FM-professional facing challenges resulting in cost and time related productivity, efficiency and effectiveness losses. However one can identify that the research is more building, project and technology based – not so much user based.

2.2 Virtual reality
The facilities managers often produce two-dimensional construction drawings which cannot be easily transformed into genuine, three-dimensional locations inside actual facilities. Even Virtual reality (VR) as a technology is still in its infancy it is possible with the use of Augmented Reality (AR) and Virtual Reality (VR) systems solve such problems. According to Pitt et al (2005) immersive virtual reality (VR) in support of building design tasks as an innovative tool, enabling more effective facilities management input at the building design phase.

Although increasing evidence has shown that VR can improve the communication efficiency in the AEC (Architecture, engineering, construction) applications, most VR studies in the AEC area have so far focused only on improving the single person experience (Shi et al, 2016). VR leads towards new paradigms of thinking and new ways of interacting. It will allow for new experiences that are not possible on existing technologies. What new opportunities will VR allow for facilities management e.g. to solve common problem to preserve hidden and toughly accessible system components like pipes, ducts, conduits, structural supports, inside walls, ceilings, floors and underground structures.

Innovative methods for integrating and visualizing information for large scale Facilities Management Information Systems (FMIS) are discussed by Mozaffar et al (2005). They describe which computational issues are needed for creating and deploying the 3D models used in FMI systems. CAD models, maps and images are integrated to create the D model of a facility, and then the resulting model is integrated with cost and scheduling information and used to collect inspection data using mobile computers equipped with tracking devices and wireless communications. Now the technology have been made available with the release of the first consumer aimed virtual reality headsets: the HTC vive, Occulus rift CV1 and

Playstation. This technology is advancing rapidly and it will become possible to offer interactive experiences on mobile in the future due to advancements in graphics and processing power, as well as position tracking technologies which will allow for users to move freely within a space, an essential requirement to prevent nausea and increase immersion and comfort. According to Shi et al (2016) recent developments in Virtual Reality have encouraged the utilization of interactive building visualization in the design, construction, and maintenance of different types of facilities. They developed a Building Information Modelling (BIM)-based VR environment tool to bring remotely located stakeholders – building occupants, facility managers, vendors and designers – together to walk through in the same virtual building. It enabled real-time interactions of remote stakeholders in the same environment, with a shared immersive walkthrough experience.

2.3 Experiential and communication challenges in Co-creation

User centred design is recognized as a crucial part of designing buildings that best serve its users. According to Kohler et al (2011) the critical challenge for co-creation in virtual worlds is not so much in devising the technological infrastructure, but in creating and maintaining an experience for participants.

There are many innovative ways designers use when communicating with their users but so far are still lacking the tools needed to be able to really show the users what they will be getting, and to be able to communicate designs in a without any misunderstandings or miscommunications. The most basic way of communicating ideas and designs is simply though text and dialog. This will inevitably leave gaps in communication where ideas are interpreted very differently. One step up from that would be to have 2D floor plans. While better than only dialog, these types of drawings can be very difficult to interpret, especially in the case of users who do not have a background in architecture or a related field and are not used to working with 2D floor plans. Even for those who may be familiar with floor plans, it is difficult to create a sense of immersion and to really understand how the space could be used and experienced.

Based on Arayici et al. (2012) case study the spaces become difficult to understand and articulate with regards to its designated use in 2D representation. With ordinary 3D CAD representations, the spaces can be visually appreciated with no specification details and quantities attached. However, during decision making on space use, the designer/FM representative need to convey proposed ideas to the stakeholder or client both visually and technically in order enable them to make a visually and technically informed decision on space use.(Arayici et al. 2012).

3D rendering and videos can be very helpful in giving an understanding of space, although have the drawback that they cannot be updated with live information, and do not offer any freedom or interaction to the users, but rather are limited to predefined angles or paths controlling where the users will look.

This is where virtual reality can be incredibly powerful. It offers an immersive 3D environment to be able to truly understand what the space feels like and how it could be used, as well as the freedom for users to interact with and navigate through the model with significantly more control and freedom. Models can also be updated real-time with information and data from other users, IOT devices, or other outside sources, in addition to being able to interact with and even alter the model themselves.

2.4 Technical challenges

There are at least three technical challenges in using BIM. Firstly, that the BIM models are highly complex, and need powerful, specialized computers to run, particularly for larger buildings. Secondly that BIM models can only be opened in specialized architectural programs such as Archicad, and Revit. These programs are designed to serve only the design and construction phase and do not have any tools available for the day to day running of the buildings. The third major threshold is that working with 3D (three dimensional) models on a 2D (two dimensional) computer screen operated with a mouse and keyboard can be particularly challenging and unintuitive.

Additionally, the quality of information has been identified as a critical factor. Arayici et al. (2012) conducted a case study in MediaCity UK, where the instant walkthroughs generated from the BIM model assist FM in having a virtual tour of the building to visually assess key considerations during relocation. Furthermore, automated quantification and scheduling capability helped in setting cost and time targets such as the development and confirmation of budget. Additionally, models accurate quantification and scheduling attribute provides detailed information on number and types of furniture to be moved and other cost intensive decision making considerations. The BIM benefit in this case study was dependent on the type, quantity and quality of information within the model. Additionally, the authors claim that it is not economically viable to adopt the BIM approach such as for relatively small projects as it requires high information quality and extensive training of its users may be required, which can compromise the time and cost savings from BIM use (Arayici et al. 2012).

All these thresholds can be addressed by converting the BIM models so that they can be used in game engines, with Virtual or Augmented reality (VR or AR). This would provide a user-friendly, agile and visual platform for facilities management to use it in interaction, communication and co-creation among diverse stakeholders.

3   METHOD

3.1   Case study Kampusareena

This study builds propositions on case study data in an attempt to investigate user experience, co-creation and VR. The data was gathered by observation and interviews within two demonstration projects conducted and reviewed. The first project is an interactive demonstration of the Kampusareena, the central building and the heart of Tampere University of Technology (TUT), Finland. The second project is of an office meeting room to be renovated inside UPF, also at TUT campus.

The Kampusareena in Tampere University of Technology (TUT), Finland, was chosen as the focus building for this research project. It was selected because of a number of factors which made it ideal as the focus building. The building is very new, being opened Autumn 2015. It has been designed with the latest research in user centred design by University Properties of Finland (UPF), one of the leading campus developers in Europe. The Kampusareena has also been equipped with many of the latest technologies and sensors. These include temperature, CO_2, light, electricity and motion sensors among others. Being based at the heart of TUT, it sees high numbers of students and other users daily. It also has a combination of three public access floors including restaurants and a library, as well as five private access floors. 3D BIM models were also available for the building which were an invaluable part of the research process.

The HTC vive was chosen as the VR headset for its field leading technology, namely room-scale tracking allowing the users head and hand controllers to be tracked and shown in VR. This allows for increased immersion and control for the users to be able to interact with their environments with their hands.

3.2   Two demonstration projects

The goal of the First demonstration project, which was the focus of this research, was to investigate in practice how the interactions with the 3D models could work in VR (Figure 1).
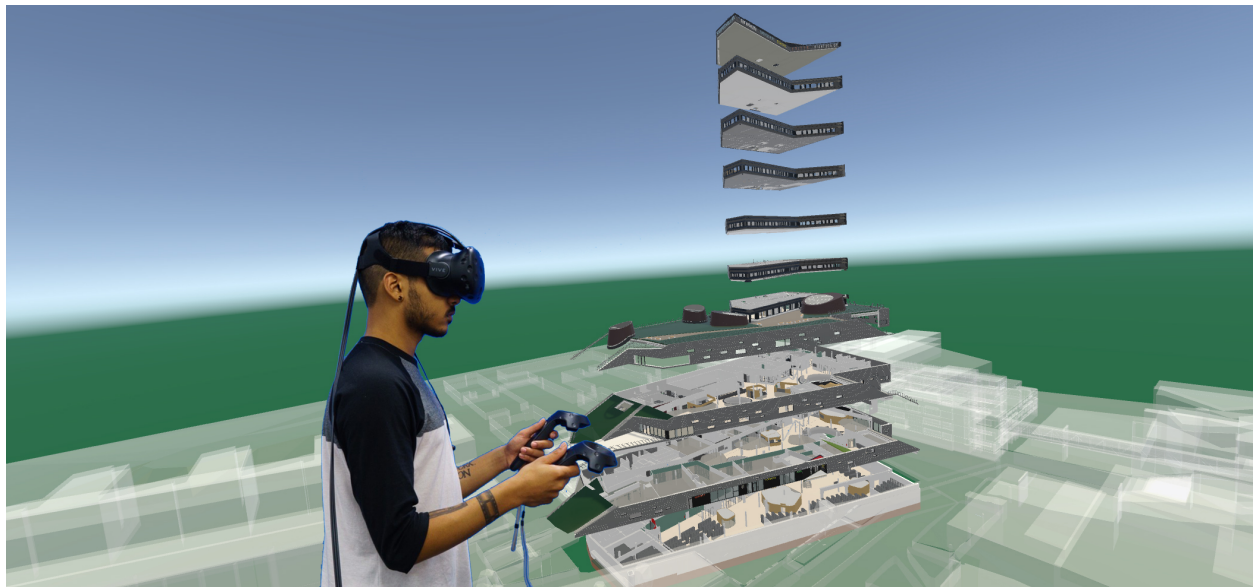
Figure 1 Kampusareena 3D model in VR (demonstration project 1)

The users would include many different fields within FM, ranging from maintenance and monitoring, to renting tenants, to the owners and future developers of campuses, who would benefit from a richer understanding of how the building is run and used. This would be done by having a 3D model of the building with all of the data shown visually on top of the model. The project has had more than 40 participants. They consisted of users both familiar with the Kampusareena building as well as those who have never been there. Most the participants have had no experience with virtual reality and little to no experience with 3D models. Eight of the participants were able to use the project through all of the different phases of the development and give feedback based on which they found to be best. The primary method of feedback was through observation and unstructured interviews both during and following experiencing the project.

The second demonstration project covered in this research was of a co-creation of the renovation of meeting room in UPF, also inside the Kampusareena. The goal of the project was to use virtual reality to allow users to see different possibilities that could be implemented within the room, and then to vote on which they would best suit their needs. The project was used by 12 participants, all employees of UPF, knowing the building and room well as it was part of their working environment. The Figure 2 and 3 illustrates the room before and after the renovation.

Figure 2 Meeting room in VR before renovation (demonstration project 2).

Figure 3 Moving furniture in VR (demonstration project 2).

The demonstrations are summarized to the Table 1.

Table 1 Demonstration projects

	Demonstration project 1	**Demonstration project 2**
Participants	40 participants	12 participants
Goal	User interaction and 3D-models in Virtual reality	Redesign of the meeting room
Scale	Kampusareena Building	One meeting room

3.3 BIM and CAD optimisation techniques

To prepare BIM models for use in game engines, a substantial amount of optimization needs to be done. It should be noted that the level of detail required should be decided before this optimization process so that the 3D models can be tailored for their specific purpose. E.g. will you need details inside the building, or only the exterior walls? should furniture and fittings

be included? These additional factors will influence the time the 3D model take to prepare, as well as the experience the users will have. The 3D model can then be prepared into layers for its intended use. This could be done per room, per floor level, per building or per object type, based in its intended use. Examples of this could include grouping all temperature sensors to a layer, which can then be toggled on or off based on whether that information is needed.

Optimising the complex BIM models for use in game engines can be an intensive and complicated process. This is primarily because of the amount of reduction of complexity larger BIM models such as the Kampusareena require, as well as incompatibility between programs. Firstly, the BIM model was opened in Archicad, where isolated into static and non-static objects, that is parts of the model that can be moved and parts that make up the core structure of the building. Each of these sets of objects was then exported as individual files per floor level. These files were then imported into 3DS max, a 3D modelling program where all the different files were combined, grouped and named. The number or vertices (points in 3D space that make up the 3D models) needed to be significantly reduced, in this case from around 12 million to about 3 million; a 400% reduction. This was done by merging vertices that overlapped of were within a certain distance from each other.

A balance was found so as not to reduce the quality of the model in any sort of visible way while getting the size of the model down to something that could be used in Unity (the Game engine.) Once optimised in 3DS max, the 3D files were then imported to Unity. Colours and textures were added to increase the visual fidelity, aesthetic appeal, and to highlight relevant information. Unity also allowed for the creation of the interactive elements and animations.

4   RESULTS

The results of two projects are reviewed here, firstly an interactive demo of the Kampusareena, the central building and the heart of Tampere University of Technology (TUT), Finland. The second is project is of an office meeting room to be renovated inside UPF, also at TUT.

4.1   User experiences in project one
To allow for users to be able to see information from all areas of the 3D model, a method of navigation was required that would be intuitive and effective, particularly for users who have limited to no experience using 3D models previously. Navigation around the environment proved to be one of the more difficult challenges in VR. This is because the moment control of head movement is taken away from the users, the majority of users will become motion sick within minutes.

Initially teleportation was used to solve this problem, where users could point to new location using the hand controllers, and press a button to instantaneously move to that new location. It was observed that this tended to be quite unintuitive for new users, and they would consistently become disorientated and unable to effectively navigate the model forgetting where they were and getting lost.

The next iteration of navigation was flying, allowing a user to point the controller where they wanted to go, and they would move as they held down a button. This method was successful in that is allowed users to navigate the 8 floors of the Kampusareena very easily while never losing their orientation, however this too triggered motion sickness for the majority of users, particularly as they were not able to anticipate and control the movement accurately.

The third method to be used was a grab and pull method, which has subsequently been named the 'Swimming' movement based on how the users are able to grab a point in space and move their hand in the direction they would like to move. This was agreed by all users to be the most predictable, comfortable and intuitive method of movement. This method did create a challenge when covering large distances as it required a lot of physical movement and was to slow, particularly with the size of the building. One would need to grab and drag the full distance they needed to cover to keep the movement predictable and comfortable. This was then solved by being able to scale down the model, so that with just a few grabs, the user could navigate around the entire model.

While scaling down the model did lower the sense of immersion, it significantly increased the ability to be able to see the entire building at once in a clear and understandable way. With the primary purpose of this model being to serve as a platform for monitoring the location based, real-time information of the building, the value of insights gained with a clearer understanding of the model in its scaled down version, combined with the intuitive 'swimming' method of navigation proved to be highly effective. With the building now scaled down, a new challenge emerged as users were asking how they could see inside the building. This was solved by exploding the different layers up into the sky, allowing users to have an elevated view down inside the building. where they could see into multiple rooms of an entire floor level, or even multiple floors simultaneously. This too proved to be very intuitive and effective in giving an overview of the building for monitoring purposes. The summary of the demonstration 1 is in the Table 2.

Table 2 Navigation of 3D model in VR

	Description of the method used	Description of user experience
Phase 1	Teleportation	Disorientating, Unintuitive.
Phase 2	Flight	Leads to motion sickness, difficult to control accurately
Phase 3	Grab and Pull (swimming method)	Highly intuitive, Fast navigation with scaled down model, Accurate, Comfortable.

Participants reported that they found the building very easy to navigate in virtual reality, and that after having tried the project, that they had a significantly better understand of the building as a whole. Information in the model such as location of users, exit routes, temperatures, maintenance issues, as well as the locations of different facilities and tenants were reported to have communicated information effectively and provide new valuable insights into the usage of the building.

4.2 User experiences in project two

The meeting room in UPF of the second project was not being used very often and the companies' employees gave feedback that the room did not offer the correct furniture too allow them to work efficiently. Renovations were required and furniture would be replaced with something that better suited the employee's needs. The goal of the project was to use virtual reality allow users to see different possibilities that could be implemented within the room, and then to vote on which they would best suit their needs.

The existing rooms was modelled up in VR in 1:1 scale with existing furniture, as well as 3 other options each with different types of furniture in various configurations. Users could

then press a button to cycle through the various options as well as pick up and move the furniture in VR to where it would have best suited their needs.

The project was used by 12 of the employees who could configure the room and then vote on the setup they would use. Before trying VR, they were asked which set up would be best and a rectangular table in a far corner of the room was chosen, however this changed after having tried the VR project. The results of the vote were that 9 of the 12 users (75%) all voted for a configuration with a large oval table being placed along side wall. The main reason for this change was that once they were able to stand in the VR room, and see the rest of the office in context, they realized that they did not want to have their backs facing the glass door, but rather preferred their sides to, so that they would be aware of others passing by, but not continually distracted by outside movements. All of the participants said that they understood the proposed renovations significantly better after having trying the VR project.

5   CONCLUSION

The idea of virtual reality can be fairly intimidating to new users who have not experienced it before, or have had negative experiences on either inadequate hardware or poorly designed experiences that have left them feeling motion sick. This, combined with many other additional influencing factors has resulted in many people being fairly reluctant to try VR out for themselves. As more research is being done into best practices within VR, as well as better hardware is being released annually, the experience will continue to improve and people will become a lot more comfortable with the concept of Virtual and augmented reality. While there are certain factors which have led to people being cautious to try out VR, those which do have had their eyes opened to a new world of possibilities as virtual reality can bring digital environments to life.

Once having overcome the initial learning curve of being in a new environment and learning the controls, it was observed that users could very quickly and effectively navigate around virtual environments. The demonstrations provide examples how the end-user can contribute to campus development by using virtual reality and advanced visualisation technologies. The elements of virtual reality can be an essential part of digitalisation strategy of campus and its Facilities Management.

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Employer's Information Requirements (EIR): A BIM case study to meet client and facility manager needs

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ABSTRACT

Purpose: This paper describes the development, testing and case study use of an *Employer's Information Requirements (EIR) Template and Guidance* document designed to meet client and facility management (FM) needs in the Building Information Modelling (BIM) process.

Theory: UK BIM standards and EIR examples formed a basis for drafting the EIR.

Design/methodology/approach: Triangulation using:1) a review of literature and BIM standards, 2) a focus-group; with the *British Institute of Facilities Management (BIFM),* 3) a case study interviews; with the *Glasgow Life Burrell Renaissance Project* who trialled the EIR, and 4) peer-reviews and interviews with BIM/CAFM experts from *BIM Academy*[2] and *FM180*[3].

Findings: There is need for FM and client specific guidance including how to prepare an EIR. Practitioners are aware of key BIM standards but not in detail. The case study EIR was used by clients, FMs and the design team as a collaboration-tool to bring stakeholders together to discuss and understand the client's information needs.

Originality/value: The full version of *EIR Template and Guidance* document is available at http://www.bifm.org.uk/bifm/knowledge. It provides a practical starting-point for capturing client information requirements in a structured way. It provides design/construction professionals with clear client instructions allowing a well aligned BIM Execution Plan (BEP) in their tender response. This will in turn ensure the BIM process delivers the right information for optimising asset usability and costs over the long term in operation.

Keywords: Facility management, Building Information Modelling, Operational Information Requirements, Asset Information Requirements, Asset Information Model

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[2] The BIM Academy website is https://collab.northumbria.ac.uk/bim2

[3] The FM180 website is http://fm180.com

1   INTRODUCTION

Reference to BIM in the construction and FM industries has snowballed in recent years. There is now an almost overwhelming range of BIM standards, best guidance and an increasing body of scientific literature on BIM as everyone tries to jump on the BIM bandwagon. This often presents a problem to FMs engaged in a BIM project who often also have busy day jobs and simply want to find out what they really need to know to get themselves up to speed. This paper addresses one key element of this pressing problem; how FMs can prepare an EIR which is tailored to the needs of the client and facility managers in the BIM process. The research aimed to publish an EIR template (via BIFM) and make it available to their 14,000+ members as well as other stakeholders in 2017. This paper presents the lessons learnt from creating the EIR and its use in practice.

2   LITERATURE REVIEW

One might ask why do FMs and clients need to have a good understanding of the BIM process? A good reason is provided by Eadie, et al. (2013) indicating that in relation to financial benefits for stakeholders in the BIM process, clients will benefit most financially from BIM followed by FMs. This is largely because the operational phase of the whole life cycle (WLC) offers the largest opportunity for delivering value in terms of cost savings, sustainability and usability of assets cost of assets. Akcamete, et al. (2010) note that the O&M of a building equate to 60% of the overall costs of a project and the potential benefits of using BIM for facility operations are compelling. Another good reason is waste. Gallaher, et al. (2004) looked at waste in the U.S. facilities industry. They estimated potential annual savings of; $67 million with respect to wasted time recapturing and transferring of the information provided by architects, engineers, and contractors and $613 million with respect to the automated transfer of information into available CAFM tools.

Dawood and Vukovic (2015) note the "WLC information flow is defined as the steady and continuous evolution and use of BIM information and knowledge from the design stage, through the construction stage, to the facility management stage" (p.1). However, Akcamete, et al. (2010) highlight a worrying trend; the utilization of BIM during building operation and maintenance is falling behind the BIM implementations for design and construction. If this continues and clients and FMs do not engage and define their requirements clearly in the BIM process, many of the potential benefits and savings will not be fully realised in operation.

BIM was mandated for all UK government projects as of April 2016 as part of the *Government Construction Strategy* (Cabinet Office, 2011). It sees BIM as essential to the digitalisation of the built environment sector. All central Government departments must now tender with suppliers to demonstrate collaborative 3D Level 2 BIM maturity through defined and compliant information and data on projects" (BSi, 2016). One of the fundamental principles of achieving BIM level 2 information modelling is the provision of a clear EIR. The UK BIM standard PAS 1192-2 (BSi, 2013) defines the EIR as a "pre-tender document setting out the information to be delivered, and the standards and processes to be adopted by the supplier as part of the project delivery process" (p.4). It notes the "EIR should be incorporated into tender documentation to enable suppliers to produce an initial BIM Execution Plan (BEP)" (p.10). The EIR aim is to ensure user's information needs are clearly defined at the start of the BIM process and it provides a mechanism for collaboration allowing project stakeholders to communicate, manage and deliver client's requirements. However, this requires a clear EIR that sets the processes and standards to be adopted by the suppliers throughout the pro-

ject life cycle" (Hafeez, et al., 2016, p. 199). Dawood and Vukovic (2015) note that "lack of in-house expertise is one of the key barriers to BIM adoption" (Dawood and Vukovic, 2015, p. 6). As such it is critical that FMs and clients acquire the skill sets to be able to fully engage in the BIM process and create an EIR that clearly states their information needs and aligns with the client asset management strategy.

3   METHODOLOGY

A triangulation approach was adopted for the development and refinement of the EIR as illustrated in figure 1. This started with a review of literature, industry standards and guidelines. This included the BIM Task Group own *Employer's Information Requirements - Guidance notes version 07* (BIM Task Group, 2013). These were not particularly FM/client orientated and so a new version was drafted focusing on the needs of the client.

The content was further refined through; 1) iterative focus group reviews via eight members of the *BIFM Operational Readiness Steering Group*, 2) parallel feedback from the case study; the *Glasgow Life Burrell Renaissance Project*, and 3) peer-reviews by BIM/CAFM competence experts via the *BIM Academy* and *FM180* organisations. 21 iterations were reviewed in total over a 9-month period whilst the project was running.
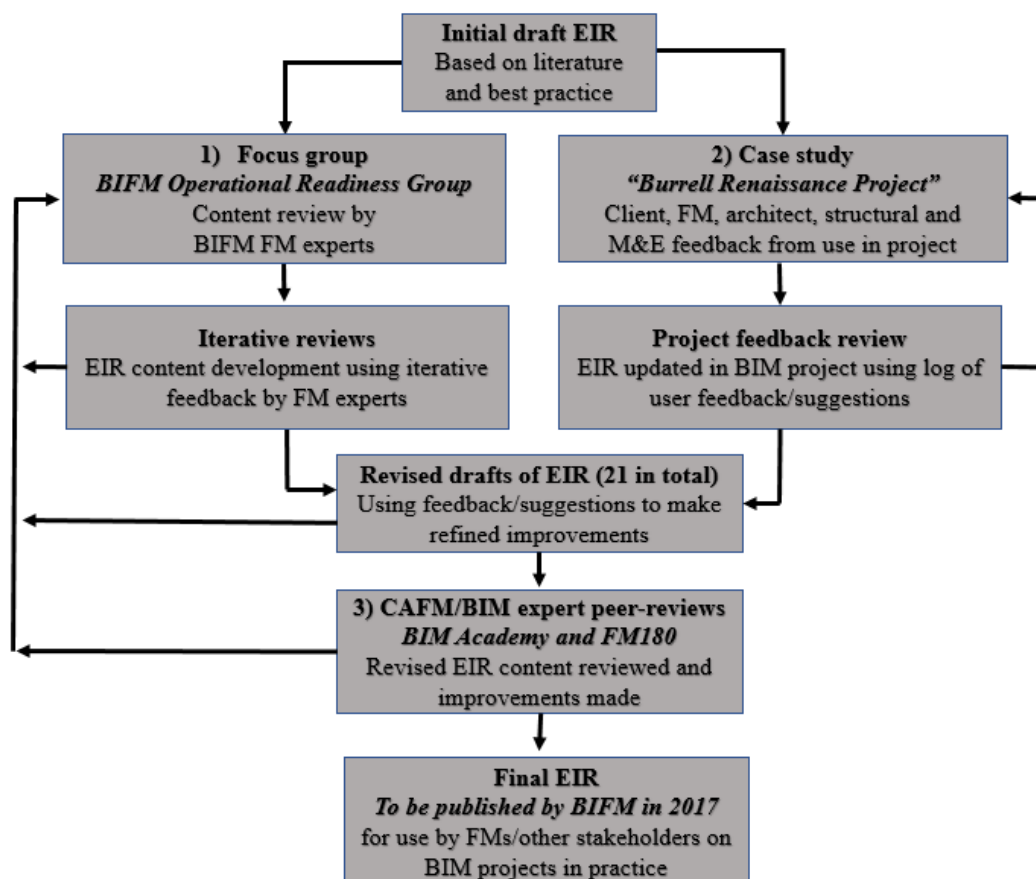

Figure 1 Methodological approach to developing the EIR

Fifteen people were involved in total as shown in Table 1. Seven stakeholder interviews were held to get user feedback; 5 from the case study, 1 FM consultant from BIFM and 1 BIM/CAFM expert

Table 1 Team members by stakeholder group

Stakeholder group	Key role	Focus Group (8)	Case Study (5)	Peer review (2)	Inter-views
Client/FM	Client – asset/information	1	2		2
FM Consultants	FM - information needs	5			1
Architect	Design - architectural input		1		1
Structural Engineer	Design - structural input		1		1
M&E Engineer	Design - M&E input		1		1
BIM/CAFM Ex-	BIM/CAFM - compliance			2	1
Academ-	BIM/EIR/FM - research	2			

Regular focus group meetings were organized (by conference-call) to review feedback/suggestions for improvement. New EIR versions were issued between meetings allowing individual members time to review amendments and provide further comments using the MS-Word track-changes function. In the case study the client/FM team circulated the EIR to the design team for initial feedback. Changes/suggestions were tracked in a change-log and new versions were issued accordingly. Interviews were also held with project stakeholders (see Table 1) to capture ongoing feedback on the EIRs usability. These were then fed into the focus group reviews.

A final round of feedback was collected through external peer-reviews/interviews with BIM/CAFM practice experts. Their comments were also fed back fed for a final review by the focus group. The EIR document was then finalized and will be officially published by the BIFM as part of a suite of BIM guidance documents for FMs in 2017.

4   FINDINGS

The *key topics*, *issues raised* and the *actions taken* to iteratively improve the EIR via the various methods are summarized in the following tables.

Table 2 Feedback and issues raised by the focus group

Key topics	Issues raised	Action taken
FM/Client orientated EIR	Group members agreed there was a clear need to develop an FM/client orientated EIR to address their needs.	The EIR was written and developed from the perspective of the client and FM with the aim of meeting their needs in a BIM project.
Need for guidance on use of the EIR and other BIM guidance documents	Early versions had a mix of general guidance and template text. Also, there was a feeling additional general BIM guidance documents should be provided to help FMs and clients understand how to engage in a BIM project and prepare/use the EIR.	The EIR template was restructured to move all guidance to a guidance section at the start which can be removed on formal issue. The BIFM also now plan further support documents to help get an overview of the BIM process. These are in development and listed in the conclusion section.

Use and reference to existing BIM standards/guidance	In order to be successful, the group agreed the "EIR should make reference to existing BIM standards/guidance" and not attempt to "re-invent the wheel".	BS and PAS BIM standards as recommended by the BIM Task group were used throughout the development of the document and are listed in Appendix B.
Level of Definition (LOD)	There was confusion regarding the term LOD used in the BIM process and if the D referred to Definition, Detail or Development.	It was agreed to use the NBS "Level of Definition" reference as this is actively being used in industry as best practice guidance. The NBS LOD are included in appendix E.
Viewing BIM models and Training	How will FMs view BIM models and get training to understand how to access and use the data in practice.	The EIR includes explicit sections to address how BIM models will be viewed. Training requirements is also addressed as a key topic
Asset Data	How to present the client's needs over the RIBA stages with respect to asset data. Early versions had long lists of tables for each RIBA stage. This was seen as useful but expanded the document considerably.	The decision was taken to remove the tables and use an Excel sheet for the "Information delivery schedule for maintainable assets". The MOJ publicly available example was suggested as a good reference (appendix C).

Table 3 Feedback and issues raised in the case study

Key topics	Issues raised	Action taken
EIR template used as a starting point for client and FM to develop EIR and define roles and responsibilities of stakeholders	The client and FM had little BIM experience. Initially they thought they could simply "ask for a BIM level 2 project and the supply chain would deliver what was needed". They were "unsure how to start the EIR" and "having a template was great help to kick-start the process". It "helped them define roles and responsibilities".	The EIR template has been structured to offer FMs, clients and other stakeholders a starting point to create an EIR. However, it makes clear the client needs to tailor the EIR to their own BIM project. The guidance makes it clear that the client should start by understanding their own OIR, AIR and using PLQ to help prepare an EIR at the start of the BIM process.
Complexity and ease of reading	The early EIR draft used in the case study was seen as trying to provide guidance and also a template. This was seen as helpful but also potentially confusing as it was not clear what to leave in and take out.	The EIR was reorganized to include a guidance section at the front of the EIR template. This can be later removed after the draft has been developed and is ready for formal issue in the BIM project.
Appendices	The early draft was seen as good but it was suggested it could be made better by moving some elements to the appendices.	Eight appendices (A-H) were implemented to help make the document easier to read. These can also be edited out if required.

Knowledge and use of existing BIM standards/guidance and	Some people felt it seemed like "walking through a minefield" trying to "understand all the BIM standards/guidance". Simpler and more specific guidance was seen as needed to help FMs and clients engage. Surprisingly BS 8536 was not referred to at all by stakeholders in practice.	The EIR is one of a suite of documents being worked on by BIFM to help FMs get guidance which focuses specifically on their needs. The EIR points clients/FMs towards using BS 8536 and other useful standards/guidance which are listed in appendix B.
BIM terminology such as OIR, AIR and EIR	The project team refer to the EIR but do not use the terms OIR and AIR. They refer to a project Master Plan.	The terms OIR and AIR are explained in the EIR and guides are planned to provide practice examples by BIFM in 2017.
COBie and the transfer of data to CAFM systems	COBie[4] was understood by all stakeholders as "a key part of the plan to transfer data into Glasgow Life's management systems" (including yet to be defined CAFM). However, there was concerns regarding the LOD with respect to COBie data to be provided by the design team in the early design stages.	The EIR includes COBie as part of the strategy for data transfer. Stakeholders are advised to use BS 1192-4 (BSi, 2014b). Guidance notes advise the client to consider in the EIR how the LOD is developed for COBie drops and tailored to individual project needs. (as these could change specific to a project).
BIM as a collaborative tool.	The EIR was generally very well received and is being used as a tool to encourage collaborative working as everyone gets up to speed with BIM.	The EIR can be issued as a draft document for discussion with stakeholders. Questions and issues can be raised and addressed before a final version is formally issued.
Alignment with the RIBA PoW	The initial EIR did not fully align with the RIBA stages which caused some confusion.	The EIR was revised to ensure full alignment with the 2103 RIBA Plan of Work and use the industry standard approach.
Multiple stage EIR	There was some debate as to if two EIRs would be issued. One to the design team and then one for main tendering purposes.	It is recognized that depending on the project procurement route the EIR might be tailored to suit a specific project requirement.

Table 4 Feedback raised by the external peer review

Key topics	Issues raised	Action taken
Clarity and complexity of the EIR	The EIR was seen as "good but fluffy". As a "document issued as part of a contract the EIR needs to be clear and specific".	The EIR was reviewed to remove any unnecessary wording or sections which were considered ambiguous.
Guidance vs. Template	Early versions were seen as trying to provide too much guidance whilst at the same time attempting to be a EIR template	Guidance notes were moved to a single section at the front of the template which can be later deleted prior to contract issue.

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[4] COBie (Construction Operations Building information exchange) is a standard format for data exchange

Client responsibility to define expectations	Initial drafts did not put enough emphasis on the client responsibility to provide the supply chain with clear requirements which were unambiguous.	The EIR was amended to emphasis the need for clients to take ownership of the EIR and ensuring clear requirements for the supply chain to use for BEPs and tender pricing.
Model ownership	The CIC BIM protocol[5] should be used as an industry recognized best practice document to address model ownership.	The EIR section on model ownership was amended to point clients towards using the CIC BIM protocol as part of the EIR.
Using best practice public domain documents	It was recognized that best practice should be referred to where possible. The MOJ released some examples of support documents for the BIM process were recommended as reference documents.	The EIR appendices point to using the MOJ references for both a list of the "PLQ" and a development table "information delivery schedule for maintainable assets".

This paper cannot provide significant detail in the limited pages regarding the final EIR. The full EIR Template and Guidance document content is significant and runs to 69 pages. The full document can be retrieved from BIFM at http://www.bifm.org.uk/bifm/knowledge.

However, Table 5 attempts to give readers an overview of the level of detail and topics covered by the document. It shows the final overall structure of the FM and client orientated EIR.

Following feedback from the focus group and case study a lot of information was also moved to eight appendices to help make the document easier to read.

Referring to feedback during the interviews the following generalizations were made; There were varying levels of direct BIM experience; the case study client had none whilst the facility manager had worked on one BIM project; Glasgow Life's Kelvin Hall. Interviewees all agree BIM will have a significant impact on the FM industry but the time period for this impact to be felt by the FM industry varied between "it is having a significant impact now" up to "the real impact will be felt over the next ten years". All the case study stakeholders agreed there is some way to go before all parties are up to speed on the BIM process. However, it was interesting that for both the focus group and case study the EIR was seen very much by all stakeholders as a collaborative tool, which could be used to help a project team get up to speed on the BIM process. There was also no clear idea of what content should be in an EIR.

"Having a good understanding of BIM standards", "early and active engagement with the BIM process" and "understanding how the EIR should be used at the start the BIM process" were seen as key issues that need to be addressed if real value is to be delivered in the operation phase. There was general agreement by all interviewees that the EIR would help benefit not only FMs and clients but also design teams and contractors by giving clear direction to the supply chain regarding the client's information needs. However, they also indicated that clients would need to take the time to create a quality EIR and not use the template with a "copy-paste mentality".

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[5] The CIC BIM Protocol (CIC, 2013) is a best practice document used in contracts to manage model ownership

5   DISCUSSION

The UK government has developed standards and guidance in place for the BIM process. They have also set up the *BIM Task Group*[6] and *BIM Level 2*[7] websites providing free access to most standards and guidance. However, the findings from the interviews and the case study indicate that people are often overwhelmed by the sheer volume of information and do not know where to start when they need to prepare an EIR. This often results in people not knowing what is important to their role and sometimes prevents a full understanding the BIM process as a whole. This was evident in the worrying lack of reference by practitioners to key documents to FM in the BIM process such as BS 8536-1:2015 *Briefing for design and construction – Part 1: Code of practice for facilities management (Buildings infrastructure)*. This may be due to it not being originally reviewed on the BIM Task Group site, although it is now referenced on the Bimlevel2 website.

Interviewees noted a lack of examples of key reference documents underpinning the BIM process, namely; the OIR, AIR and EIR. This issue is critical as PAS 1192-2 (BSi, 2013) and PAS 1192-3 (BSi, 2014a) both note that start of the BIM process should be a clear understanding of the client`s OIR and AIR. However, a framework of reference examples in practice are rare and people don't know how to start. This aligns with research from Dawood and Vukovic (2015, p.2) in which they note a framework is required to enable the "whole lifecycle information flow underpinned by BIM". They refer to "four pillars: processes, technology, policy and people". The case study and focus group feedback provided information critical to finalizing the EIR Template and Guidance document over 21 iterations. The key issue highlighted by the research is that people and their knowledge of the process is key to the success of the BIM process. Dawood and Vukovic (2015) sum this up as the *people pillar* including training, competency assessment standards for both, people and organisations leadership, teamwork and others. They observe that the people pillar cuts across all three other pillars, as technology, processes and policy will not operate properly unless well-trained and developed human resource are available.

6   CONCLUSION

The main lessons from the whole process can be summarised as follows: 1) Trying to fully understand and comprehend the BIM process is not easy. This is largely due to the sheer amount of information individuals need to read, understand and internalise. 2) BIM requires a paradigm change in thinking by all stakeholders with a focus on improved planning of client information needs for the future right from the start of a project. 3) FM professionals (and other stakeholders) are not sure where to start when it comes to preparing an EIR. 4) The FM industry would benefit from a framework of easily digestible guidance documents specific to FMs and client needs.

A key aspect from the research with respect to preparing an EIR is that practitioners are looking for good reference examples and guidance. The research has provided such a document and has tested in a real life BIM project as a case study. Based on the findings further BIM guidance is now being developed and provided by the researchers and other BIFM members through a suite of BIM guidance documents available at http://www.bifm.org.uk/ bifm/knowledge/resources/BIM. The interviews revealed the need for such guidance and in-

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[6] UK BIM Task Group website is http://www.bimtaskgroup.org

[7] UK BIM Level 2 website is http://www.bim-level2.org

terestingly also referenced the UK Ministry of Justice which has produced a similar framework of BIM documents (Ministry of Justice, 2016). This indicates there is a significant audience who are waiting for such reference examples specifically with their needs in mind.

Table 5 Overall structure of the final version of the "FM and Client Orientated EIR"

0. General guidance and notes (note: this section is provided as guidance and is removed on formal issue)		
1. Purpose and scope 1.1 The purpose of the EIR 1.2 Use of the terms client, client's representative and contractor		
2. Client BIM and asset management strategy and objectives		
3. Project details 3.1 Project information 3.2 Project contact list		
4. Management Requirements	**5. Technical requirements**	**6. Commercial Requirements**
4.1 Applicable standards and guidelines	5.1 Software	6.1 Exchange of information in line with RIBA project stages
4.2 CIC BIM protocol	5.2 IT and system performance constraints	6.2 Supplier BIM assessment form
4.3 Project roles and responsibilities	5.3 Data exchange formats	6.3 BIM tender assessment
4.4 Existing client CAFM/IWMS or enterprise asset management systems	5.4 Common co-ordinates system	
4.5 Model creation and ongoing management	5.5 Levels of definition	
4.5.1 Planning the work and data segregation	5.6 Specified model and information formats	
4.5.2 Model management plan	5.7 Site information, floor and room data information	
4.5.3 Collaboration process		
4.5.4 Model size		
4.5.5 Model viewing		
4.5.6 Volumes, zones and areas		
4.5.7 Naming conventions		
4.5.8 Model co-ordination, quality control and clash-detection process		
4.5.9 Use of BIM to help health and safety		
4.5.10 Delivery of asset information to the client		
4.5.11 Information publishing process		
4.5.12 Security of model information		
4.5.13 Training		
4.5.14 Model audits by the client		

Ongoing research work is planned with the BIFM to benchmark FM awareness of BIM and address guidance documents for the OIR and AIR. The authors recommend that further research might consider looking at contractually issued EIRs with their respective BEPs to see

how they align and to consider further reviews with practice to help improve the current template.

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3   Workplace design

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Factors facilitating effective workplace designs for knowledge workers

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ABSTRACT

Purpose: This paper investigates factors that facilitate effective workplace designs for knowledge workers.

Design/methodology/approach: During spring 2016, the 4535 employees in a large Norwegian institution for research and higher education, a large consultancy company and a medium size consultancy company received invitations to participate in an anonymous online survey about workplaces and facilities. 1670 respondents (37 per cent response rate) answered the survey. The data from this explorative study have been analysed with IBM SPSS version 23, among others through use of exploratory factor analysis and OLS linear multiple and dummy regressions.

Findings: Most respondents at the institution for research and higher education have cell offices. Most respondents in the two consultancy companies have various types of open and flexible offices. Three factors (controlled for seven other factors) are of particular importance for the perceived workplace design's effectiveness, namely common areas, freedom of choice and meeting rooms. This study has also shown that knowledge workers actually may prefer flexible offices and so-called NewWoW to cell-offices if the workplace is well designed and adaptable to various tasks.

Practical implications: The findings provide useful guidelines for facility managers and others responsible for workplaces and related services.

Originality/value: This is a large N empirical study among knowledge workers in three organisations, one public administration and two private enterprises. The findings support some former studies, but also provide some new insights.

Keywords: Facility management, Knowledge workers, Norway, Survey, Workplace design.

1   INTRODUCTION

Today, most industrialized countries are highly dependent of the productivity of so-called knowledge workers. Drucker (1995, p. 231) claimed that since the 1950s knowledge workers have succeeded blue-collar industrial workers, and knowledge work is distinguished from blue-collar industrial work because knowledge work require "a good deal of formal education and the ability to acquire and to apply theoretical and analytical knowledge". An alternative term for knowledge work according to Ramirez and Nembhard (2004) is "white-collar work". Drucker (1995, p. 234) claimed that in a "knowledge society, it is not the individual […] but the organization that performs". Hence, most knowledge workers work together with other knowledge workers in organizations at workplaces, usually at offices.

This paper is a study of how workplace design, facilities and services facilitate knowledge workers' ability to their job. The European standard EN15221-1 defines Facilities Management (FM) as "Integration of processes within an organization to maintain and develop the agreed services which support and improve the effectiveness of its primary activities" (CEN, 2006). Application of FM ideas and principles is thus of high relevance if the aim is to develop workplaces that support and improve the effectiveness of organizations' primary activities; hereunder improving organizations' ability to achieve their goals through application of their knowledge workers' knowledge and skills. This explorative study of factors that are important for the knowledge workers' (the end-users') perceived productivity has been made in three Norwegian knowledge organizations, one institution for research and higher education and two consultancy companies.

2   LITERATURE

Physical offices are still the most common workplace for knowledge workers, even if the last decades' development of ICT has made virtual workplaces far more common. This study emphasizes physical workplaces and offices.

Jensen (2001, p. 129) distinguish between four main categories of offices at workplaces. The first is open landscapes; i.e. large rooms with several desks or workstations. The second category is cubicles or cell offices, usually for individual workers or small numbers of workers. The third category is group offices where the employees are seated according to their organizational belonging. The final category is so-called activity based offices with different zones and kinds of workstations that permit different kinds of work, ranging from individual concentration work to group work that require interaction and communication.

Another question concerning workplaces, offices and workstations, is whether the employees have a personal desk or workstation at a particular office, or if the organization has implemented a shared space scheme through so-called flexible offices, combi-offices or hot-desking, where a department or team share a number of workstations (Jensen 2001, p.121; Booty 2009, p. 359; de Been and Beijer 2014). The most extreme concept of space sharing at workplaces is so-called free seating, where the organization's workstations are available across organizational boundaries. Flexible offices or hot-desking, i.e. fewer workstations than employees can save organizations for considerable space and even costs, particularly if the employees spend significant time at other places than their workstations. According to Booty (2009, p. 359), there are no rules of thumb for "the correct ratio" of desks or workstations to employees in hot-desking arrangements. The hot-desk-employee ratio typically depends on how much time the employees spend other places, whether the employees can or are permit-

ted to carry out their deskwork somewhere else, and whether the employees can use other departments' free desks or workstations if their own department's desks are occupied.

One of the problems with knowledge work is that knowledge work is intangible and "difficult to map and assess" (Greene and Myerson, 2011). It is thus rather difficult to measure knowledge workers' productivity, and thereby the effect of different kinds of workplaces and interventions on workplaces (Ramirez and Nembhard, 2004; van der Voordt et al., 2016; de Been et al., 2016). One approach to overcome these challenges is to measure the "*perceived* (impact of facilities on) productivity" (de Been et al., 2016, p. 149).

When organizations replace traditional offices with free seating or hot-desking concepts, they typically have to compensate the employees by providing different kinds of facilities in addition to the traditional offices with desks or workstations (Booty, 2009, 352-353). Examples of such facilities are among others social zones or breakout areas with kitchenettes, coffee machines, coffee tables, sofas, etc. and various kinds of touchdown areas for those who don't need a workstation but only a place to read e-mails. Such compensation measures may also include different kinds of quiet areas, and even study boots to permit concentrated work, as well as meeting rooms. In most organizations, about two thirds of the meetings involve six persons or fewer, and approximately fifty per cent of the meetings involve four persons or fewer (Booty, 2009, p. 353). Thus, many organizations need few large meeting rooms, but several smaller meeting rooms. In organizations with open offices, small meeting rooms are often also used for phone calls, concentration work, etc. Replacement of traditional offices with free seating and hot-desking is often also compensated with other facilities such as an improved canteen or company restaurant, facilities for physical exercises, etc. (Booty, 2009, p. 330 ff.)

A study of introduction flexible offices at Delft University of Technology's Faculty of Architecture (N = 266) showed that the respondents in general were satisfied with their new flexible offices, because the new offices are not crowded. The workstations were functional and available, and facilitated informal meetings and conversations. However, there were limited possibilities for confidential phone conversations, "insufficient visual and auditori privacy", and few opportunities for control of the indoor environment. There were also respondents who questioned the security, because of open environments and few lockable doors. There were also limited possibilities for storage of personal and collective belongings. The flexible offices offered workstations designed for different tasks, but very few respondents changed workstation during the day. However, after introduction of flexible offices the average degree of working from home increased from 16 to 27 per cent of the week (Gorgievski et al., 2010). Thus, it was evident that introduction of flexible offices in an academic institution had pros and contras.

Greene and Myerson (2011) made ethnographic studies of 20 knowledge workers, and derived four ideal types, depending on mobility and work patterns. The first ideal type was the "Anchor", the traditional office worker who is present at their desk every day. Anchors typically spend most of their time on concentration work, often in a noisy environment. The second ideal type is the "Connector", who typically spend half the workweek at different locations at the workplace in meetings, etc. Most Connectors are managers or coordinators. The third ideal type is the "Gatherer" who generate many relationships outside the office, and spend approximately half the week away from the workplace. Gatherers typically get a shared desk. The last ideal type is the "Navigator", who occasionally visit her own office. Naviga-

tors are typically salespersons, contractors or consultants. Today, in many organizations gatherers and navigators are frequent users of virtual workplaces.

Between 2007 and 2013, Delft University of Technology's Center for People and buildings (CfPB) have made 105 case studies of employees (N = 14,980) at 35 traditional offices with personal desks, 14 combi-offices with personal desks, 52 combi-offices with shared desk schemes, 2 open landscapes and 2 miscellaneous spaces. These studies indicate that about two thirds of the employees are reasonably satisfied with their organization, work and workspace. However, the employees are least satisfied with support for concentration, storage facilities, indoor climate and acoustics. A closer comparison between traditional offices and flexible offices with personal desks and offices where the employees not have personal desks revealed that offices without personal desks often had better architectural qualities, but were questionable concerning privacy and possibilities for concentration (van der Voordt et al. 2016). These findings are very similar to de Been et al.'s (2015) findings based on 20 case studies (N = 2733 survey respondents and 57 group interviews (N = 271)). De Been et al. (2015) found that respondents with workstations in open areas were distracted by telephone calls and conversations. De Been et al. (2015) therefore recommended establishing meeting rooms or meeting areas next to the open workspaces. Some of these findings are rather similar to Gorgievski et al.'s (2010) findings after introduction of flexible offices at Delft University of Technology's Faculty of Architecture.

Data from Leesman Office, a consultancy company that since 2010 has collected data about employees' satisfaction with their office environments, based on studies of 115 organizations at 370 different locations with all kinds of offices in five Western European countries (N = 47,913) indicate that employees are not satisfied with indoor climate and, privacy. Leesman Office's data also include some facilities services. In average, the employees are satisfied with coffee and tea, security and mail services, but they are not satisfied with hospitality services, leisure facilities, atriums and other common areas, according to van der Voordt et al. (2016).

Based on data from Leesman Office, Appel-Meulenbroek et al. (2015) investigated whether employees with activity-based workplaces (so-called "NewWoW") had different opinions concerning workplaces compared to employees with traditional workplaces (so-called "TradWoW"). Based on t-tests of the respondents' answers (N = 43,791), Appel-Meulenbroek et al. (2015) found that employees with NewWoW were significantly more satisfied with office climate, office décor, office leisure, cleanliness and seclusion rooms, than employees with TradWoW. On the other hand, respondents with TradWowW compared to respondents with NewWoW were significantly more satisfied with general facilities, desk and chair, privacy, and storage.

Thus, the literature review has shown that development of workplaces that knowledge workers perceive as effective is not always straightforward. There are obviously some tensions between the facilities managers' desire to reduce the area and the organization's carbon footprint and the knowledge workers' requirements to functional and well-designed workplaces.

3   METHODS

Bakken et al. (2016) collected the data. The study was approved by NSD Norwegian Center for Research Data (permit no. 48312), who is The Norwegian Data Inspectorate's partner for implementation of the statutory data privacy requirements in the research community. In April and May 2016, all the 4535 employees in a large Norwegian institution for research and

higher education, in a large consultancy company and in a medium size consultancy company received an e-mail invitation to participate in an anonymous online survey (census) about workplaces and facilities. The survey was administered by Oslo and Akershus University College of Applied Sciences' ICT Department, which operate safe servers for surveys. 1670 respondents answered the survey. 37 per cent response rate is very good for this kind of survey in Norway. The sample fairly well represent the employees in these three organizations.

The online questionnaire included questions about the building where the respondents' workplace is located (3 items) and whether the respondents' could regulate the interior climate (4 items). This information is not used in this paper. The questionnaire also included questions about the respondent's physical workstation (4 items), and questions with a 10 point Likert scale about the respondents' perception or attitudes where 1 indicated no/very little degree and 10 indicated very high degree. The questions with the 10 point Likert scale were about the following topics: Lighting (5 items), temperature (5 items), ventilation (5 items), acoustics (5 items), workstation (6 items), seclusion rooms (6 items), meeting rooms (6 items), canteen (6 items), breakout areas (6 items), kitchenettes (6 items), social zones' influence (6 items), freedom of choice (6 items), access to facilities (6 items), and workplace design (6 items). Finally, the respondents got some demographic questions (gender, age group, position and length of service in the organization).

The survey data have been analysed with IBM SPSS version 23. The most important analytical methods have been descriptive statistics (frequency, mean, cross tables, etc.); check of reliability, exploratory factor analysis (EFA), and OLS multiple linear regressions.

The questionnaire's reliability was tested through calculation of Cronbach's Alpha for each group of questions concerning perceptions or attitudes; i.e. those with a 10 point Likert scale. Cronbach's Alpha is a measure of internal consistency, and ranges from 0 to 1, .60 is usually considered the lower limit of acceptability in exploratory analyses, but the rule of thumb is to require Cronbach's Alpha of .70 or better (Hair et al., 1998, p. 88, 118). All the questionnaire's groups of questions with a 10 point Likert scale had acceptable reliability (Cronbach's alpha between .824 and .972), except the group Access to facilities which had a Cronbach alpha of .666. However .666 is acceptable for an exploratory study. Thus, all the questionnaire's groups of questions with a 10 point Likert scale have been included in the EFA.

The EFA is based on Maximum Likelihood (ML) factor extraction that maximise the canonical correlation between variables and factors (Tabachnick and Fidell, 2014, p. 689). Rotation of factor solutions simplifies the interpretation, and the EFA is based on Varimax rotation because orthogonal rotation usually provides clear separation of the factors; i.e. high or low factor loadings (Hair et al., 1998, p. 109-110). All other things equal, clear separation between the factor loadings simplifies interpretation of the rotated solution.

The EFA was used to establish new composite variables (constructs); i.e. summated scales by adding variables loading on the same factors and calculating the mean score. Summated scales reduce measurement error and simplify identification of common factors (Hair et al., 1998, p. 116-117). Based on the factor analysis 12 constructs were established. These constructs are continuous and vary between minimum 1 and maximum 10, and are thereby possible to use as data for OLS linear regressions. Even the constructs' reliability has been tested through calculation of Cronbach's Alpha. The constructs have been analysed through multiple linear (OLS) regression with factor F7 Workplace design effectiveness as dependent variable (DV), to identify which factors that are most important for the respondents' perception

of the workplace design's effectiveness. So-called dummy regression (Hair et al., 1998, p. 83-85, 167-168) has been used to test whether different categories of respondents have significantly different perceptions of factor F7 Workplace design effectiveness.

4 RESULTS

This section includes three subsections, the first about the respondents, the second about the EFA, and the last about the regression analyses.

4.1 The respondents

1670 respondents answered the survey. 1019 in the institution for research and higher education (61.0 per cent), 605 in the large consultancy company (36.2 per cent) and 46 in the medium size consultancy company (2.8 per cent). There are 745 female (55.7 per cent) and 592 male respondents (44.3 per cent). 340 respondents did not reveal their gender. The respondents age distribution were 123 who are 29 years or younger (9.1 per cent), 286 between 30 and 39 years (21.2 per cent), 365 between 40 and 49 years (27.0 per cent), 336 between 50 and 59 years (24.9 per cent), and 241 60 years or older (17.8 per cent). 326 respondents did not reveal their age. Table 1 presents an overview of the respondents and where they are seated at their workplace.

Table 1 The respondents' offices

	Flexible office with free seating (%)	Flexible office with reserved positions (%)	Cell office with reserved positons (%)	Total (%)
Research and higher education	44 (4.6)	53 (5.6)	850 (89.8)	947 (60.6)
Consultancy company (L)	5 (0.9)	368 (64.2)	200 (34.9)	573 (37.6)
Consultancy company (M)	1 (2.4)	38 (90.5)	3 (7.1)	42 (2.7)
Total	50 (3.2)	459 (29.4)	1053 (67.4)	1562 (100.0)

Table 1 shows that approximately 90 per cent (850) of the respondents employed by the institution for research and higher education have cell offices with reserved positions. Most respondents in the two consultancy companies have flexible offices with reserved positions. Very few respondents (50) have flexible offices with free seating or hot-desking, and most of these are employed by the institution for research and higher education.

Table 2 Respondents with seats in open or semi open landscapes

	Traditional open/semi open office shared by several persons (%)	Group based office (organizational belonging) (%)	Activity based office depending on activity (%)	Total (%)
Research and higher education	47 (50.5)	14 (15.1)	32 (34.4)	93 (18.6)
Consultancy company (L)	232 (63.0)	115 (31.3)	21 (5.7)	573 (73.7)
Consultancy company (M)	26 (68.4)	8 (21.1)	4 (10.5)	42 (7.6)
Total	305 (61.1)	137 (27.5)	57 (11.4)	499 (100.0)

499 respondents who answered they had a workstation in open or semi open landscape also answered the question about what kind of landscape their workstation was located in. 305 respondents had a workstation in traditional open or semi open landscapes. 232 of these were employed by the large consulting company. 137 respondents were located in group-based offices according to organizational belonging. The large consultancy company employed 115 of these. The institution for research and higher education employed 32 of the 57 respondents with activity-based offices. The large consultancy company employed 21.

How about the respondents' sharing of office? 1505 respondents informed about office sharing. In the institution for research and higher education, 663 respondents (73.4 per cent) had their own office. 158 (17.5 per cent) shared office with 1-3 colleagues. 41 (4.5 per cent) with 4-10 colleagues, 15 (1.7 per cent) with 11-20 colleagues, and 26 (2.9 per cent) shared office with more than 20. In the large consultancy company, 173 respondents (30.9 per cent) had their own office. 37 (6.6 per cent) shared office with 1-3 colleagues, 90 (16.1 per cent) with 4-10 colleagues, 89 (15.9 per cent) with 11-20 colleagues, and 171 (30.5 per cent) shared office with more than 20. In the medium size consultancy company 4 respondents (9.5 per cent) had their own office. 6 (14.3 per cent) shared office with 1-3 colleagues, while 20 (47.6 per cent) shared office with 4-10 colleagues. 10 (23.8 per cent) shared office with 11-20 colleagues and 2 (4.8 per cent) shared office with more than 20. Thus, 840 (55.8 per cent) respondents had their own office, while 201 (13.4 per cent) shared office with 1-3 colleagues, 151 (10.0 per cent) shared office with 4-10, 114 (7.6 per cent) shared office with 11-20 and 199 (13.2 per cent) shared office with more than 20 colleagues. Most respondents in the two consultancy companies shared office with four or more of their colleagues.

Table 3 The respondents' weekly use of their workstations

Organization/employees	More than 30 hours (%)	21-30 hours (%)	10-20 hours (%)	Less than 10 hours (%)	Total
Institution for research and higher education					
Technical/administrative employees (included managers)	168 (51.9)	108 (33.3)	40 (12.3)	8 (2.5)	324
Researchers and teachers	207 (43.4)	163 (32.2)	84 (17.6)	23 (4.8)	477
Consultancy company (L)					
Top managers	1 (25.0)	2 (50.0)	1 (25.0)	0 (0.0)	4
Middle managers	36 (43.4)	32 (38.6)	12 (14.5)	3 (3.6)	83
Administrators	27 (71.1)	8 (21.2)	2 (5.3)	1 (2.6)	38
Project staff	268 (74.4)	75 (20.8)	11 (3.1)	6 (1.7)	360
Consultancy company (M)					
Top managers	0 (0.0)	2 (66.7)	1 (33.3)	0 (0.0)	3
Middle managers	5 (50.0)	4 (40.0)	1 (10.0)	0 (0.0)	10
Administrators	6 (85.7)	1 (14.3)	0 (0.0)	0 (0.0)	7
Project staff	16 (94.1)	1 (5.9)	0 (0.0)	0 (0.0)	17
Total	734	396	152	41	1323

Table 3 shows that technical/administrative employees at the institution for research and higher education spend more time at their workstations than researchers and teachers do. In the two consultancy companies, administrators and project staffs spend most of their week at their workstations, while managers seem to spend considerable time in meetings, etc.

4.2 Exploratory factor analysis

EFA with Maximum Likelihood extraction and Varimax rotation gave 13 factors. The 13th factor was not established as a construct because of low factor loadings (< .30) and unacceptable reliability (Cronbach's alpha < .60). The remaining factors became the basis for 12 constructs (additive composite variables). Table 4 show the factors/constructs in diminishing order according to the factor loadings.

Table 4 Factor and constructs established through EFA

Factor/Construct	Factor loadings	No. of items	Valid N	Cronbach's alpha	Mean	SD
F1 Common areas	.820-.672	8	601	.950	6.89	2.222
F2 Ventilation and temperature	.900-.819	8	1299	.968	6.92	2.275
F3 Freedom of choice	.881-.594	6	900	.944	7.75	2.041
F4 Seclusion rooms	.877-.483	6	607	.930	6.13	2.456
F5 Workstation efficiency	.851-.691	4	1290	.926	7.15	1.956
F6 Canteen	.785-.683	5	868	.926	5.60	2.480
F7 Workplace design effectiveness	.775-.646	3	1276	.928	7.42	2.042
F8 Meeting rooms	.793-.408	5	981	.915	6.68	2.022
F9 Lighting	.810-.640	4	1320	.946	7.17	2.105
F10 Office leisure	.793-.337	2	1164	.979	5.57	2.652
F11 Acoustics	.823-.804	2	1419	.977	6.70	2.590
F14 Adjustment of indoor climate	.485-.458	3	1434	.807	7.94	1.916

Table 4 also show the results of the reliability tests of the constructs based on the factors derived. All the 12 factors/constructs have acceptable reliability (Cronbach's alpha > .70).

4.3 Regression analyses

Based on the literature review, F7 Workplace design effectiveness was chosen as the dependent variable. F5 Workstation efficiency is also a highly relevant dependent variable, but that is a subject for another paper. F5 Workstation effectiveness is thus omitted from further analysis.

Table 5 shows the result of the results of an OLS multiple linear regression with F1 Common areas, F2 Ventilation and temperature, F3 Freedom of choice, F4 Seclusion rooms, F6 Canteen, F8 Meeting rooms, F9 Lighting, F10 Office leisure, F11 Acoustics, and F14 Adjustment of indoor climate as independent variables, to explain how these variables controlled for one another explained the variation in the dependent variable F7 Workplace design effectiveness.

The model is significant according to the F-test (F 20,643, p .000). The R^2 of this model is .477 (adjusted R^2 .454). Thus, this model explains approximately half of the dependent variable's variance. There are no indications of multicollinearity, because the independent variables' variation inflation factor (VIF) is larger than .2 and smaller than 5 (Field, 2013, p. 325). Beta, which shows the zero order correlation between each independent variable and the de-

pendent variable, varies between .261 (F1 Common areas) and .018 (F11Acoustics). The partial correlation is the correlation between the independent and the dependent variable controlled for the effect of other variables on both variables (Field, 2013, p. 881). The partial correlation varies between .211 (F3 Freedom of choice) and .019 (F11 Acoustics). The part correlation (semi-partial correlation), is a measure of the variance in the dependent variable controlled for the other variables, which is explained by the independent variable (Field, 2013, p. 883). The part correlation is thus the net effect of each independent variable on the dependent variable. Table 5 show the part correlation varies between .211 (F3 Freedom of choice) and .014 (F11 Acoustics).

Table 5 OLS multiple linear regression with F7 Workplace design effectiveness as dependent variable

Independent variable	Unstd. B [95% CI]	SE	Beta	t	Sig.	Partial correlation	Part correlation	VIF
Constant	1.610 [.419-2.00]	.604		2.664	.008			
F1 Common areas	.241 [.122-.360]	.060	.261	3.989	.000	.256	.192	1.845
F2 Ventilation and temperature	.112 [-.013-.238]	.064	.124	1.760	.080	.116	.085	2.137
F3 Freedom of choice	.228 [.126-.331]	.052	.237	4.380	.000	.280	.211	1.268
F4 Seclusion rooms	-.054 [-.155-.047]	.051	-.067	-1.053	.294	-.070	-.051	1.742
F6 Canteen	.046 [-.049-.140]	.048	.058	.954	.341	.063	.046	1.599
F8 Meeting rooms	.194 [.064-.323]	.066	.200	2.945	.004	.192	.142	2.002
F9 Lighting	.048 [-.077-.174]	.064	.048	.763	.446	.051	.037	1.690
F10 Office leisure	.087 [-.004-.177]	.046	.116	1.879	-.062	.124	.090	1.660
F11 Acoustics	.015 [-.088-,119]	.052	.018	.291	-.771	.019	.014	1.742
F14 Adjustment of indoor climate	-.065 [-.161-.031]	.049	-.067	-1.332	.184	-.088	-.064	1.082

The dependent variable F7 Workplace design effectiveness is most influenced by F1 Common areas (B .241, p .000), second most by F3 Freedom of Choice (B .228, p .000), and third most by F8 Meeting rooms (B .194, p .004). The other factors/constructs in the model are not significant.

Do respondents in the different organizations and with different kinds of offices have different perceptions concerning F7 Workplace design effectiveness? The mean score on F7 Workplace design effectiveness for respondents in the institution for research and higher education was 7.177 [95% CI 7.035-7.320]. The mean score for respondents in the large consultancy company was .600 (t 5.067, p .000) higher. The mean score for respondents in the medium size consultancy company was .717 (t 2.135, p .033) higher than the mean score for the respondents in the institution for research and higher education. Thus, the respondents in both consultancy companies have significantly higher mean score on F7 Workplace design effectiveness than the respondents in the institution for research and higher education.
Do respondents with flexible offices have different perceptions concerning F7 Workplace design effectiveness compared to respondents with cell offices? The respondents with cell offices had a mean score of 7.287 [95% CI 7.151-7.422] on F7 Workplace design effectiveness. The respondents with flexible offices and reserved seats have a mean score that is .387 (t 3.056, p .002) higher. The respondents with flexible offices and free seating have a mean

score that is .595 (t 1.913 p .056) higher than those with cell offices. Thus, respondents with flexible offices with reserved seats have a significantly higher mean score on F7 Workplace design effectiveness than respondents with cell offices. Even respondents with flexible offices and free seating have a higher mean score, but this difference is not statistically significant.

Finally, do respondents with workstations in different kinds of open or semi open landscapes have different perceptions concerning F7 Workplace design effectiveness? The benchmark is respondents with traditional open or semi open offices shared by several persons, with 7.354 [95% CI 7.234-7.474] as mean score on F7 Workplace design effectiveness. The respondents with group based offices according to organizational belonging had a mean score that was .568 (t 2.848 p .004) higher, while respondents with activity based offices had a mean score that was .385 (t 1.258 p .209) higher. However, only the respondents with group-based offices according to organizational belonging had a significantly higher mean on F7 Workplace design effectiveness than respondents with traditional open or semi open offices shared by several persons.

5   CONCLUSION

This paper has presented the results from an explorative large N survey (N = 1670) of knowledge workers' perception of factors facilitating effective workplace designs. The response rate of 37 per cent is good for this kind of survey in Norway. The respondents are fairly well representative for their organizations. 1053 respondents (67 per cent) had cell offices. 459 (29 per cent) had flexible offices with reserved positions, and 50 respondents (3 per cent) had flexible offices with free seating.

Analysis of the respondents' use of their workstations (c.f. Table 3), based on Greene and Myerson's (2011) framework revealed that most respondents were so-called anchors, who spent most of their time at their workstation. Many of the institution for research and higher education's technical and administrative staffs and researchers and teachers were so-called connectors. 33 per cent of the technical and administrative staffs and 32 per cent of the researchers and teachers used their workstations 21-30 hours per week. Even most top and many middle managers in the two consultancy companies used their workstations 21-30 hours per week.

The EFA gave 12 factors and constructs with high reliability. OLS multiple regressions with ten constructs as independent variables explained most of the variation in the dependent variable F7 Workplace design effectiveness, and gave a high R^2 (.477) without indications of multicollinearity. Controlled for the other seven independent variables, F1 Common areas (B .241, p .000) influence the dependent variable F7 Workplace design effectiveness most, F3 Freedom of choice (B .228, p .000) second most, and F8 Meeting rooms (B .194, p .004) third most. The other independent variables were not statistically significant. Thus, it is worth to notice that F1 Common areas concerns common areas and compensating measures. F3 Freedom of choice is very much a question about how the work is organized. F8 Meeting rooms concerns the physical layout as well as acoustic challenges and facilitation of concentration work and co-creation.

These findings make sense given Gorgievski et al.'s (2010) findings at Delft University of Technology's Faculty of Architecture. At Delft TU, the opportunity to work from home was important for the staffs' acceptance of the new flexible offices. The need for freedom of choice is also one of the Norwegian respondents' main messages. Indoor climate, hereunder

the acoustics is also important, such as indicated by Appel-Meulenbroek et al. (2015), de Been et al. (2015) and van der Voordt et al. (2016). Meeting rooms can remedy acoustic challenges and facilitate concentration work in flexible offices, such as indicated by among others de Been et al. (2015). Finally, the Norwegian respondents emphasized common areas, which Leesman Office's studies (Appel-Meulenbroek et al., 2015; van der Voordt et al., 2016) also indicated their respondents asked for. To conclude, further research is needed. However, this study has provided some strong clues concerning which factors facilitate workplace design effectiveness for knowledge workers. This study has also shown that knowledge workers actually may prefer flexible offices and so-called NewWoW to cell-offices if the workplace is well designed and adaptable to various tasks.

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I need a work space! The benefit of Real Time Occupancy Information for employees investigated with Customer Journeys.

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ABSTRACT

Purpose: Managing space is core business for facility managers. High occupancy rates are cost effective, but may decrease employee satisfaction. To avoid peak occupancy in particular areas, employees looking for a workspace could be provided with real time occupancy information (RTOI), showing them the occupancy rate of areas in the building. This paper aims to investigate the effect of RTOI on occupancy as well as on employees' experiences when they look for a workplace.

Design: The research has a mixed approach. Occupancy rate was measured 24/7, based on Wi-Fi signals of devices used by the employees. The experience of finding a workspace was investigated in five panel groups, consisting of a balanced mix of regular users of the test area. Using service design techniques, namely customer journeys (CJ), five panel groups discussed the process of finding a workspace, with and without RTOI. Three personas could be distinguished in the results.

Findings: Overall, occupancy of the test area increased due to RTOI, showing a direct effect on employees' behaviour. Customer journeys showed different touch points before and after introduction of RTOI. Three personas could be identified. Persona one: a fixed worker not influenced by RTOI. Persona two: a connected worker that uses RTOI provided that (s)he does not experience adverse social effects. Persona three: a flexible worker that makes maximal use of the RTOI.

Practical implications: The paper demonstrates suitable techniques to investigate employees' experience of RTOI. Managerial decisions on investing in a RTOI system should depend on the type of personas present in the company.

Originality: There is little research on the potentially beneficial effects of RTOI for user experience; this research combines quantitative occupancy measurements with qualitative service design techniques (customer journey, personas).

Keywords: Service design, customer journey, persona, occupancy, experience.

1 INTRODUCTION

A major part of the core business of a Facility Management (FM) department is managing space for organizations. In past years the main challenge for FM was to reduce costs, e.g. by increasing utilization and reducing the number of m^2 per person. (BCO, 2013; Van der Spil et

al., 2012). Although a challenge in itself, increasing utilization has its limits. Most consultancy and advisors prescribe an occupancy rate between 60% and 80% (BCO, 2013; CfPB, 2015), although Weijs-Perrée et al. (2016) have reported an occupancy rate of 88% for co-working spaces. A low utilization is not cost effective, but high rates may have a negative impact on the employees working in the building.

The case organisation for this research is a major financial institution in the Netherlands, a product of various mergers. Traditionally, it had a strong physical presence in business districts and city- and shopping centres throughout a large number of cities. Due to a change in business model, from a physical presence into digital channels, large numbers of widespread offices are no longer needed. Subsequently, offices with a low utilisation are being closed, combining the remaining business lines in more centrally located offices. As a result, one of the major office buildings of the organisation initially designed for approximately 3000 employees, currently houses more than 6500 employees. On average 2500 employees work in the entire building per day, but this number can peak at above 6000 people.

Utilisation of this building is near 95% on peak moments, resulting in lower employee satisfaction due to crowding. Employee surveys have shown that employee satisfaction is negatively impacted by this high occupancy rate and employees pinpointed problems regarding the availability of office space. The case organisation is not unique in this aspect. In the years to come a further movement to the head offices can be expected, furthering the pressure on already precious space in expensive buildings. This poses a challenge for the Facility Management department. A challenge that cannot be solved by the Facility Management departments' usual working processes alone.

2   LITERATURE REVIEW

In managing the office space, the Facility Management department focuses on optimizing services for core business; cost reduction and increasing productivity are common objectives (Gemmel et al., 2013; Jensen et al., 2012; Van der Voordt & Van Wegen, 2005). Both aspects are indicated as added values of FM in the FM Value Map created by Jensen (2010). Gerritse et al (2014) have shown that these two values are highly appreciated by financial institutions: a survey among users measuring their appreciation of the added values of showed that they gave the highest mark to provision of a comfortable and suitable workplace at office. Reducing square meters is one of the best ways to cut costs (Van der Spil et al., 2012; Baane et al., 2011; Apgar, 1993); it results in less rent, service costs and/or overhead. So, strictly from a cost perspective: an organisation wants to use as little office space as possible. Giving a corporate perspective; focusing on improving cost structures and increase asset utilization (Kaplan, Davenport, & Norton, 2004) This corporate perspective is the perspective used in this paper; and is the first of the two elements imperative in managing office space.

The second element is that of productivity. And in this case: the productivity that can be attributed to, or influenced by the built environment. Van der Voordt & Van Wegen (2005) distinguish two factors that influence productivity in buildings; the functional quality or utility value and the aesthetic quality. These two factors are described as form and function by Preiser and Vischer (2005). Where aspects of form and function can be assessed objectively, the influence it has on employees is of greater value for productivity. This is why usually user satisfaction studies are being performed in the field of Facility Management.

Occupancy studies are survey methods usually carried out to support reductions in the amount of workspace and thereby save costs (Oseland et al., 2013). Measurement of occupancy based on sensors for electro-magnetic signals (RFID, Wi-FI, Bluetooth) has been demonstrated to have the ability to provide occupancy information on user location, presence, count, identity and track (Labeodan et al., 2015). Up to now, these detection systems have been primarily used in research contexts to adequately estimate and/or simulate the number of users, in order to optimize energy consumption (Martani et al. 2012; Duarte et al., 2013; Klein et al., 2012). However, if both presence and location of building users are determined, preferably real time, facility managers would have an excellent tool to determine occupancy at any moment and use these data in decision making on reduction of m^2.

However, Van Maarleveld et al. (2009) have shown that employees are usually not evenly distributed over a building. If employees in an organisation do not have private desk, but shared desks, would it be possible to even out this distribution by informing them of (real time) occupancy of various workspaces? We as consumers already use real time information to decide what public transport to take or were to park (Caicedo, 2010; Chatterjee et al., 2002; Fonzone, 2015; Nawaz et al., 2013). Why not provide building users with real time occupancy information, with the purpose of persuading them to look for a workplace in less crowded parts of the building, in stead occupying there usual desk in a crowded area, even when the ambient noise will distract them and lower their productivity?

Therefore, this paper aims to answer the question 'To what extent does provision of RTOI influence average and maximum occupancy rates, and how do employees evaluate this RTOI information?'. To this end, occupancy rates of six areas (accessible to all employees) in the building were measured continuously, before and after introduction of the RTOI. Furthermore, the process of finding a workplace - before and after the introduction of RTOI - was mapped as customer journeys, in five panel groups of employees. The results show both the effect on occupancy rates of the six areas, and the experience of the employees using these areas.

3 RESEARCH METHODS

3.1 Case
The case study represents 8 areas within a large office of a major financial institution in the Netherlands, including 2 of the 80 team areas, 2 of the 6 catering areas and 1 of 3 event locations, with in total 231 workplaces. These are all areas in the building that are accessible to all employees. Other team areas have restricted access. Figure 1 shows the areas.

3.2 Occupancy measurements
Current methods of measuring occupancy are either from a historical point of view, for example using access cards as a mean to measure utilisation daily (NSecure, 2016) or not frequent enough, counting occupants for a period of time manually at best 6-8 times a day (Measuremen, 2016). Since the goal of this research is to determine whether providing real time information changes utilization, real time data collection is required.

For this research occupancy was measured by detecting roaming Wi-Fi signals of occupants in various areas. Standard Wi-Fi access points were used to pick up roaming signals from devices (phones, laptops). A network of access points was installed in the test areas for this purpose. However, people in the test area may carry several devices that emit a roaming signal, and this number of devices may be different in the 8 test areas. Therefore, for each area a

specific ratio was determined by a comparison of approx. 15 manual counts with 15 systems counts in all six areas. This ratio varied from approximately 1.5 signals for areas 1 and 2 to less than one for restaurant zones. Furthermore, three tests were performed to verifying the data quality. A comparison of the corrected Wi-Fi data showed a satisfactory accuracy of the measurement. A second test showed that the signals were placed in the correct locations (Fig. 2). The spatial accuracy of the system; placing a signal in the right area, is sufficient with a 95% confidence level.

Area team 1

12 desks
20 fixed employees

Area team 2

14 desks, 4 alternative workplaces
28 fixed employees

Flexible work area

6 desks, 20 alternative workplaces

Concentration area

12 desks

Booths

28 alternative workplaces

Forum

40 alternative workplaces

Restaurant

60 alternative workplaces

Terrace

35 alternative workplaces

Figure 1 Overview of the areas.

Signals were measured continuously. However, data were recorded every 5 minutes, and only data collected between 7.00 and 19.00, on weekdays, were used for the analysis. Outside this time frame occupancy was rarely above 8 unique persons for the whole test area. Data were collected for 6 weeks prior to the introduction of the RTOI, and 16 weeks after the introduction.

3.3   Customer journeys and personas

A suitable method to gain insights into user experience is by creating a customer journey. The basis for this was laid in the early 1980s by Shostack, and developed further in the field of service design. (Kalbach, 2011; Shostack, 1984). Business and consultancy sources provide a large number of whitepapers and reports on the subject of customer journeys (Kalbach, 2011), but academic research is limited.

Figure 2 Comparison on manually and system positions of people. For each person these two positions are linked by a straight line.

'The Customer Journey is a systematic approach designed to help organisations understand how prospective and current customers use the various channels and touch points, how they perceive the organisation at each touch point and how they would like the customer experience to be.'(Nenonen, Rasila, Junnonen, & Kärnä, 2008). And 'the customer journey map is an oriented graph that describes the journey of a user by representing the different touch points that characterize his interaction with the service' (Service Design Tools, 2016).

To create a customer journey (map) first all touch points need to be determined. Touch points are moments of interaction between the user and a service. Next, users are asked to grade their emotions at each touch point. The resulting graph is a visual representation of the user processes, needs and perceptions (Kramp, 2011; Van Oosterom, 2010). Because users are not a homogeneous group of people, often personas are created to that represent particular groups of users. Personas is a user-centred design tool originating from the field of human computer interaction (Chang, Lim, & Stolterman, 2008). They are fictional user archetypes (Long, 2009), used whenever a rich customer profile is required (Van Oostrom, 2010). Personas, may either be based on individual singular users, or created by combining various characteristics of real users into a single persona (Chang, Lim, & Stolterman, 2008).

In five panel groups customer journeys were developed. These customer journeys describe the process of finding a workspace from arrival at the office to being seated, with and without RTOI. Participants of the panel groups determined all steps in this process, and via empathy mapping indicated their subjective experience of each of the steps.

Approx. 50% of the employees working in the area were invited, 25 employees participated. All participants had experience working in the tested area. Their positions, responsibilities, type of work, age, and genders were representative for the population of employees working in this building. The panel groups were lead by one of the researchers, recorded and transcribed. Data were analyzed using open and axial coding, and used to create personas that illustrate different types of employees.

4 RESULTS

4.1 Occupancy rates

Figure 3 shows the average occupancy of the different test areas, based on the number of roaming Wi-Fi signals corrected for the average number of devices per person. Measurements before introduction of the RTOI are averages of 6 weeks, measurements with the RTOI are averages over 10 weeks; weekends and holidays were excluded from the data.

Before the RTOI was introduced, occupancy rates varied between approx. 7% and 38% (Fig. 3), somewhat lower than occupancy rates reported by e.g. Van Maarleveld et al. (2009). Especially the flexible offices and the concentration area were underutilized. On the other hand, the dedicated team areas 1 and 2 and the booths shows the highest average occupancy. However, these data are averaged over all data collected during 6 weeks. Fig. 4 shows the average of the maximum amount of employees per test area per day; occupancy peaked at around 70% for the team areas, whereas forum, restaurant, concentration areas and flexible workspaces do not exceed 20% maximal occupancy. This shows that indeed employees are unevenly distributed over the test areas, and several areas are underutilized.
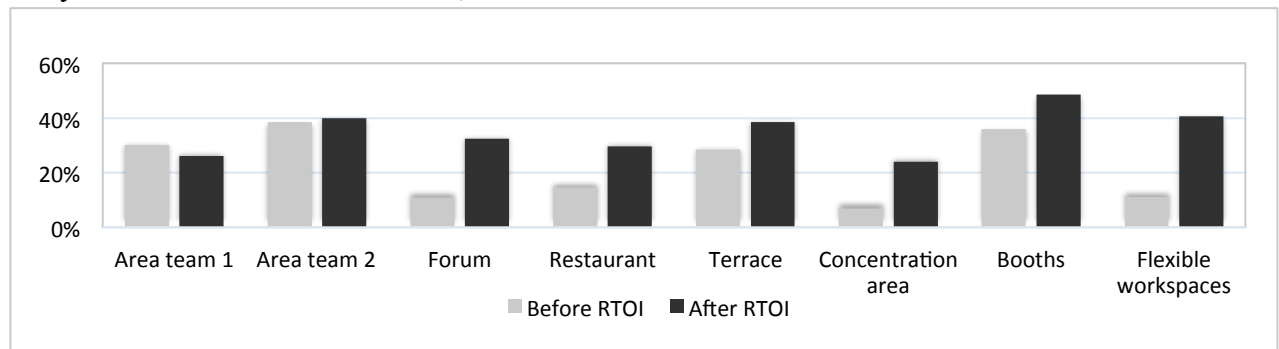

Figure 3 Average occupancy of the test areas before and after introduction of the RTOI.
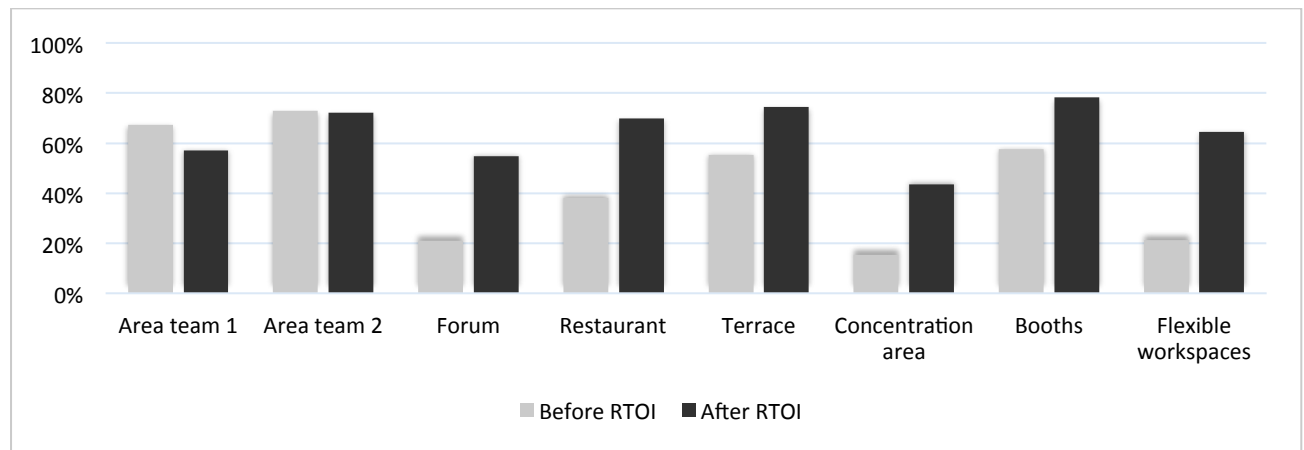

Figure 4 Maximum occupancy of the test areas before and after introduction of the RTOI.

In November 2015 the RTOI was installed: a monitor at the entrance of the building showed an indication of the available percentage of desks in each section of the test area (Fig. 5). The result of displaying RTOI was that both the average and the maximum occupancy of six test areas increased significantly. Occupancy of the flexible workspaces e.g. more than tripled.
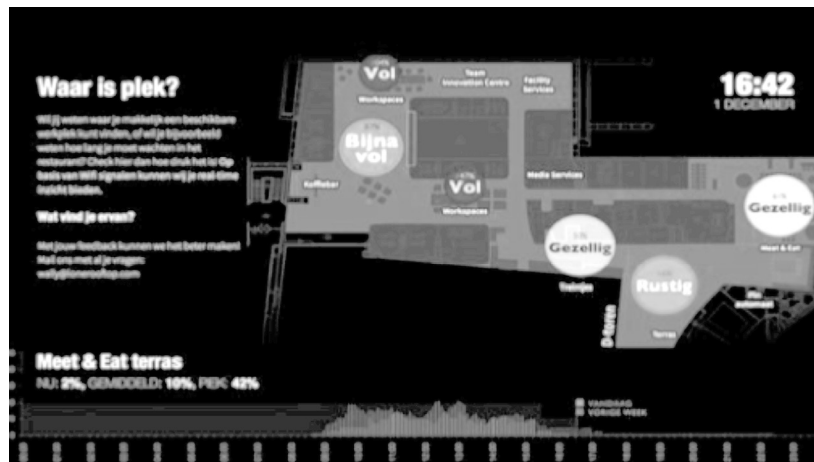
Figure 5 Monitor showing Real Time Occupancy Information (RTOI) for the test area. Indicated is no available workspace ('vol'), almost no available workspace ('bijna vol'), medium occupancy ('gezellig'), low occupancy ('rustig').

The RTOI had no effect on occupancy of the two team areas. The results of the personas will show that this is due to characteristics of the employees that frequently use these team areas. However, average occupancy in the other 6 areas was increased significantly. RTOI apparently creates awareness that these areas are available and stimulates employees to use these instead of areas with restricted access allocated to specific departments.

A more in-depth analysis of the data shows that the occupancy of terrace, booths and forum is not significantly increased on Mondays and Fridays, whereas on Tuesdays, Wednesdays and Thursdays one or two of these areas show a significant increase. The increase in occupancy for the concentration area, restaurant and flexible workplace was significant on each day of the week. This indicates that the effect providing RTOI is not merely a Hawthorne effect.

4.2 Customer journey

Figure 6 shows the customer journey for panel group 2, before and after the introduction of the RTOI. Group 2 consisted of two regular users of the test area, 2 frequent users and 4 occasional users. Indicated touch points were selection of a work area/building, travelling, entering the office building, meeting your colleagues, finding a workspace. On average, the respondents were (to some extent) satisfied with the whole process, except when they could not find a suitable workplace. One the touch point and dissatisfier 'elevator', included by two groups, was not mentioned by this group, other touch points are comparable.

Regarding differences before and after introduction of the RTOI: it somewhat increased the touch point 'being welcomed into the office' due to the possibility of checking availability when entering the building. Next is meeting up with colleagues. Meeting up with colleagues was still part of their journey whether there is information on occupancy or not. They did indicate a decline in satisfaction due to RTOI, losing contact with direct co-workers being the main reason. Third is finding a workplace, being highly dissatisfying when not finding a suitable workplace. The effect of RTOI is deemed very large in this aspect, completely removing the touch point 'Did not find a workplace that fulfils needs', indicating a big positive influence for this phase as a whole. Last, some of the group make the assumption that this is true for all types of workplaces, also positively effecting and simplifying the last touch points. Not all participants agreed, stating that the occupancy of some types is very high, not being able to find an available workplace, even with use of a RTOI system.
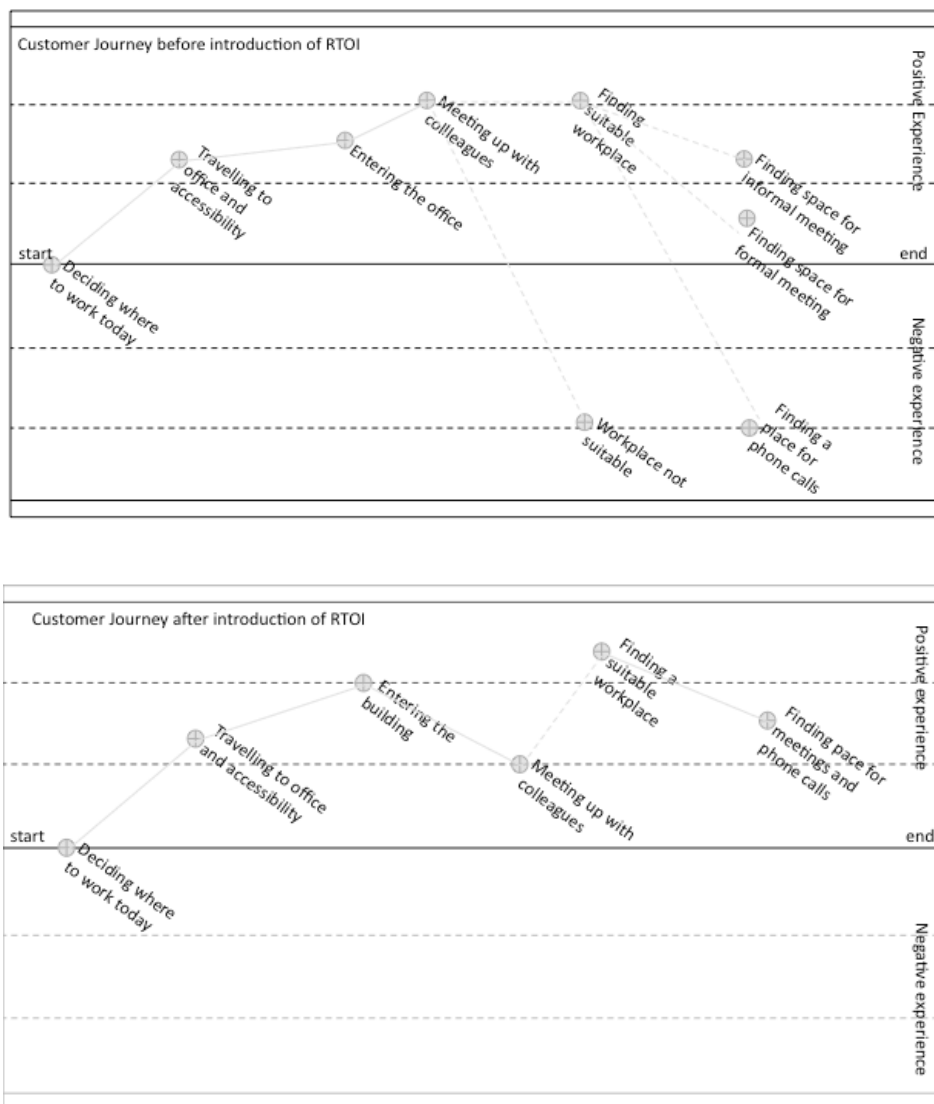
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Figure 6 Customer journey for the process 'finding a work place', starting at home and ending at find-ing a work place, before (above) and after (below) introduction of the RTOI, for panel group 2.

4.3 Three personas

During the panel discussions three patterns emerged, representing three different personas that illustrate different kinds of users. The descriptions of the personas are based on a detailed analysis of the transcripts of the panel discussions, and they illustrate why some employees will benefits from RTOI, whereas others will simply ignore this information.

Persona 1: Peter, the fixed worker

Peter has worked at the company for more than 20 years. He goes to the office every day, and works at the same desk, using the same chair, in a team area. He needs it, due to his back problems. Working effectively is something he is proud of. Working closely together with his colleagues on the adjacent desks, everyone always knows where to find Peter. That is im-portant, both for colleagues and suppliers, and for the customers. How else would you pro-vide effective service. RTOI? No use. His work place is always available. He's always early, and colleagues know that this is his spot, and just don't sit there.

Workspace preferences: Peter doesn't mind whether his workplace is in an open or closed environment, but he does want to have a private desk. He chooses his workspace because of both a social and functional orientation: he needs to be close to the colleagues in his team, and needs to be easily accessible for other colleagues. The team areas fulfil these needs, and RTOI does not add value for him.

Persona 2: Marie, the connected worker.
Marie has an ever-changing schedule, working on the same topics, but always at a different spot, but preferably not in the concentration area. Every day she starts by choosing where to work, depending on the people that she wants to meet up with. If Marie has no meetings, she stays at home: coming to the office is all about talking to people and working together. Marie works in a flexible manner, and changes location multiple times a day. Therefore, the 'perfect' work place often already taken. But, being flexible, she settles for anther desk in the vicinity. A minor inconvenience, as she does have some specific requirements for her workplace. These requirements are sometimes hard to find outside of normal working areas. When being confronted with the possibility of checking real time occupancy, she wonders if this technology also can be used to find the right people? If not, she would use this information as only a secondary source. Sure, it could help to find an available workplace, checking for requirements and still be close by. On the other hand, if there is no chance of sitting with the people she had in mind, possibly; there is another spot. And this spot likely provides new opportunities to her, expanding her network and adding to her job satisfaction.

Workspace preferences: as most of Marie's work at the office requires interaction with colleagues, she chooses her workplace and social grounds, close to the people she needs. She therefore prefers an open workplace that allows easy communication with different people. RTOI would be perfect for her if the system would also show who is sitting where. Furthermore, Marie's flexibility regarding her workplace also means that she will work at home whenever she does not need interaction.

Persona 3: Frank, the opportunistic flexible worker
Frank has a lot of work and tries to be as effective as possible. Frank knows precisely what type of working environment fits best with any of his tasks and picks his workplace very deliberately. He doesn't not mind where in the building that spot is (although he hardly uses the team areas, to crowded for his taste). Colleagues? If he needs to meet them, he'll organize a meeting or make a phone call. He reacts positive on the options offered by RTOI. This kind of information makes his life easier. When looking at the occupancy information, making a decision where the go. One thing is for sure, if he sees a floor is fully occupied, he won't go there. Better to walk a bit further and find a place that is more suitable.

Workplace preferences: Peter uses the RTOI to its full extent, as it shows him where in the building he may find a quiet space if he needs one. As his orientation when looking for a desk is purely functional, all he needs is RTOI.

5   CONCLUSION AND RECOMMENDATIONS

This study shows that occupancy rates can be increased by the use of RTOI, but also that this increase will depend on the type of employees involved. Three situations can be defined. In situation the organization primarily consists out of fixed workers (persona 1). People will hardly react to the RTOI, and may even show an adverse reaction. Minimal changes in factual and perceived use of a workplace are to be expected.

In situation 2 the organization primarily consists out of connected workers (persona 2). Implementation of RTOI will cause a partial change in behaviour regarding occupancy: employees that work in dedicated areas will choose a workplace close to their colleagues, diminishing the sought-after changes in occupancy, irrespective of the information provided by the RTOI. Only those that use flexible workspace will be influenced in their behaviour. In situation 3 the organization primarily consists of flexible workers (persona 3). The investment for RTOI in this type of organization can be worthwhile, as this group will use the new information to its full extent. Research shows a major increase in occupancy in especially flexible but closed-off sections of the building (e.g. concentration areas), thereby increasing the total realistic capacity of a building. Also sections like the company restaurant or event locations, normally with low utilization, will see a steep incline after implementing RTOI.

The realistic view on organizations is that these types are mixed. An organisation interested in using RTOI to manage occupancy needs to determine their mix of personas 1, 2 and 3. The situations drafted above therefore can be used to get an indication in what way the different, very recognizable types of people, will react to providing RTOI. However, in organisations with primarily persona 1, RTOI will not be cost effective. For organisations with primarily persona 2, it is recommended to add e.g. an App, allowing people to locate colleagues easily.

RTOI data can also be use to optimize cleaning services and security services, plan maintenance (the data will show on what days and time of the day certain areas are usually less in demand). Data may be used to determine what areas are underutilized; this is the first step in uncovering underlying reasons for limited use of areas. On a larger scale, RTOI data collected over a longer time period can be used to manage building portfolios. Each of these options will increase the efficiency of the building.

To conclude, the results of this study show that using RTOI may help facility managers optimizing occupancy rates of offices, provided that they gain insight in the personas present in the organisation, in order to predict the effects of the RTOI on employees' behaviour.

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THE INFLUENCE OF PERSONAL- AND BUSINESS CENTER CHARACTERISTICS ON SHARING TYPES OF KNOWLEDGE IN BUSINESS CENTRES

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ABSTRACT

Knowledge sharing is a process where individuals mutually exchange knowledge to create new knowledge. Understanding the knowledge sharing process, in which organizations share spaces, facilities and services, is highly important for business centres and their residents. However, there is hardly any research into sharing types of knowledge in business centres. This paper addresses this research gap and analyses the influence of personal- and business centre characteristics on sharing several knowledge types in business centres.

Data was collected by using a questionnaire that was completed by 268 users of 53 business centres in the Netherlands. A seemingly unrelated regression analysis (SUR) was used to simultaneously analyse the influence of personal- and business centre characteristics on knowledge sharing.

The results show that public- and private non-codified knowledge is more frequently shared with people from other organizations by those who have more business club memberships and more frequently use an event space, lounge space, canteen or consultancy services. Public codified knowledge is more frequently shared by people who use a flexible workspace. All types of knowledge shared with colleagues were influenced by the use of individual closed workspaces, meeting spaces and a restaurant/canteen, working as freelancer and gender.

Owners and managers of business centres can use these results to optimize their business centre by offering specific facilities, services and workspaces to attract a specific group of tenants. In addition, organizations that seek to promote knowledge sharing with other organizations could stimulate specific employees to use shared facilities and services.

Keywords: Business centre, knowledge sharing, facilities, personality, seemingly unrelated regression analysis

1   INTRODUCTION

Organizations, especially freelancers and SME's, are increasingly looking for an accommodation in a business centre because of several advantages, such as the decreasing need of workspace, the increasing need for flexibility and increasing need for a higher service level (e.g. Gibson, 2003; Barber et al., 2005). A business centre can be defined as 'a building with a number of spaces and possible some common facilities and/or services, which are offered to multiple organisations' (Calder and Courtney, 1992; Weijs-Perrée et al., 2016).

One of the most important advantages of a business centre is the opportunity for knowledge sharing with other organizations, because knowledge is a highly important resource for organizations (e.g. Wang and Noe, 2010). Four types of knowledge can be distinguished, namely sharing public non-codified knowledge, public codified knowledge, private non-codified knowledge and private codified knowledge (Marouf, 2007). This distinction is based on the level of codification (i.e. documented in some form) of knowledge and whether knowledge is public or private (i.e. not publicly available or guaranteed by third parties). It is recognized that non-codified knowledge is most important for the innovation process of organizations (Marouf, 2007).Therefore, for organizations, it is important to get insight in their knowledge sharing behaviour and which factors of the physical work environment of business centres influence sharing the different types of knowledge. Owners and managers use such insights to create work environments that stimulate specifically private non-codified knowledge sharing between organizations and thus make their office an innovative hotspot.

Research into the influence of the physical work environment of business centres on knowledge sharing between and within organizations is still scarce. Previous studies mainly focused on the influence of the layout of the work environment of single-tenant offices on knowledge sharing within a larger organisation. These studies showed that shared facilities or spaces, open and flexible workspaces are important for facilitating knowledge sharing (e.g. Staplehurst and Ragsdell, 2010; Kastelein, 2014; Rashid et al., 2009; Appel-Meulenbroek, 2010).

It is also recognized that personality and demographics are important indicators for knowledge sharing. For example, differences were found between men and women for sharing non-codified knowledge (Pangil and Nadurdin, 2008). With regard to personality, research showed that people who are more agreeable and conscientiousness are also more willing to share knowledge (e.g. Gharanjik and Azma, 2014; Matzler et al., 2008; Gupta, 2008). However, these studies all focus on knowledge sharing within larger organizations, instead of between smaller organizations (i.e. freelancers or SME's) at the scale of a business centre. In addition, so far, research into the relationship between personality, demographics and the physical work environment in business centres is limited.

The aim of this study is, therefore, to analyse the influence of personal- and business centre characteristics on knowledge sharing in business centres. Data was collected among 268 users of 53 business centres in the Netherlands. The data were analysed by using a seemingly unrelated regression analysis (SUR).

The following section reviews the existing literature on knowledge sharing, personal characteristics, the physical work environment and knowledge sharing. Then, the data collection and methodology are described. In the fourth section the main results of the analyses are discussed. The final section contains the conclusion and discussion.

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2   KNOWLEDGE SHARING

Knowledge can be described as (Alavi and Leidner, 2001, p. 109): *'information possessed in the mind of individuals: it is personalized information (which may or may not be new, unique, useful, or accurate) related to facts, procedures, concepts, interpretations, ideas, observations, and judgments'*

Several studies have tried to categorize knowledge into different forms or types. First, Polanyi's (1958) distinction between explicit and tacit knowledge is widely used in research on knowledge sharing (e.g. Nonaka et al., 2000; Seidler-de Alwis and Hartmann, 2008). In addition, it is recognized that knowledge can also be individual (within a person's mind) or collective (knowledge of a group of people) (e.g. Kastelein, 2014) in nature. Marouf (2007) used the terms codified and non-codified, instead of explicit and tacit knowledge, and whether knowledge is private (not publicly available or guaranteed by third parties) or public (available and verifiable through third parties), distinguishing:

- Public non-codified knowledge: general, work-related, context-free, depersonalized, verifiable through third parties and not documented in any form;
- Public codified knowledge: general, work-related, context-free, depersonalized, verifiable through third parties, documented in some form and written in the form of standard instruments (e.g. company reports and manuals);
- Private non-codified knowledge: personal or informal, context-specific, subjective, personally sensitive and not documented in any form (e.g. beliefs, viewpoints, insights and experiences);
- Private codified knowledge: informal or personal, context-specific, personally, sensitive, and documented in some form (e.g. correspondence and personal notes).

This typology is an extension of the widely known distinction between codified and non-codified knowledge, which is more reflective to real-world situations. For example, not all codified knowledge is available for use and not all non-codified knowledge is private (Marouf, 2007). These different forms of knowledge are simple, easy to use in models and easy to explain to people in practical life (Marouf, 2007; Mládková, 2014).

Especially, private non-codified knowledge is important for the target groups of business centres (i.e. freelancers and SME's), which is mostly shared through (informal) face-to-face interactions (Wang et al., 2010) and important to be creative and innovative (Ngah and Jusoff, 2009). In addition, it is recognized that non-codified (tacit) knowledge adds more value to the innovation process than codified knowledge (Marouf, 2007).

Knowledge sharing, which is an activity through which knowledge is exchanged, has received increasing attention. For example, Easterby-Smith et al. (2008) suggested that knowledge sharing between organizations is more complex than knowledge sharing within an organization, because of different boundaries, cultures and processes. However, organizations could improve their competitive advantage, knowledge and innovative capabilities by sharing knowledge across organizations (Easterby-Smith et al., 2008). Therefore, it is important to analyse knowledge sharing within and between organisations.

An increasing number of studies analysed personal factors (e.g. personality, demographics and work-related characteristics) that could influence this knowledge sharing. First, it is recognized that personality is an important indicator for knowledge sharing (e.g. Matzler et al.,

2008; Gupta, 2008). The Big Five Factor Model (extraversion, agreeableness, conscientious-ness, openness and neuroticism) is a generally accepted model for describing individual's personality (Cabrera et al., 2008). Previous studies showed that people who are more agreea-ble and conscientious are more involved in knowledge sharing activities (Gupta, 2008) and people who are more conscientious, agreeable, open and neurotic are more willing to share knowledge (Gharanjik and Azma, 2014; Matzler et al., 2008).

Next, several studies analysed the relationship between demographics and knowledge sharing (e.g. Ismail and Yusof, 2009; Pangil and Nadurdin, 2008). These studies did not find any re-lation between age, education level, work experience, organizational tenure, job tenure and knowledge sharing. However, evidence of the influences of gender differences is mixed. Studies showed that female entrepreneurs have a smaller entrepreneurial network (Klyver and Grant, 2010) and less often discuss their work during an interaction (Pangil and Nadurdin, 2008). On the other hand, Alhammad et al. (2009) found no significant relation between gen-der and knowledge sharing.

3   BUSINESS CENTER CHARACTERISTICS

Business centres could vary depending on the level of shared services and facilities/spaces that are offered. Several services can be described based on existing literature (e.g. Weijs-Perrée et al., 2016; Laterveer, 2011; Calder and Courtney, 1992; Ketting, 2014; Troukens, 2001), namely business services, secretarial services, cleaning and maintenance, security, managed technology, consultancy services, networking events, catering, use of coffee and tea makers and furniture. Business centres also provide concentration rooms, office space with fixed workstations, office space with shared workstations, a combination of fixed and shared workstations, atelier space, laboratory space, conference room, informal/social space, pro-ject/creative space, reception, kitchen, coffee corner, storage room, showroom or a business unit (Weijs-Perrée et al., 2016).

Previous studies showed the importance of the physical work environment for knowledge sharing within larger organizations. It is, for example, recognized that different office designs and workspaces probably could influence knowledge sharing in a different way (Kastelein, 2014; Suckley and Dobson, 2014; Rashid et al., 2009). Open-plan offices stimulate the num-ber of interactions and therefore probably knowledge sharing behaviour as well (Blakstad et al., 2009; Becker and Sims, 2001; Chigot, 2003). A workstation (desk) is one of the most important knowledge sharing facilities (Staplehurst and Ragsdell, 2010), because interactions often occur in or near workstations (e.g. Rashid et al., 2009). Van der Voordt and Van Meel (2000) suggested that a non-territorial office space (a workspace flexibly used by employees who do not own a workspace) could lead to problems for interactions, as people cannot find each other or a workspace. It is also recognized that meeting spaces (Staplehurst and Ragsdell, 2010), informal spaces (Chevez and Aznavoorian, 2014), flexible individual work-spaces (Binyaseen, 2010), open and common workspaces and common shared areas (e.g. kitchen, play/game rooms, lounges and library) (Kastelein, 2014) are important facilities or spaces that increase the number of interactions and eventually knowledge sharing.

In summary, based on previous studies in single-tenant offices, it is assumed that personal differences (i.e. demographics and personality differences), the use of offered facilities and services (e.g. meeting spaces, informal/social spaces) as well as the workspace type may in-fluence knowledge sharing (see Figure 1). Previous studies have not considered the influence of the physical work environment of business centres on sharing the different types of

knowledge. Especially in business centres, where organizations share spaces, facilities and services, and where knowledge sharing an important motivation to use these offices (e.g. Sykes, 2014), research on knowledge sharing is needed.
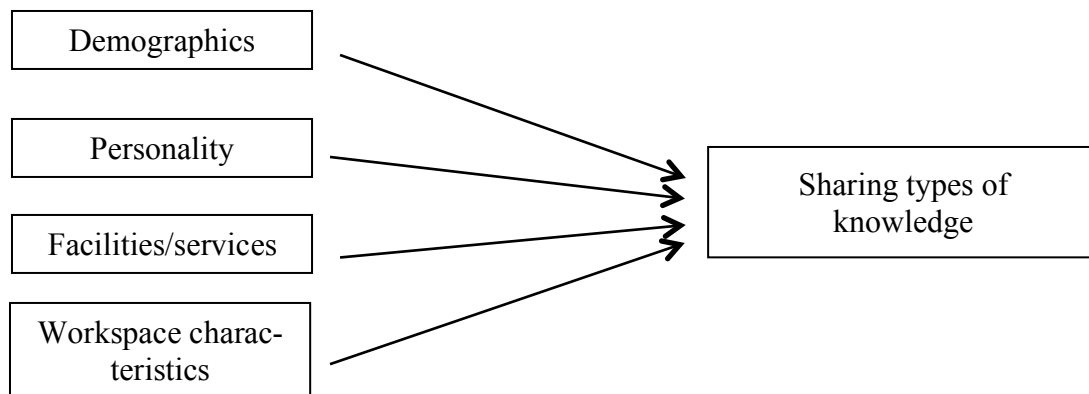

Figure 7 Conceptual model

4 METHODOLOGY

Data was collected in January and February 2016 by means of a questionnaire. In this questionnaire, open and multiple choice questions were asked about demographics, organizational type, workspace type, the frequency of using offered facilities and the use of services. The aim of the data collection was to collect data of users of 139 business centres that participated in a previous study. Owners and managers of these business centres were asked to distribute the questionnaire among all their tenants, who were subsequently asked to distribute the questionnaire among their employees. In addition, some business centre users were personally approached to increase the response rate. This resulted in a total of 299 questionnaires (177 online and 122 paper-and-pencil questionnaires). Only 268 questionnaires were used in the final analysis, because 32 questionnaires had several missing values.

The sample consists of 68% men and 32% women. The age of the respondents on average is 40.0 years with a standard deviation of 12.0. A high percentage of the respondents (80%) have a high educational level (undergraduate or post graduate). Most respondents work as a freelancer (30%) or work at a SME (39%). Only a small percentage of the respondents (15%) work at a start-up enterprise or at a large enterprise (8%). Many respondents (40%) work on a fulltime basis.

Respondents were also asked about their personality. Personality was measured based on the Five Factor Model (extraversion, agreeableness, conscientiousness, emotional stability and openness), using the Ten-Item Personality Inventory (TIPI) (Goslin et al., 2003). Respondents were asked to indicate if they agree with ten personality traits (i.e. extraverted, enthusiastic; critical, quarrelsome; trustworthy/ disciplined; anxious, easily upset; open to new experiences, complex; reserved, quiet; sympathetic, warm; disorganized, careless; calm, emotionally stable; traditional, uncreative), ranging from (1) strongly disagree, to (7) strongly agree.

The four types of knowledge sharing were measured based on the distinction by Marouf (2007). In the questionnaire, respondents were asked about the frequency, ranging from (1) never to (7) multiple times a day, they share the four types of knowledge sharing with colleagues and people from other organizations.

With regard to the business centre characteristics, respondents were asked about their workspace type and use. Respondents could choose from the following types of workplaces namely if they work alone in a closed space, together with others in a closed space, an open space with and without partitions. In addition, they were asked about the use of their workspace (i.e. a personal office that is used by one person, a workspace that is shared by two or more fixed users and a flexibly used workspace that is freely used by all employees) (adapted from Van Meel, 2000). Furthermore, respondents could indicate the frequency that they use an offered shared facility on a 7-point Likert scale ranging from (1) never to (7) multiple times a day. If the facility was not available in the business centre, respondents reported the frequency as 0 (never). In addition, the use of services was measured by asking respondents if they use (yes/no) offered services in the business centre.

Although the frequencies of sharing the different types of knowledge measured on a 7-point scale, these are considered as interval variables in the analyses. To simultaneously analyse the relations between different sets of personal- and business centre characteristics (independent variables) and different types of knowledge sharing (as dependent variables) in a single model system, a seemingly unrelated regression analysis (SUR) was used. A SUR is used when multiple regression equations, with different dependent variables that are related to each other and different sets of independent variables, are analysed at the same time (Sun et al., 2014). In this study, the equations with the four types of knowledge sharing as dependent variables are also related to each other. Therefore, SUR is a suitable method, as an extension of linear regression analysis that allows correlated errors between equations (Sun et al., 2014).

First eight multiple regression analyses (stepwise) were performed. Based on these analyses, variables that were found to have a significant effect on the dependent variables were included in the SUR analysis. The normal probability plot of the residuals of the regression analyses showed that most of the residuals are normally distributed. Some of the residuals are slightly skewed and therefore the results should be interpreted carefully.

5. RESULTS

The results of the SUR (see Table 2 and 3) indicate that the four sharing types of knowledge are influenced by demographics, personality, the frequency of using offered facilities/services and workspace characteristics. The regression sum of squares (SSR) measures how much of the total variation is explained by the regression. In addition, the mean square error (MSE) measures the fit to the data. The smaller the MSE, the better the model explains the data (Li, 2010).

The first model (i.e. knowledge sharing with colleagues) has an adjusted R^2 of 0.334 for explaining the public non-codified knowledge, 0.466 for explaining public codified knowledge, 0.459 for explaining private non-codified knowledge and 0.412 for explaining private codified knowledge. The personal- and business centre characteristics explain between 33.4% and 48.4% of the total variance of the types of knowledge sharing. In the second model (i.e. knowledge sharing with people from other organizations), personal- and business centre characteristics explain between 18.6% and 31.2% of the total variance of the types of knowledge sharing. In addition, probably other characteristics are important for explaining knowledge sharing with people from other organization than for knowledge sharing with colleagues. For example, differences in organizational cultural (Xerri and Brunetto, 2010), structure (Chen and Huang, 2007), size (Chevez and Aznavoorian, 2014) could also influence knowledge sharing between organizations.

5.1 Knowledge sharing with colleagues

The results show that the four types of knowledge sharing are all influenced by age (negative), being male (positive), frequently using a canteen (positive) and meeting space (positive), and having an individual closed workspace (negative). Kastelein (2014) also showed that open and common workspaces, common shared areas (e.g. canteen or lounge space) and meeting spaces are the most important facilities for enabling interactions between colleagues. In addition, meeting rooms could be seen as one of the most important knowledge sharing facilities for SME's (Staplehurst and Ragsdell, 2010).

Table 2 shows that people who work at a start-up enterprise share less private codified knowledge with colleagues than in other organizations (SME's or large organizations). More private non-codified knowledge is shared by people who more frequently use a space for copying and printing. An area for printing and copying stimulates unplanned encounters, for example when people are waiting for printouts (Hua et al., 2010). The results also show that frequently using a project- or class room negatively influences the frequency of sharing public knowledge with colleagues. As can be seen, knowledge sharing with colleagues is not influenced by one of the personality traits.

Table 2 Results knowledge sharing with colleagues

	Public non-codified KS	Public codified KS	Private non-codified KS	Private codified KS
	Coeff.	Coeff.	Coeff.	Coeff.
Personal characteristics				
Age	-0.037**	-0.037**	-0.041**	-0.029**
Male	0.558*	0.879**	0.829**	0.889**
Low education				-0.457**
Hours working				
Freelancer	-1.051**	-2.617**	-1.882**	
Start-up enterprise	-0.157	-0.331		-0.537*
Club membership				
Personality traits				
Traditional/ uncreative				
Trustworthy/ disciplined				
Sympathetic/ warm		0.087	0.104	
Frequency of using an offered shared facility/service				
Lounge space				
Event space				
Canteen/restaurant	-0.160*	0.175*	0.200**	0.201**
Space for copying and printing			0.0758**	
Meeting space	0.256**	0.224**	0.249**	0.259**
Project- or class room	-0.196*	-0.172*		
Consultancy services				
Workspace characteristics				
Non-territorial workspace				
Individual closed workspace	-1.286**	-0.968**	-1.029**	-1.152**
R^2	0.354	0.484	0.475	0.429
Adjusted R^2	0.334	0.466	0.459	0.412
SSR (Regression Sum of Squares)	990.861	1016.264	927.305	1092.32
MSE (Mean Square Error)	3.826	3.939	3.580	4.217

* and **, indicate that the coefficient is significant at the 0.05 and 0.01 level.

5.2 Knowledge sharing with people from other organizations

As can been seen in Table 3, freelancers share more public non-codified knowledge with people from other organizations in the business centre. Club-membership increases the frequency of sharing private non-codified knowledge. With regard to personality, traditional or uncreative people share less frequent private non-codified knowledge with people from other organizations (e.g. beliefs, viewpoints, insights, and experiences). Previous studies also showed that people who are more open to new experiences are more willing to share knowledge (Matzler et al., 2008; Gharanjik and Azma, 2014).

Table 3 Results knowledge sharing with people from other organizations

	Public non-codified KS	Public codified KS	Private non-codified KS	Private codified KS
	Coeff.	Coeff.	Coeff.	Coeff.
Personal characteristics				
Age				
Male		0.126		
Low education				
Hours working				0.004
Freelancer	0.234*			
Start-up enterprise				
Club membership	0.054		0.102*	0.054
Personality				
Traditional/ uncreative			-0.083**	
Trustworthy/ disciplined	0.0619			
Sympathetic/ warm				
Frequency of using an offered shared facility/service				
Lounge space	0.266**	0.285**	0.307**	0.339**
Event space	0.150*		0.138*	0.168**
Canteen/ restaurant	0.088*	0.093*	0.116**	0.094**
Space for copying and printing		0.021		
Meeting space				
Project- or class room				
Consultancy services	1.098**		0.301	
Workspace characteristics				
Non-territorial workspace		0.313		0.458**
Individual closed workspace				
R^2	0.283	0.201	0.269	0.312
Adjusted R^2	0.264	0.186	0.253	0.312
SSR (Regression Sum of Squares)	280.592	290.514	358.369	315.853
MSE (Mean Square Error)	1.079	1.109	1.373	1.210

* and **, indicate that the coefficient is significant at the 0.05 and 0.01 level.

The results show that the frequency of using a lounge space and canteen/restaurant increases the frequency of sharing all four types of knowledge with people from other organizations. In addition, people who use an event space more often, share public non-codified and private knowledge more frequently with people from other organizations. This is also related to the idea that common areas stimulate interactions between people (Kastelein, 2014). Private and public codified knowledge is more frequently shared by people who use a flexible workspace that is used by all business centre users. A previous study showed that interactions often occur in or near workstations (e.g. Rashid et al., 2009). Therefore, the use of workspaces is also very important for knowledge sharing, especially for sharing codified knowledge. Furthermore, the frequency of using consultancy services was found to have a positive influence on the frequency of sharing public non-codified knowledge.

6   CONCLUSION AND DISCUSSION

This study revealed that demographics, personality as well as business centre characteristics influence the four different types of knowledge sharing within and between organizations. With regard to knowledge sharing within an organization, only a few differences were found between the different types of knowledge. All types of knowledge sharing with colleagues were influenced by the frequency of using an individual closed workspace (negatively), meeting space (positively) and a restaurant/canteen (positively). Thus, the use of these informal spaces and working in a more open and flexible workspace is important for knowledge sharing. In addition, people, who are more willing to share knowledge, probably use more frequently these spaces.

Besides knowledge sharing within organizations, the study also analysed knowledge sharing between organizations, at the scale of a business centre. Especially frequently using an informal meeting space (i.e. lounge space, event space and canteen) is important for sharing non-codified knowledge with people from other organisations. Thus, owners or managers of business centres could focus more on knowledge sharing between organizations by offering more informal/social spaces (i.e. lounge space, canteen/restaurant and event space) and flexible and open work spaces. Also, managers of organizations should steer their employees to use informal/social spaces, meeting spaces and project spaces, to increase knowledge sharing with colleagues and people from other organizations.

Public non-codified knowledge is frequently shared by people who use offered consultancy services. No other relations were found with regard to services. This suggests that physical characteristics are more important for knowledge sharing with people from other organizations, than non-physical characteristics (i.e. offered services) of business centres. In addition, these services will probably be used less often than spaces and facilities. Therefore, owners and managers of business centres should focus more on the physical aspects of the building to attract innovative tenants that focus on knowledge sharing.

Overall, the results show new insights on the influence of the physical work environment of business centres on sharing types of knowledge within and between organizations. In addition, results show that knowledge sharing can also be explained by personal characteristics. These results are interesting for facility managers to focus on and support tenants that want to share knowledge and to be innovative. For example, facility managers could select innovative tenants, organize meetings between tenants that could learn from each other and organize networking events. They could also monitor the perceived support for knowledge sharing of tenants and adapt to these outcomes.

The generalizability of the results can be improved in future work by drawing on a larger dataset by analysing real-time knowledge sharing behaviour in business centres. Also, data from different countries could give more insight into cultural differences with regard to knowledge sharing. Further research is needed on this topic and needs to include several other important influences (e.g. network size, organizational culture, business sector and trust between people) to strengthen the analyses. Also, it would be interesting to analyse the influence of personal characteristics on knowledge sharing and thereby the mediating effect of the use of space. This would give more insight in different user groups of business centres and their knowledge sharing behaviour.

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Ways to Measure User Experience in Co-working Places

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ABSTRACT

The amount of Co-working places, which allow diverse users to rent offices and infrastructure on a monthly, weekly, daily or even hourly basis, is growing increasingly. These spaces tend to foster an interactive, stimulatingly interdisciplinary and pleasant atmosphere, and in this way potentially influence positively on our mood, well-being, motivation and productivity. Such an atmosphere and the corresponding user experience are, however, a sum of several elements – such as technical conditions of the environment, physical appearance and social collaboration and communication possibilities.

The aim of this paper is to describe a holistic way to measure the user experience of a co-working place through a case study. The investigated co-working space is called a living laboratory for new ways of working and well-being. It is located in the capital area of Finland and opened in 2016. The question answered in the paper is "How to integrate different methods and data sources to measure user experience of a co-working place?"

The results are presented in the form a Customer Journey Map, which is a visual interpretation of the overall experience with a service over time and across channels. This paper contributes to workplace development by presenting an integrative approach to combine data about performance of technical system, the building and the individual users. The integrative measurement technic provides a tool for facilities managers to combine the hard and soft data connected to user experience of a co-working place.

Keywords: Co-working, User experience, Well-being, Customer journey, Measuring

1   INTRODUCTION

Co-working spaces provide a productive, creative, and satisfying work atmosphere, not just for freelancers, but also for organizations (Rief and Stiefeel 2016). Giving employees the choice of where and how to work makes them more effective, and flexibility also makes employees happier (Gaskell 2016). The spaces invest into a pleasant atmosphere in order to contribute to the fact that an environment influences our mood, our sense of well-being, our productivity and our motivation.

A cosy atmosphere is a sum of managing both the technical conditions of the environment e.g. indoor air, thermal conditions, acoustics, lightning, functional space arrangements and elements of subjective individual experience like a response to individual needs and well-being, a response to social collaboration and communication as well as a response to cultural habits and values. Measuring and monitoring customer value or co-working place´s value to multi-locational employees is challenging (Nenonen et al. 2013).   According to Ouye et al. (2010), one third of examined companies did not track the distribution of how their employees use alternative workplaces.

The aim of this paper is to describe a holistic way to measure the user experience of a co-working place by presenting a case study. The question answered is "How to integrate the different methods and data sources to measure user experience of a co-working place?". The second part of the paper opens theoretical viewpoints of co-working places, user experience and well-being. The literature on co-working space was also assessed in order to get an insight to the latest research around the topic. After that the case study research design and the empirical results in the form of a customer journey are presented. The paper ends with conclusions and suggestions for future research.

2   CO-WORKING, WELLBEING AND USER EXPERIENCE

2.1   Co-working space typologies
Being a relatively new phenomenon, only few academic definitions of co-working spaces exist, and some differences in perspectives occur. For example Spinuzzi (2012) describes co-working spaces as "open-plan office environments in which they [coworkers] work alongside other unaffiliated professionals for a fee". Capdevila (2013a), however, views that such definition does not consider one of the most important features of co-working spaces, which also differentiates them from mere shared rented offices: the focus on the community and its knowledge sharing dynamics.

This paper focus on co-working spaces, which according to Spinuzzi´s (2012) classification are partly like Community Work Spaces, which serve local communities by offering quiet spaces for locals to work alongside each other and partly un-offices encouraging discussions, meetings and social interactions and generally recreating the office dynamics for independent workers. Capdevila (2013) draws upon the literature on industrial clusters (Porter 1990) to describe co-working spaces as micro clusters, which are intermediary-configurations between firms and their clusters (Capdevila 2013) that cultivate knowledge embedded in local places and relationships. (Capdevila 2014). Capdevila (2014) offers a nested model of three kinds of collaborative activities represented by the single term 'co-working'. The interest in this paper is both to resource-based collaboration where agents seek access to new knowledge and resources and relational collaboration where agents invest in the dynamics of the community as a whole rather than transactions between individuals. Knowledge is at the core of resource-

based collaboration and the health, vibrancy and 'absorptive capacity' (Cohen and Levinthal 1990) of the community itself is the focus of relational-collaboration. The maintenance of a culture of relational collaboration will thus likely involve judicious selection of participants by a co-working site, based on the logic of shared values and identity rather than a mere market transaction (Capdevila 2014).

The individual user is in the main role in deciding where to work. Self-employed people such as freelancers and larger organizations' mobile employees are the main user groups of co-working places. (Van Meel and Brinkø 2014). Co-working spaces aim to replace the stiff, competitive, closed office with an open, community-based environment (Ng 2016). Ross and Ressia (2015) state that much of the coworker research to date has focused on links between collaboration, innovation and entrepreneurship between unaffiliated 'free-lance' coworkers. They state that co-working centers are occupying an increasingly important niche area as an alternative workplace of choice for an emerging new cohort of workers and are therefore a highly relevant area of research in relation to the future of work in an era of deregulated labor markets, telework and rapid technological change.

2.2   User experience, well-being and co-working space

User experience is an important aspect of mobile technologies (Gebauer et al., 2010) and refers to a person's perceptions and responses resulting from the use or anticipated use of a product, system or service (ISO 9241-210, 2010). User experience is affected by the user, the system and the context, in which the interaction between user and system takes place (Forlizzi and Ford, 2000; Hassenzahl and Tractinsky, 2006). In co-working places context of use is the main differentiator of services and systems. Context of use includes user characteristics, tasks, as well as technical, physical, and social environment (ISO standard 13407, 1999).

The user experience is based on individual perceptions, which is context dependent and cannot be objectively measured. However there are varieties of ways to capture the knowledge of user – experience and create descriptions of the non-measurable, intangible conditions. (Nenonen et al. 2015) A space is a resource for people to do things. It has an identity and creates meaning in itself. It is an extension of those who use it and influences what users do and how users do it. We need to understand spaces to foster the purpose we ascribe to them (Ng 2016). According to Reason et al. (2016) there are four key factors in measuring customer experience: From who do you ask? In which channel do you ask? What do you ask? When do you ask it?   The channels need to be carefully chosen according to the purpose: what do we want to figure out? This is a truly important point for the measuring. Also the timing is significant: Customers do not want to answer the questions concerning the things that have happened in past (Figure 1).
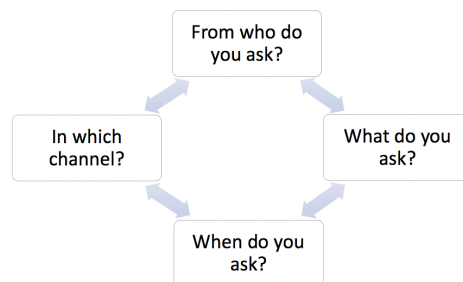

Figure 1 The key factors in measuring the customer experience (adapted from Reason et al. 2016)

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Various external context-related factors include physical, temporal, task, social, and technical and information contexts (Jumisko-Pyykkö and Vainio, 2010). Accordingly, Vischer (2006) has analyzed the workplace as a physical, functional and psychological entity in order to identify features related to comfort and fit between a workplace and an employee. When the environment sets inappropriate or excessive demands to users, in spite of their adaptation and adjustment behaviors, it manifests the concept of misfit. In a good fit there is a balance between a person's abilities, skills, degree of control and decision latitude and the work environment's demands, complexity, expectations and challenges. The nature of person-environment transactions arouses the sensation of either comfort or stress. Comfort may be considered as the fit of the user to the environment in the context of work (Vischer 2006).

When trying to understand a co-working space, it is important to measure two things: flows and interactions. Flows refer to the way that people move within a space. They signify how people walk through a space and the pace at which they do so; the frequency of and amount of time users spend in an area of a space. Additionally both the interactions between people as well as between people and the physical space are measurable. The tools needed to measure interactions are dependent on the kind of space (Ng 2016).

Study of 45 co-working spaces around the world (Waber et al 2014) discovered that people had chosen them because they believed that their performance would improve more rapidly in such spaces than in an office building or at home. Deskmag is a webportal, which publishes surveys and research findings about coworking, co-working related events, tips and spaces. Accordign to their survey (2011) more than 1,500 coworkers in 52 countries supported her findings:

- 75% reported an increase in productivity since joining their space
- 80% reported an increase in the size of their business network
- 92% reported an increase in the size of their social circle
- 86% reported a decrease in their sense of isolation
- 83% reported that they trusted others in their co-working space (Foertsch 2011).

Waber et al. (2014) also write about the case study about corporate co-working places and already their early results show that the small, shared nature of the neighborhood fostered mobility and created collisions on a greater scale. Exploration and energy were very high. After six months, data revealed a 42% increase in face-to-face encounters, a 78% increase in participant-generated proposals to solve specific problems, and an 84% increase in the number of new leaders—participants who initiated work and collaboration and developed project scope and objectives. Based on the research a new metric: "collision able hours," or the number of probable interactions per hour per acre. Research by Bosua et al. (2013) notes that employees identified increased feelings of wellbeing when utilizing flexible working choices where there were fewer or no work-related interruptions providing the ability to apply mindfulness to tasks with control over distractions.

Pestalozzi (2014) examined connections between relationships, co-working and the field of positive psychology and suggests that independent workers can use co-working spaces to support their personal and business relationship needs. Co-working spaces appear to be creating environments that promote relationship health specifically, and individual and community well-being generally. She also proposes that the study of human and institutional thriving can both inform and be informed by the practices being implemented at co-working spaces, in order to cultivate and elevate successful communities of flourishing individuals.

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Research conducted by Sterlitz (2011) indicates the importance of a change in scenery to keep feeling happy and healthy in the workplace. In fact, 74 per cent of respondents said changing up the location significantly helps improve work-life balance, which is why co-working spaces are taking off. The co-working place is provided as open space for defined user group within the owner-companies network free from charge. This co-working space will be investigated next by using both Vischer´s classification (2006) and investigation of flow and interaction with people and place.

3   RESEARCH DESIGN

3.1   Research methods

The purpose of this study was to describe a holistic way to measure user experience of a co-working place. Thus, the research question of this study was *"How to integrate the different methods and data sources to measure user experience of a co-working place?"*. With this question in mind, the research methods included both qualitative and quantitative aspects to assess the user experience. Qualitative methods included semi-structured interviews on user experience for people who had worked in the space several times. Quantitative methods included observation of how people interact and use the space as well as data provided by an automatic feedback collection system. Smileys feedback refer to a service by the company Happy-or-Not. The service consists of a stand with four buttons with smiley faces, ranging as follows: very happy (dark green) – happy (light green) – unsatisfied (light red) – very unsatisfied (dark red). It was equipped with a panel that had question "How satisfied were you with the space?". The question was in Finnish. The stand was located near the door to the co-working space, with the intention that the users would have an easy way to give instant feedback about their satisfaction as they leave. The Happy-or-Not system collected the data and performed analysis and reports. Additionally the indoor climate data was gathered by sensors. Individual worker's emotional arousal measurement was conducted by using special Moodmetric rings. Moodmetric is a ring that measures the electro-dermal (EDA) activity of a person. EDA refers to emotional arousal, which is a component of individual's experience of emotions. Being a measurement of the arousal component of emotion, EDA does not tell the describe the valence of the experience, i.e. whether the event was considered positive or negative. The Moodmetric ring collects the data with skin conductance, stores the data and sends the data to a mobile application. The mobile application visualizes the data.

3.2   Case study: a co-working place in Finland

The research design is based on a case study method. The investigated co-working space is called a living laboratory for new ways of working and well-being. It is located in the capital area of Finland and was opened in the Autumn 2016 (http://tyohuonepasila.fi/tietoa-tyohuoneesta/tilan-esittely/). 150 sqm place, which was unoccupied by owner, has been designed and developed together with a group of partner companies, which provided the technical infrastructure and indoor environment solutions as well as furniture and digital infrastructure and services for the co-working place, which activate users and even the well-being of brains during the work. The technical systems include solar panels for energy consumption as well as the state-of-art ventilation system.

The users are mobile knowledge workers from the stakeholder network: they have workplace provided by their employee but use the co-working place occasionally. The access is offered to the members of the companies and their clients who have been joining to the design and realizing the concept. There is no fee for the use during the first testing phase.

Zoning was in a major role in space planning. There are zones for

1. Presenting and exhibiting zone (violet)
2. Informal meeting in cafeteria (light green on the left)
3. Brainstorming zone (green on the right)
4. Individual working zone (blue)
5. Formal meeting in team rooms (grey)

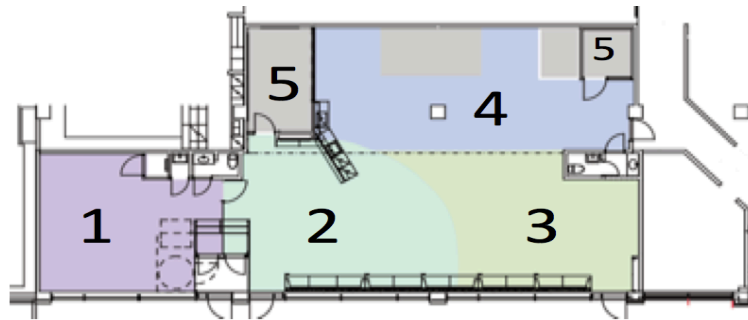These zones are presented in the Figure 2 below.


Figure 2 Zoning in co-working place

Co-working place is partly open plan environment. The attention has been paid to the acoustics and the visual contact in the space. Flooring, walls and ceiling have their own attractive features e.g. paintings.

The cafeteria area (Picture 1) is for a cross-communication flow between coworkers. There are rules that one should comply with in order for the users to feel good. The tables have an anti-bacteria surface.
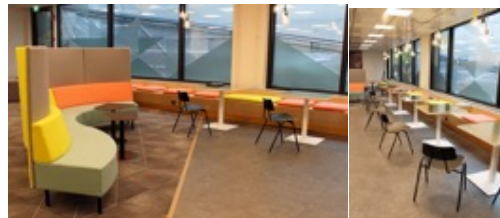
Picture 1 Zone (area 2 in fig. 2) for informal collaboration

Brainstorming area (Picture 2) stimulate not just the creativity of the users but also their productivity providing e.g. wall painted with a special paint that allows writing directly on it. This helps users to structure their thoughts and define them visually. The intention is not only to boost the brainstorming sessions but also give life to place if to have creative people with painting skills.
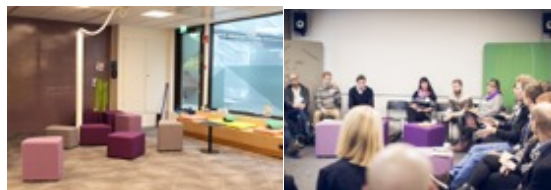
Picture 2 Brainstorming zone (area 3 in fig. 2)

Showroom is for presentations and exhibition. It is good option for putting on micro-events for the users of the community. Individual working area (Picture 3) has diverse options for

working and having break. The adjustable furniture and diversity to work in different positions is supported.

Picture 3 Individual working zone (area 4 in fig. 2)with different solutions

Lot of effort have been put to communicate with the users and get their feedback. The intention is that co-working space pleases users and makes them happy. There are various ways to gather as much feedback as possible about the concept and how to improve it.

4   RESULTS

The data gathering has been taken place during the autumn 2016 by different methods. The diversity of number of users in different days and weeks have made the first testing phase challenging and the data so far is in this point providing only some directions for thorough investigation.

4.1 A holistic way to measure user experience in a co-working place

By combining the measurement of flow and interaction with Vischer´s (2006) comfort factors (physical, functional and psychological comfort) the following methods were identified (Table 1). The case results described in this paper base especially on diary, observation and interview data, but also the sensor and smiley feedback data were used in the analysis in order to have holistic view. The used data sources in the case study are highlighted with blue color in Table 1. To sum up, the table below describes generally what can be measured in the co-working space and how, the blue cells refer to data sources used in this study.

Table 1 Ways to measure user experience in co working places

	Physical comfort	**Functional comfort**	**Psychological Comfort**
Flow of people	Sensors: Indoor environment conditions in different zones	Sensors: The movements in the space, data from reservation system about the reservation rate	Observations: Users using different zones and having ownership of the space
Interaction with place	Sensors and observation: users using the adjustable possibilities to effect to indoor environment	Observation: users using the possibility to arrange the space according to their needs	Smileys feedback system: Satisfaction with the space Observation: Users using the well-being programs or other well-being solutions
Interaction among people	Observation: Amount of interaction, situations of interaction Diaries Interviews: Experiences of social activities	Observations: Amount of meetings: Diaries Interviews: Experiences of the meeting facilities and accomplished tasks	Emotion measurement Diaries Interviews: Individual stress-level Satisfaction with the work done in the place

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4.2 Physical comfort

The data produced by sensors indicate the indoor environment conditions (Picture 4). It also activates the user to regulate the temperature of the room. Based on feedback this increased the satisfaction e.g. in showroom area, when there was an event for more than 20 people. The possibility for all participants to see the indoor environment conditions and the possibility to adjust them made the conditions for the event more comfortable as well as manageable effecting also to functional comfort. According to the interviews, the indoor air quality is regarded very good and fresh, but occasionally the co-working space is too cold.

Picture 4 Sensors and user interface in case study space

4.3 Functional comfort

The flow of people has been investigated e.g. by collecting the information about the use rate of the place by using the data about the entrance sensors (Figure 3).
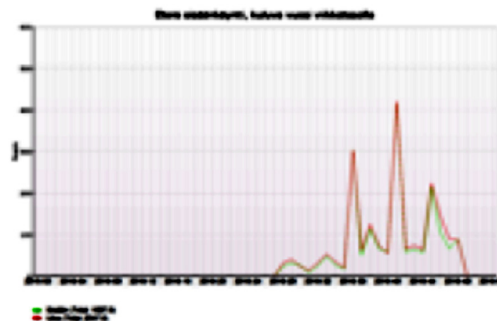

Figure 3 The entrance rate to case study place

According to the observation results the functionality of the place needs improvement. The issues e.g. signage, instructions for different equipment, cafeteria area, wi-fi connections have caused some confusion. The same themes were found in the interviews, during which people wished eg. more ergonomic chairs, lockers for personal belongings and basic white boards to help innovation. In connection to interaction among people observation results indicate that diverse users tend to stay in their own tasks and the interaction across diverse groups is occasionally. The communication among larger groups e.g. using showroom area seems to happen more. The use of well-being elements in the space has occurred, but more based on the curiosity than on systematic use.

4.4 Psychological comfort

The approachable, anonymous and easy-to-use 4 Smileys feedback system was used to collect feedback from the case study place by visitors. There was a question to capture the users´ feelings. The question in the first test period has been "How satisfied were you with the space?" (in Finnish). The system provides feedback reports weekly or daily basis (Table 2). The n refers to the amount of feedback to the Happy-or-Not smileys feedback system. The n means how many answers are given to the category in question and the categories are very happy, happy, unsatisfied, very unsatisfied. For example, during week 42 12 people were very satisfied with the

space. The percentages refer to how the given answers are divided between categories, as in week 42 98% of the feedback was "very happy" and the rest 8% was "happy".

Table 2 Results from smileys feedback system

week	Very happy	Happy	Unsatisfied	Very unsat-isfied	Very happy	Happy	Unsatisfied	Very unsat-isfied
	n	n	n	n	%	%	%	%
42	12	1	0	0	92	8	0	0
43	18	4	0	1	78	17	0	5
44	25	1	0	0	96	4	0	0
45								
46	31	4	1	0	86	11	3	0
47	22	1	0	0	96	4	0	0
48								
49	33	1	0	0	97	3	0	0
50	105	11	1	3	87	9	1	3
51								
52	1	2	0	0	33	67	0	0

Users seemed to be very satisfied with the co-working space. There are few weeks without activities due to the holidays. According to the interviews, the interior design and colours in the space are pleasant and the general look of the space is attractive. During the days when there were only few people working in the space, some interviewed people complained that the quietness of the space is even scary.

In order to get deeper information about user experience and psychological comfort the Moodmetric ring measures were conducted with the test group. The ring was used through the day and it worked as a sleep tracker in the night. In this phase the data from three people using the ring has been achieved. The data consisted of the ring EDA-data (electro dermal activity) and diary documents. During the measuring period the users used different work settings, including the co-working space. According to the first results no preliminary links between use of a certain work space and stress levels were found. However, this data need to be investigated more thoroughly and the interpretation of the result need to be contextual – that is why the additional data with more interviews is important.

4.5   Customer Journey framework to integrate the variety of data

In our research we found out that many kinds of measurements are useful, when measuring the user experience of a co-working place and the factors that effects on users' wellbeing, but the challenge is to present the data from different data sources in a comprehensive way. To visualize the measurements and the results, we ended up using a chronological service blueprint with different channels (digital, social, physical, experimental). The comfort factors and the findings of flow and interaction are more easily described by this framework. The next phase of data gathering will be categorized according to the following framework. Customers move through different phases and stages and want to get value out of them. Service blueprint includes a Customer Journey Map, personas, timelines, emotions, touchpoints and

channels. The underlying ecosystem providing the infrastructure and platform for experiences is analyzed carefully (Figure 4)
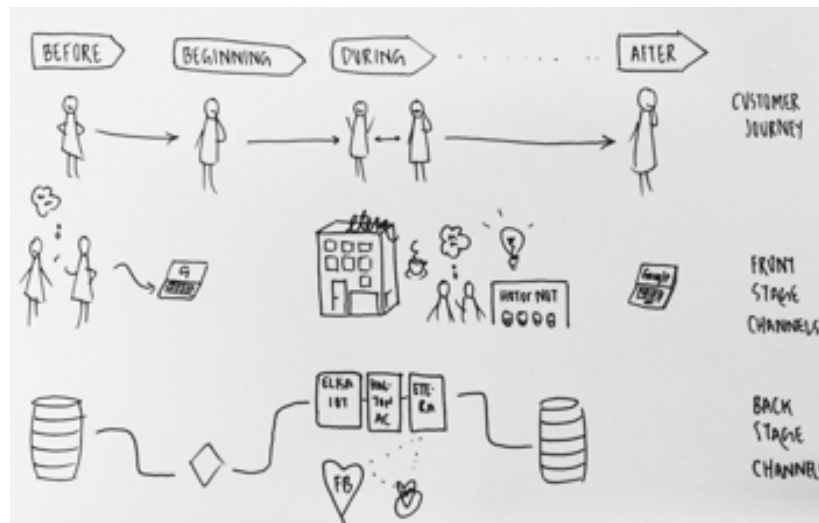

Figure 4 Customer journey

Reason et al. (2016) divided the timeline into four segments, which describes the phases *before* the customer relationship starts, the *beginning* of the relationship, and how the relationship develops *during* the relationship and *after* it. The customer experience begins before the actual customer relationship starts, and the customer is browsing through the available options. Using the co-working space customer, a freelancer or a corporate employee had heard about the co-working space from the colleague or found the place from the www-pages of the investigaged co-working place. Booking system for a suitable space or room had functioned well, but it could include e.g. pictures about the places – now the information is only provided as written text. In the *beginning*, user arrives to the coworking space. This critical touch-point got very good feedback – the location is suitable for the users, it is easy to access and it is also easy to find. The availability is good too.

In our context, *during* means using the space, meeting rooms, show room, wellbeing equipment etc. The feedback has been really positive and people using this particular co-working space seem to be fairly courious – all of the provided wellbeing equipment (both digital and physical) have been in use, and people think that the use is fun and easy. The attraction is in the possibility to use variety of different places and solutions based on their activity. The multiuse of the space was also mentioned as an important factor. In practice this means that people carry furniture to different places and are crafting the place. Users have an ownership to the place.

After leaving the space, feedback was asked both in written and digital format. The methods were easy-to-use and voluntary. Some of the loyal customers were also interviewed for further service development as well as some of those users, who have used the space only once, but never returned. The loyal customers state that the positive experience of use engage them to come back and also to bring their colleagues or customers with them. The one´s who never returned referred to functional reasons as a reason for not coming again: their needs were not fulfilled with the concept. The feedback was gathered also from social media: tweets in twitter by visitors and users have been analysed and the general characteristics of the tweets is positive.

5   CONCLUSION

This paper has searched answers to research question of "How to integrate the different methods and data sources to measure user experience of a co-working place?" Through theoretical discussion on co-working, work wellbeing and user experience the grounds for empirical case study were firstly built. The case study was then designed and carried out in order to find appropriate techniques to holistically measure the user experience in co-working spaces.

The user experience was measured in this study by integrating the different kinds of available data sources. As conclusion this paper proposed the Customer Journey Map as a framework for analyzing the overall user experience. This kind of mapping has been used often in consumer behavior studies in retail context, but based on the present study it offers also a fruitful framework for workplace development studies, particularly in the context of co-working spaces, where the employee can easily be understood also as a customer who chooses for the appropriate working space and evaluates the choice from several viewpoints, The results of the study bases on just one case co-working place, and for this reason the integrated measurement technique still needs more validation through other co-working space cases. The well-being data and its interpretation need to be investigated not only in physical but also in digital context.

The Customer Journey Mao can be used as practical tool for facilities managers to combine the hard and soft data connected to user experience. Results by integrative method can be used in both current state review and future state visioning. The originality is based on integrative approach to combine data about performance of system, building and individual as a basis of user experience of a co-working place.

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Modern Learning in Universities of Applied Sciences: How to align bricks with future education?

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ABSTRACT

Purpose: This study aims to explore Modern Learning (ML-)scenarios in Dutch higher education towards 2030 and corresponding consequences for Facility Management (FM) and Corporate Real Estate Strategy (CRES) of Dutch Universities of Applied Sciences (UAS).

Design/methodology/approach: The Designing-an-Accommodation-Strategy-model is used to retrieve the match between demand and supply in real estate of Dutch UAS for both the present and future. The application of this model resulted in a scenario-planning session with education experts to determine future demand in education towards 2030. Subsequently, the Corporate Real Estate (CRE)-managers of nine Dutch UAS were interviewed concerning this subject.

Findings: The results show that the CRES of Dutch UAS is only partly aligned to the consequences of Dutch ML-scenarios towards 2030. Most respondents possess real estate portfolios that are only partially flexible, so changes in qualitative and quantitative demand due to ML-scenarios are not easy to adapt to. The consequences for FM and real estate of two ML-scenarios seem manageable for Dutch UAS, whereas the other two ML-scenarios lead to major portfolio problems.

Originality/value: There is an on-going interest in developments in higher education combined with FM and CRES and its alignment with the corporate vision. Previous studies into modern ways of learning mainly focused on the organisations themselves. However, this study is explorative and explores possible ML-scenarios. These scenarios can contribute to awareness among Dutch UAS and those abroad in relation to setting up a long-term vision. Moreover, these scenarios enable Dutch UAS Facility and CRE-managers to develop a future-proof strategic housing plan aligned with the corporate vision.

Keywords: Modern Learning scenarios, Dutch Universities of Applied Sciences, Corporate Real Estate Strategy, CRES alignment, Facility Management.

1 INTRODUCTION

There is broad agreement that the Western world's economy is changing from an industrial to a knowledge-based and learning economy (OECD, 1996; Powell & Snellman, 2004; WRR, 2013). This new economy is driven by developments in Information Technology (IT), it affects the labour market and results in new didactical methods used (Sursock, 2015). Educational content and skills taught need to be aligned accordingly (Vergunst, 2010; Van den Oetelaar, 2012; EIU, 2014). These developments are captured under one heading in this study: "Modern Learning".

Modern Learning (ML) is demand-driven, self-responsible learning in a blended enriched learning environment accommodated by IT applications in a global setting. ML enables students to learn whenever they want, wherever they are. One of its major examples is e-learning with several applications, such as blended and game-based learning. E-learning causes a paradigm shift from supply-driven to demand-driven learning (Garrison, 2011; Beckers & Van der Voordt, 2013; Johnson et al., 2016). Due to ML, the Universities of Applied Sciences evolve from a place of knowledge-transfer into a place that facilitates project-based collaboration between students, with the lecturer as coach.

Higher Education in the Netherlands consists of Dutch UAS and Research Universities. UAS offer higher vocational education programmes, and can be compared with Polytechnic Universities. After 4 years of theoretical and practical training, students are awarded a bachelor degree. Research Universities offer bachelor-master programmes, whereas only some UAS offer professional masters.

With regard to Dutch Universities of Applied Sciences, ML results in more competition between UAS, a fading border between learning and working, an abundance of information and knowledge, and raising knowledge networks (communities). Simultaneously education is confronted with increasing globalisation and internationalisation, as well as growing emancipation and assertiveness of the individual (OECD, 2009; Van 't Riet, 2013; Sursock, 2015; University of Oxford, 2015). This strong focus on internationalisation will persist in the future: research Universities and UAS together have set an agenda for internationalisation with 4 shared ambitions, among which the ambition to deepen and broaden strategic partnerships across borders, and to increase the participation of Dutch students in international internships or exchange programmes (Vereniging Hogescholen, 2017).

As a consequence, these developments result in a very different demand in the usage, function and size of real estate in higher education (Pinder et al., 2009; Den Heijer, 2012; Beckers et al., 2015a; Johnson et al., 2016). This paper therefore aims to answer the following research question: are Dutch UAS capable of aligning their real estate strategy with the consequences of Modern Learning towards 2030?

2 THEORETICAL BACKGROUND

2.1 Corporate Real Estate Strategy

Since the early 1990s there is an interest in aligning the Corporate Real Estate Strategy (CRES) with an organisation's goals. In this context Nourse and Roulac (1993) stated that "an organisation's real estate decisions will be effective to the extent such decisions support the enterprise's overall business objectives". However, several studies indicated that many Dutch UAS buildings are not sufficiently equipped for future needs and that the majority of

Dutch UAS had little or no integral long-term visions on education without corresponding strategy for real estate and facilities (De Vries *et al.*, 2008; Beckers & Van der Voordt, 2013, 2014; Beckers *et al.*, 2015a).

2.2   CRES at Dutch Universities of Applied Sciences

In 2015, Dutch UAS enrolled nearly half a million students (Vereniging Hogescholen, 2015a). These institutes have an estimated 2.34 million square meters floor area of buildings, based on an extrapolated benchmark study of NFC (2014). De Vries *et al.* (2008) indicate that real estate of Dutch UAS is not sufficiently prepared for future demands due to limited understanding of the alignment of educational real estate with new developments in education as part of the corporate strategy. More recently, Beckers and Van der Voordt (2014) carried out a study among Dutch UAS that showed the necessity to bridge the gap between the CRE-manager and education, corroborating the findings of De Vries *et al.* (2008). Besides, Beckers *et al.* (2015b) illustrate that Dutch UAS lack a long-term vision on education while the "CRE-managers have to cope with the dilemma of having a time horizon for their property that goes far beyond that of education". In the transition from traditional education towards ML, a different learning and working environment is required. Several studies pinpoint the value of the proper spatial surroundings for the intended function and usage as this environment can add value to the primary process when it is aligned with its function (Kok *et al.*, 2011; Van Sprang, 2012). It is precisely this foreseen transition in education that is not adequately taken into consideration by Dutch UAS as they tend to react passively to education innovation. As a result UAS lag behind social and technological developments (Van 't Riet, 2013). De Vries (2007) concludes that in case of an insufficiently aligned CRES to the corporate goals, a significant discrepancy might arise between the intended and achieved results. This lack of vision combined with a building portfolio lagging behind changing demands due to ML, means it is critical for Dutch UAS to develop a future-proof strategic housing plan. Such a plan must be aligned with the organisation's vision, mission and strategy in order to (continue to) add value to the organisation's internal clients (Krumm *et al.*, 1998).

2.3   DAS-framework

In order to make recommendations on the real estate strategy of Dutch UAS, it is necessary to determine the gap between the current housing supply and the future demand. With the 'gap'-analysis a comparison is made between the actual performance (ist) and the desired performance (soll). In the field of CRES, De Jonge *et al.* (2009) developed the validated Designing-an-Accommodation-Strategy-(DAS-) framework. Van der Zwart *et al.* (2009) combined the DAS-framework with the scenario planning method, as depicted in Figure 1.

Figure 1 DAS-framework combined with scenario planning (Van der Zwart et al., 2009).

3 METHODOLOGY

This qualitative study combines literature review, a scenario planning session with 6 leading field experts and academics, and in-depth interviews with CRE-managers of the 9 largest Dutch UAS. The participating UAS are located throughout the Netherlands. Together these UAS represent circa 300,000 students, corresponding to approximately 68 per cent of all students at Dutch UAS.

The research framework for this study is based on the DAS-framework (Figure 1). By interviewing CRE-managers of the 9 largest UAS the match between current demand and supply was retrieved. The future demand was determined by applying scenario planning with a group of experts. Scenario planning is a technique where one can learn about, and manage uncertainty within, the strategic planning process of organisations and companies (Van der Heijden *et al.,* 2002; Harris, 2013). The panel consisted of 6 experts, all related to the education sector (lecturers, researchers, business suppliers of (virtual) learning environments and advisors in strategy and change processes). Each of the experts is linked to the mayor developments in new ways of learning as retrieved in the literature review. The scenario planning session resulted in 4 ML-scenarios. These ML-scenarios were subsequently discussed with the aforementioned CRE-managers. The housing consequences of ML are determined by matching future demand (target year: 2030) with the current supply of UAS's real estate.

4 RESULTS

4.1 Current supply and CRES
Nearly all CRE-managers interviewed do have a real estate strategy or long-term housing plan, but this is not well aligned to the corporate strategy. It was found that the participating UAS – without exception – have a short-term corporate vision, which impedes the CRES alignment process because real estate has a far longer time horizon. However, a CRES with flaws can still correspond to the supply concerned. Key aspects in the CRES (and FM strategy) of the respondents are campus development, facilitate meeting, minimising occupancy costs and increase flexibility. In some cases these strategies interfere with each other, *e.g.* minimising costs has a negative influence on flexibility and *vice versa*. Executing these strategies is an on-going process. Overall, the CRES of the UAS corresponds with their supply, although this CRES in itself is not well aligned to the corporate goals due to a short-term corporate vision.

4.2 Current demand
On the demand side, the CRE-managers experience a minor change in users' space requirements. A shift has occurred from the traditional classrooms towards new open spaces that are used for projects carried out by small groups, albeit on a small scale. The CRE-departments responded to this demand and facilitated not only this change but also the need to stimulate (informal) meetings and encouraging social contact as addressed by their CRES. Despite the aforementioned change in demand, the interviewees assess the user's demand as rather traditional and unclear. Almost all respondents mention the importance of actively retrieving core needs underlying the demand. The CRE-managers apply varying techniques to retrieve these. They indicate that by continuously asking questions, this eventually leads to quite another demand. The user's input in demand is often focused on solutions instead of presenting the needs.

4.3 Current match
Based on the DAS-framework, the match between current supply and current demand was scrutinised by questioning the CRE-managers. It was found that the current real estate (sup-

ply) of the participating Dutch UAS matches the current demand, whereby noted that this demand is rather unclear, traditional and expected to change towards near future. Notwithstanding, the CRE-managers do their utmost to identify the user's (current and) future demand. To cope with the absence of a clear (near) future demand, the CRE-managers focus on flexibility. The perception of what flexibility is, and the actual (physical) flexibility of UAS's real estate, varies per CRE-manager. In general, younger buildings are more flexible, although not all on a building (component) level. Altogether the process of matching demand and supply is far from optimal. The user's demand is not incorporated in the CRES, nor can it be derived from the corporate vision and strategy, but the answer – flexible real estate – is. Still, the respondents keep trying to understand user demand in order to adjust their real estate towards the future, substantiating that their portfolios are not fully aligned with their CRES.

4.4 Future demand: Modern Learning scenarios

Using scenario planning techniques, the expert panel determined 4 ML-scenarios for Dutch UAS towards 2030. Firstly, based on the STEEP analysis tool (which stands for Social, Technological, Economical, Environmental and Political themes), the panel identified the most important developments whereof they expect will change Dutch higher education towards 2030. The acquired developments were pooled jointly and clustered by the panel. Secondly, the panel determined the pattern of change of these clusters (trend, hype, gradual and abrupt discontinuity). Thirdly, the clusters were assessed on impact and placed in an impact diagram (Figure 2). In this figure the horizontal axis represents the degree of uncertainty from low to high. The vertical axis represents the impact level from low to high impact.
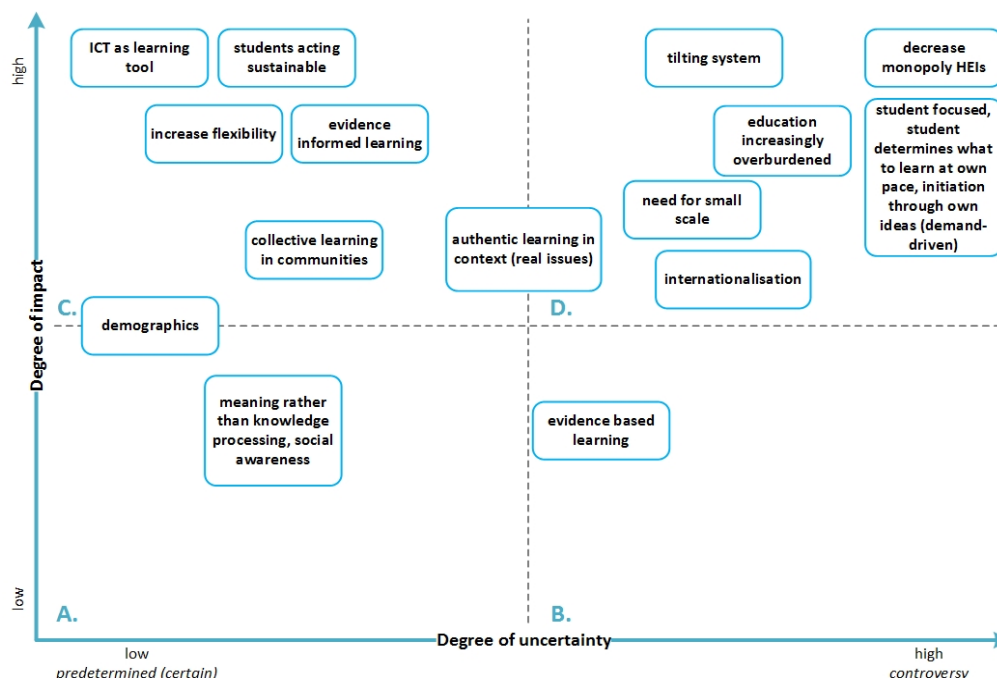
Figure 2 Impact diagram

The driving forces in the quadrants A and B have an impact below average, and are therefore excluded for scenarios of Modern Learning in 2030. In the quadrants C and D, all clusters have an average to high impact resulting in the driving forces for Modern Learning. Lastly,

the key uncertainties were derived from the main driving forces, being a movement towards student-focused demand-driven education, and a student-focused system changeover where Dutch UAS lose their current monopoly.

These key uncertainties resulted in two axes that are plotted against each other (Figure 3). One axis represents the contrast of the current organised (solid) system against a disorganised (fluid) system. The perpendicular axis represents the current supply-driven education system against a demand-driven approach. Subsequently the panel appointed the scenarios in each quadrant, which resulted in the following four ML-scenarios (Figure 3).
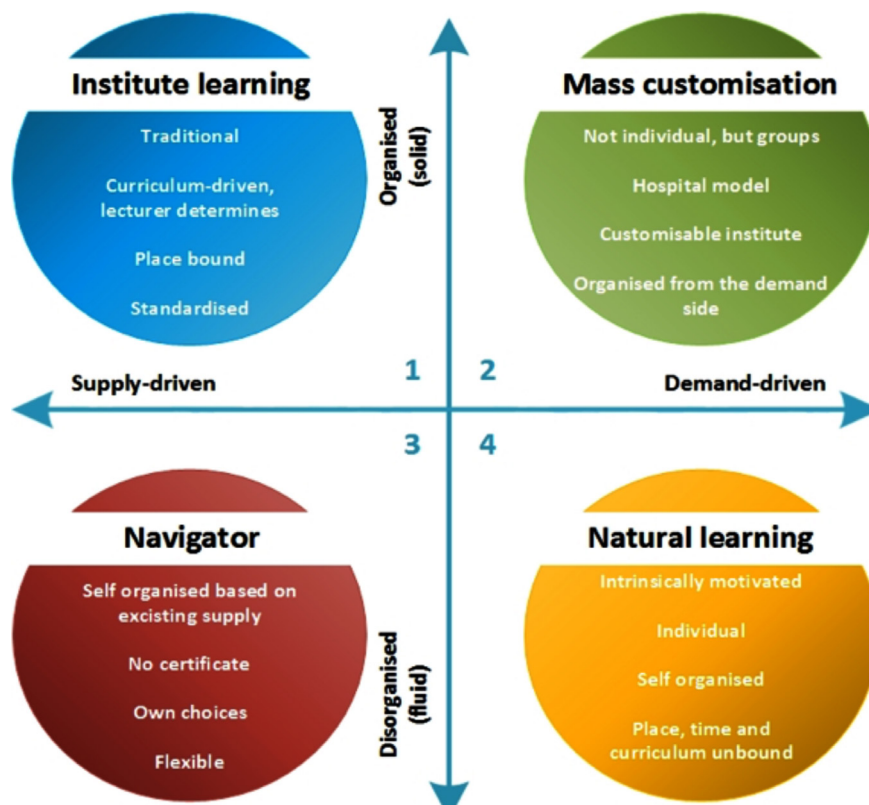
Figure 3 Modern Learning scenarios

1.   Institute learning
Closely related to the current state of Dutch higher education. This scenario is illustrated as traditional and inflexible, driven by the government and UAS (supply-driven).

2.   Mass customisation
Fully tailor-made education that corresponds to the demand-driven aspects. Key in this scenario is the student, following a personal training programme based on individual study aims, wishes and abilities.

3.   Navigator
Part of a higher education system changeover, but still supply-driven. Key in this scenario is the decline in the monopoly of Dutch UAS and simultaneously the increase of alternative suppliers of education. At the same time, the student gains control of its own learning pace and content, including the provided funding from the Dutch government.

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4.   Natural learning

Like scenario 3, this is part of a changeover of the higher education system. Other similarities are the decrease in the monopoly of Dutch UAS, the increase of alternative suppliers of education, and the student control over funding. The curriculum is not static but rather defined by a portfolio and based on real issues, with a strong position of the intrinsic motivated student. Experiments with aspects of natural learning already take place on a small scale; also referred to as 'Agile Learning'.

4.5   Future match

The 4 identified ML-scenarios have an increasing influence on UAS real estate and FM, consisting of five elements as addressed by the expert panel (Figure 4).
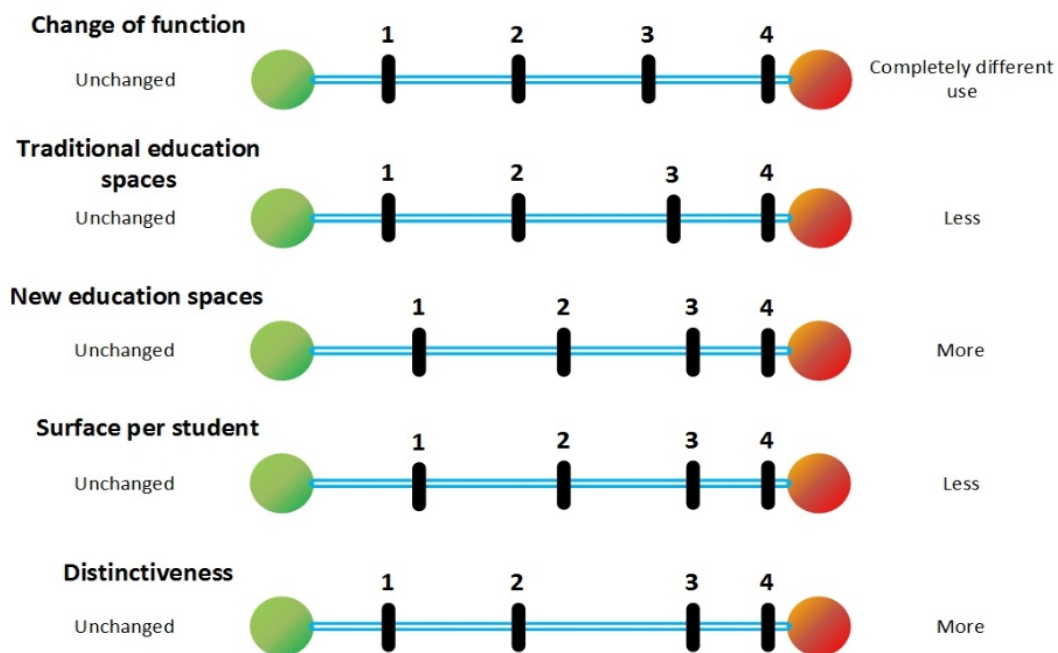
Figure 4 The 5 elements that influence Dutch UAS FM & RE related to the ML-scenarios.

For facility and CRE-managers the impact of the scenarios is translated to corresponding learning environments. This will help forecast future needs of end users, and thus determine the potential future (mis)fit.

1.   Institute learning

In this supply-driven, place-bound scenario, the function of educational buildings remains unchanged. The major implications of this scenario are the result of extrapolating the current trends, such as the increased use of IT. A mild form of blended learning will be applied, with the emphasis on face-to-face learning and only a small share of e-learning and related technologies. Fewer classrooms are necessary and more informal project space is required. As a result the ratio surface area per student is expected to decline. In order to facilitate this scenario, the learning environment must be adaptable to a change in use and to a lesser extent easy to divest because less surface is required at a constant student number.

2.   Mass customisation

A wide diversity of spaces is needed to facilitate this new tailor-made education on a large scale. The learning environment has a physical and virtual (blended learning) dimension. An

increased share of virtual environments (compared to scenario 1) results in a reduction of floor surface. Competition will not only emerge internationally, but also on a national scale. This leads to a need for a greater distinctiveness. Hospitality experience is key; the environment, services & education, and behaviour are consistent and aligned with the (hospitality) concept. Overall, learning environments must be highly adaptable.

3.   Navigator
In this time-and-place unbound scenario students find their own way to modular education offered by a variety of new suppliers besides the Dutch UAS. Competition requires an attractive organisation, distinction from competitors, and buildings and learning environments are used for branding. Students receive their funding directly from the Dutch government and are not registered at a particular UAS. The students as it were 'shop' at the (new) suppliers of education. The impact of IT results in a highly reduced surface per student. Buildings must be highly adaptable to facilitate these changing needs, such as fewer classrooms and more informal project spaces.

4.   Natural learning
Scenario 4 is the most drastic change from the current situation. In this scenario each student is in control of his or her own learning track and receives – like scenario 3 – the funding directly with no assigned registration at an UAS. Students are unbound in time, place and content. Meeting and learning in communities is a cornerstone. Learning communities consist of the students' own network, companies, fellow students, and lecturers acting as coaches. Community meetings can take place anywhere. In case of strategically positioned and well equipped school buildings – for instance at infrastructure nodes or high-tech digital learning environments – it is possible that UAS can facilitate this specific demand. Still, this will be on a small scale. Altogether this scenario is disruptive and would trigger a paradigm shift in Dutch higher professional education.

5   DISCUSSION

Scenario planning is an explorative method for future events and therefore its output is not conclusively certain. Nevertheless, one can benefit from this method to (try to) be prepared for the future.

Other studies into higher education scenarios for UAS and/or Research Universities were compared with the results of this study. A study by Vincent-Lancrin (2004) showed the variable 'lifelong learning' in the scenarios which is currently obsolete. Lifelong learning is widely recognised as certain trend and is therefore incorporated in each scenario nowadays. Yet, this same study indicated driving forces in governance and funding, and the rise of new actors in higher education, identical to the present study. An Australian study focused on the importance of innovation management at the Higher Education sector on an international scale, in order to remain a sustainable entity beyond 2025 (Blass & Hayward, 2014). A study of Vereniging Hogescholen (2015b) tried to explore scenarios in higher education towards 2025, but only presents some recommendations based on extrapolating trends. Still, all studies show some similarities with the present study, substantiating the ML-scenarios determined.

The ML-scenarios and their impact on UAS housing needs were discussed with the 9 CRE-managers. It was found that the ML-scenarios 1 and 2 could be facilitated, although it will be a challenge for Dutch UAS to meet the qualitative demands concerned due to limited flexibil-

ity in their real estate. Scenarios 3 and 4 are a true challenge for most of the UAS. In these scenarios a major share of their real estate must be divested, while not all these buildings are prepared for other functions (low marketability), let alone whether there is a demand in the real estate market for these properties. Consequently, most of the participating UAS are not prepared for ML-scenarios that incorporate a system changeover. The probability of scenarios 3 and 4 occurring cannot be predicted, but taking into consideration the accelerated integration and application of physical and virtual learning environments, it is likely that future education systems are closer to those scenarios than to the current situation. The magnitude in real estate portfolios of this event remains uncertain. However, based on the interviews where the CRE-managers indicated that the older half of students could learn in scenario 3 and 4, a conservative estimate would be a bandwidth of 25 to 50 per cent reduction in floor space. This implies that there is a mismatch (gap) between current supply and future demand.

6   CONCLUSION AND RECOMMENDATIONS

Confronting the respondents with the ML-scenarios revealed that none of them had tested future demand scenarios on this scale. The main reason is found in the short-term corporate vision of the UAS and the unclear education demand of the users. These aspects impede a long-term vision and a well-aligned real estate strategy. To conclude, the real estate strategy of most Dutch UAS is only partly aligned to the consequences of Modern Learning towards 2030 for scenarios 1 and 2. In all, Dutch UAS do not have a real estate strategy that is aligned to the ML-scenarios that would result in a system changeover of higher education (scenario 3 and 4). Corresponding implications are inevitable divesture of real estate on a large scale in an uncertain (future) real estate market. This would most likely lead to high book losses among the majority of UAS, as they own most of their real estate. The remaining real estate – if properly located – must be adapted to the changing demand, as only these buildings are sufficiently flexible to accommodate expected changes due to ML in higher education.

Initially, the ML-scenarios were developed for Dutch higher professional education and are therefore not directly applicable to other education sectors or other countries. Yet, there are studies with a European or worldwide scope, exhibiting strong similarities with the ML-scenarios found in this study. Closest to Dutch UAS, in terms of similarity, are the research universities. It is likely that these organisations more or less face the same challenges when it comes to Modern Learning. The ML-scenarios are to a lesser extent applicable to secondary vocational education. Future research into the exact impact of ML-scenarios on the learning environment is necessary, because technological developments tend to be disruptive.

This paper provides useful recommendations for CRE- and Facility Managers when it comes to the future of education. First and foremost, fostering awareness across an organisation to create and maintain a long-term vision on both the organisation itself and on developments in its environment is crucial. At the same time, this vision should contain an overview of possible future events. With regard to the ML-scenarios, flexibility is of major importance, both on a portfolio level as well as on a building and building component level. Inflexibility at building level will result in frequent demand for internal renovations and additional high facility costs. Also, a structural dialogue and alignment between the sections of education, CRE, FM, ICT and Human Resource Management is required when it comes to determining demand and needs for the mid- and long-term. Besides, this study shows that the largest group of users – students – are hardly involved in the development of the (future) learning environment. In a declining market student satisfaction is a critical success factor, which would advocate for more involvement of this user group. Besides the first impression offered by the appear-

ance of a building and its accessibility, the physical learning environment's quality and the extent to which it facilitates ML, knowledge exchange, but also supporting facilities such as restaurants and fitness studios, influence the choice of students for a certain UAS. An interdisciplinary translation of ML-scenarios to the required learning environment is therefore of utmost importance.

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4 Papers presented at combined business and research tracks

4.1 Assessing the Added Value of information systems supporting facilities management business processes
Poul Ebbesen and Per Anker Jensen

4.2 Employee's preferences for services and facilities offered in serviced offices: Results of an empirical study
Mike van de Kar, Rianne Appel–Meulenbroek, Pauline van den Berg and Theo Arentze

4.3 The role of FM in disaster resilience: Integrating the Sendai Framework into disaster risk management
Keith Jones, Andrea Bartolucci and Katie Hiscock

4.4 Out of the Shadows: Influencing Train Passengers' Perceptions and Satisfaction by Increasing Visibility of Cleaning Staff
Martijn C. Vos, Jessica Sauren and Olaf Knoop

Assessing the Added Value of Information Systems supporting Facilities Management Business Processes

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ABSTRACT

Purpose: To present a method for assessing the added value of Information Systems (IS), which are implemented to support the business processes in Facilities Management (FM).

Theory: The method is based on a supply chain management model of FM, general value dimensions such as efficiency and effectiveness and the concepts of Value Adding Management (VAM) and Functional Affordances of IS.

Design/methodology/approach: From case studies of IS implementation processes in FM in different countries, a general picture of the expressed added value of IS in FM was established. Based on this insight a method for assessing the added value of IS in FM was developed. The proposed method is applied to one of the cases.

Findings: The paper analyses how a specific IS supports the management of a specific operational process – cleaning in an airport. The assessment shows that the IS definitely adds value to the cleaning process and because the resulting increase in user experience of the cleaning level is aligned with the strategy of the corporation, the IS also adds value to the primary process of the organisation. The analysis reveals that a well organised management setup is required to gain value from IS. It also illustrates that implementing IS includes both organisational and technological changes and demonstrates that the proposed assessment method is applicable to practice.

Originality/value: This is the first paper using a supply chain management model of FM, general value dimensions, VAM and Functional Affordances to access the added value of IS in FM.

Keywords: Information Systems, Added Value, Facilities Management, Business Processes, Functional Affordances

1   INTRODUCTION

Assessing the added value from the effort of implementing Information Systems (IS) supporting Facilities Management (FM) processes is associated with major challenges. It is often unclear what added value is expected and what part of the supply chain of FM deliveries that benefits from the IS. One reason for this might be that the concept of value is not well de fined and as a consequence can be difficult to use as a sole parameter. Furthermore it is often

not understood very well how the parts in the supply chain of FM deliveries are interconnected. This paper therefore proposes a general method for assessing the added value of IS in FM. The underlying research question of this paper is: How can the added value of IS supporting FM business processes be assessed?

The structure of the paper is as follows: In section 2 different value concepts and dimensions relevant for this paper are presented as well as the concept of Value Adding Management (VAM) and the Supply Chain Management Model of FM. Section 3 gives an overview of the added value from IS as expressed by respondents in five IS implementation cases. It shows that only parts of the value picture are explicitly expressed, and that there is a need for a general model for assessing the value of IS. The methodology of the research leading to the development of the method is explained in section 4. The case study used to exemplify the proposed model is presented in section 5 and in section 6 the assessment method is discussed and conclusions are drawn.

2   VALUE CONCEPTS

There is no commonly accepted definition of value (Thyssen, 2011, p. 53). The plural version "values" is often related to ethics or moral issues. In this paper value is understood as benefits to the business. There are of course many types of benefits. To achieve value, or to add value, often some sort of effort or sacrifice is required. Examples of benefits from the effort of implementing an IS can be increased efficiency and improved effectiveness of the business processes, and improved Interoperability. But implementing an IS in an organisation, can of course also have many other types of benefits, e.g. improved working conditions. Each type of benefit can add value to the business. The left side of the tree structure in Figure 1 illustrates the explained relations between these value concepts.
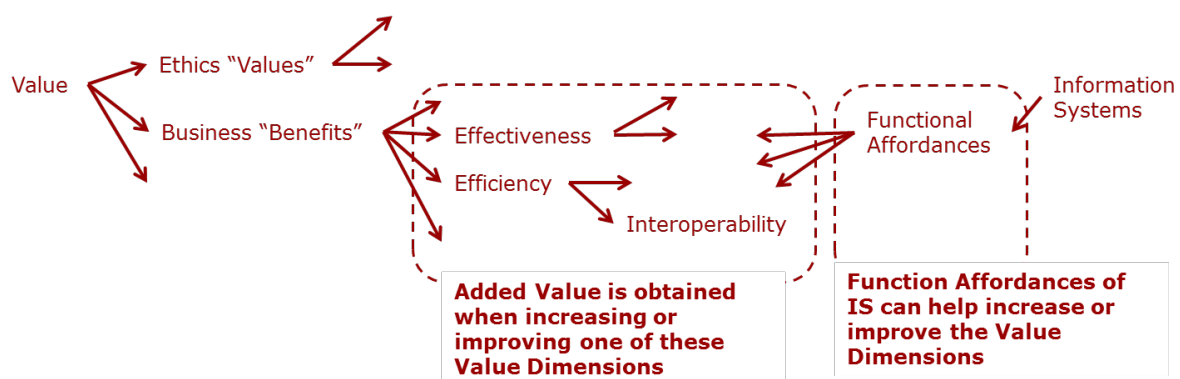
Figure 1Value and IS concepts

The right side of Figure 1 shows that IS can offer functional affordances, some of which can improve effectiveness, increase efficiency or improve interoperability. The concepts of functional affordances and interoperability are explained more detailed below. When assessing added value, one should of course ask whether e.g. the increased efficiency and the improved effectiveness is worth the effort.

In the FM standard EN 15221-1, FM is defined as "Integration of processes within an organisation to maintain and develop the agreed services which support and improve the effectiveness of its primary activities" (CEN, 2008). Jensen et al. (2012) combine this definition of FM with an extensive review on value terminology in the FM literature and conclude that

creating **Value** to the core business, translates for FM into – as a minimum – delivering and maintaining services that – at a competitive level – support the effectiveness of the primary activities. To create **Added Value** it is necessary for FM also to develop the services in such a way that they improve the effectiveness of the primary activities (Jensen, 2012, p. 279). In addition they conclude that FM also can contribute considerably to the efficiency of the primary processes and to the efficiency and effectiveness of the supporting processes as well. This paper focuses on added value, such as increased efficiency and improved effectiveness of FM processes, which mainly are supporting processes, from implementing and using IS in FM.

Different types of value can be found in the literature. Exchange value and use value both relate to change over time. In terms of exchange value the focus is on cost and the relationship between output and input in a business process. The added value can be defined as the value of the product reduced by the value of the resources used during the process. Thus reducing cost by increasing efficiency leads to exchange value (Jensen et al., 2012, p. 59). Use value only relates to the output, and possibly the outcome of a process. Improved output by improving effectiveness leads to added use value. See Figure 2.
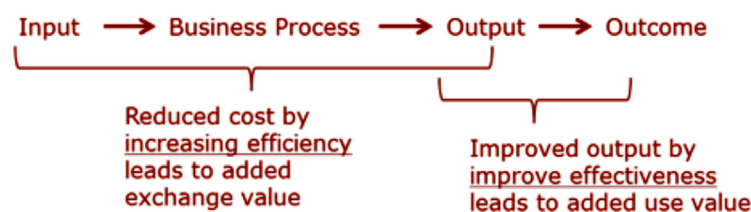
Figure 2 Added exchange value and added use value

Based on Jensen et al. (2012, fig. 4.1) an ideal relative development over time in cost and use value of an FM service, initiated as a result of an IS implementation process in an organisation, is illustrated in Figure 3.
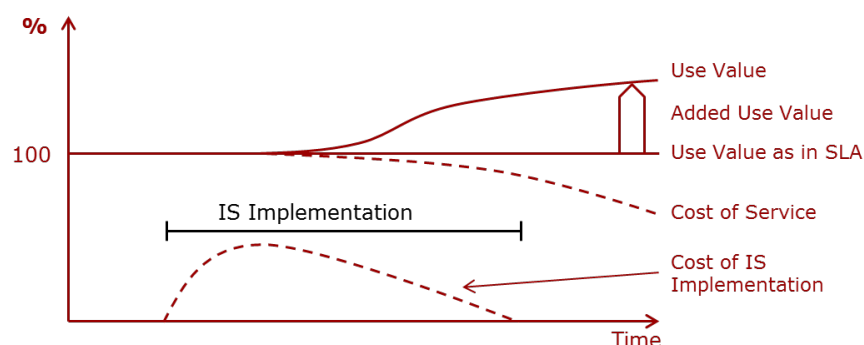
Figure 3 Ideal relative development over time in use value, cost of service and cost of IS implementation (Based on Jensen et al., 2012)

The base line for use value can be specified in a Service Level Agreement (SLA). The use value of the service can for instance be measured by Key Performance Indicators (KPI) with a minimum level of customer satisfaction. An increase in use value will occur if the customer satisfaction over time gets higher than the minimum level of customer satisfaction. This means that added use value is created. A cost reduction of the service occurs, if the cost of the service goes down below the base line without lowering the customer satisfaction below the minimum level. The curve in the bottom of Figure 3 shaped as a hump represents the investment in the IS implementation. It can be seen as the effort of IS implementation.

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2.1 Two central value related concepts: Efficiency and Effectiveness

The two concepts efficiency and effectiveness are central to the IS assessment method presented in this paper. Most organisations strive to be more efficient and more effective, but there is no common definition of the two concepts. Table 7 gives an overview of some of the definitions of the two concepts which are explained in the following.

Efficiency and effectiveness both describe the performance of business processes (Chaffey, 2014). The most simple definition of efficiency is "doing the thing right", and the most simple definition of effectiveness is "doing the right thing".

According to Schneider and Leslie (2015) increasing efficiency means allowing an organisation to do the same amount of work with fewer resources and examples of this can be automation of manual processes or organisational restructuring/outsourcing. Improving effectiveness means allowing organisations to generate higher revenue, independently of resources required. (Schneider and Leslie, 2015).

Table 7 Definitions of Efficiency and Effectiveness

	Efficiency	Effectiveness	Reference
Definitions	Doing the thing right	Doing the right thing	(Chaffey, 2014)
Increase / Improve	Do the same amount of work with fewer resources	Generate higher revenue, independently of resources required	(Schneider and Leslie, 2015)
	Reduced cost by increasing efficiency leads to added exchange value	Improved output by increasing effectiveness leads to added use value	(Jensen et al., 2012)
Management	Industrial Management	Preparedness Management	(Jensen and Katchamart, 2012)

2.2 Interoperability

Interoperability is the ability to exchange data between applications, which smoothes workflows and sometimes facilitates their automation (Eastman et al., 2011). Improved Interoperability may therefore add value to business processes. Interoperability can provide information not only used for FM processes, but also used by the rest of the organisation (Keller, 2013). Interoperability can shorten the time it takes to retrieve information and thereby increase efficiency of business processes. In Figure 1 Interoperability is therefore shown as a sub value dimension under efficiency.

2.3 Functional Affordances

Affordance can be understood as the multiple uses for which artefacts may be employed (Gibson, 1986). According to Gibson we do not perceive the qualities of objects but their affordances. The concept has been employed in sociological studies of technology and recently in the IS literature (Schellhammer, 2011). "Although the material properties of a technology are common to each person who encounters them, the affordances of that artefact are not. Affordances are unique to the particular ways in which an actor perceives materiality." (Leonardi, 2011, p. 153). Functional affordances are potential uses of IS based on users' interpretation of their material properties dependent on the use context (Markus and Silver, 2008). Some func-

tional affordances of IS may add value, e.g. in the form of increased efficiency or improved effectiveness of a business process. See the right side of Figure 1. Functional Affordances is a core concept for understanding the added value of IS. It is the people involved who interpret potential uses (affordances) of an IS and whether these are useful in the given context.

2.4 VAM and the Supply Chain Management Model of FM

The concept of Value Adding Management (VAM) in FM as developed by Jensen and Katchamart (2012) focuses on the relationships between FM and core business and is concerned with how FM can add value to the core business and to relevant stakeholders. VAM draws on the management model of FM from the FM taxonomy standard CEN (2011), which is shown as a basis for Figure 6 in the case analysis. In the model a distinction is made between the demand side and a supply side, and relations between the two sides are based on FM agreements. Interaction between demand and supply takes place on three levels: Strategic, tactical and operational, which are related to client, customer and end user, respectively. Primary processes and activities of the organisation take place on the left side. Support processes and facility services from internal and external providers take place on the right side. Demands can be based on Service Level Agreements (SLA) and delivery can be measured by Key Performance Indicators (KPI).

Compared to other forms of management, VAM can be distinguished in relation to efficiency and effectiveness, which is show as a basis for Figure 7 in the case analysis. VAM is placed in the upper right corner where both efficiency and effectiveness have high priority. A lack on management focus may result in low efficiency and effectiveness, which is shown as Laissez Faire Management. A primary management focus on optimizing efficiency is shown as Industrial Management, which could e.g. be LEAN or AGILE management. A primary management focus on effectiveness is shown as Preparedness Management, which as an extreme example could be found in a fire brigade, where an organisation is constantly prepared for an occurrence of an undesired event (Jensen and Katchamart, 2012).

3 EXPRESSED ADDED VALUE IN 5 CASE STUDIES

As part of a qualitative study of IS implementation cases in FM departments employees and managers, involved in the IS implementation process, were asked about the value added from the IS being used (existing) and from the IS being implemented (future). An overview of the responses given in five of the cases is shown in Table 2. Different areas such as information retrieval, cost, political positioning in the organisation, business processes, user experience, alignment with business strategies are improved and thereby adds value, according to the respondents. Improvements in each of these areas increase efficiency or improve effectiveness. In each case there seems to be a general lack of clarity and focus on the overall added value of the IS being implemented. Only parts of the "value picture" are expressed by the respondents, and it is often unclear what part of the supply chain of FM deliveries should benefit from the IS. Awareness or knowledge of the value added can be both explicit and implicit. The respondents may know much more about the value added than they express during the interview.

4 METHODOLOGY

As the prior section shows, there is a need for an overall method for assessing the added value of IS in FM. An attempt was made to establish such a method by including existing concepts and models from the different disciplines, which is illustrated in Figure 4. The approach

is somewhat deductive; observations are analysed using predefined theoretical perspectives. First value parameters (value dimensions) suitable for describing the value of business processes and IS were found in the existing literature on value, IS and FM. Secondly an overall concept (functional affordances) for describing what IS can offer in relation to the value dimensions were found in the literature. Next a model describing the FM context (FM supply chain model) was found, and finally a model for assessing the value of management based on the value dimensions was included (VAM). As illustrated in Figure 4 these four elements, the Value Dimensions, Functional Affordances, the FM supply chain model and VAM constitutes the basis of the proposed method for assessing the value of IS in FM.

Table 8 Respondents description of value added from the IS being implemented

| Case	Type of IS	Citations from interviews describing the added value	Area of improvement	Value Dimensions Increased / Improved	
				Efficiency	Effectiveness
A	Future BIM/GIS based maintenance management system	"It sends an important message that we are involved in this. It will attract others in the organisation to use this system. It is a role we would like to have in our organisation"	Political positioning in the organisation		X
	Existing CAD based space management system	"Improved lease management and improved overview of square meters and real estate portfolio overview"	Business process		X
			Information retrieval	X	
	Existing Helpdesk system	"A user survey shows that 84% of the users experience improvements in maintenance management"	Business Process.		X
			User experience		X
B	All existing and future IS systems	"The overall strategy of the organisation is about simplification , so a lot of these IT solutions are about simplification"	Alignment with business strategy		X
C	Existing BIM and laser scanner based facilities information system	"Trying to come up with a benchmarking system that enables you to see that moving down BIM is cost effective"	Cost	X	
	Existing BIM and laser scanner based facilities information system "Next time you come along and if you are surveying in the same area we know it is accurate, so you save the cost of surveying"		Information retrieval.	X	
			Cost	X	
D	Future web and fiber based building automation system	"The market sees us at leading in real estate management"	Alignment with business strategy		X
E	Existing CAD/GIS based visualisation management system	"Easy access to information, and very often the graphical accesses is the easiest access"	information retrieval	X	
	Future CAD/GIS based visualisation management system	"It becomes more and more like the system that everyone knows from the internet"	Information retrieval	X	
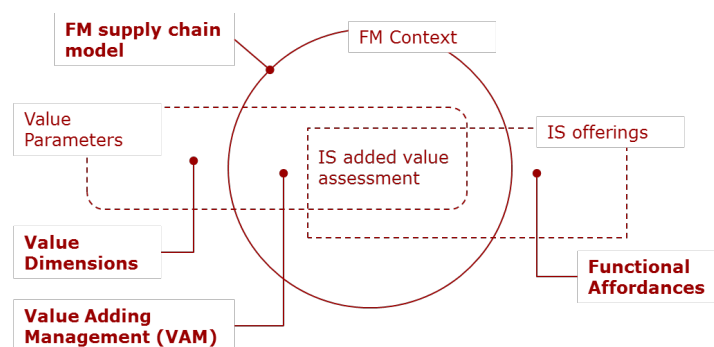
Figure 4 Elements constituting the IS added value assessment method

The method consists of three main steps as illustrated in Figure 5. In the first step the IS case is analysed using the FM supply chain model. Activities, roles and levels involved in and interacting with the IS are found. In the second step increase in efficiency and improvement in effectiveness as a result of the IS implementation is assessed. This is done using the definitions of efficiency and effectiveness as illustrated in Figure 2 and Figure 3. Furthermore the Functional Affordances of the IS which contributes to increase in efficiency and improvement in effectiveness are identified. Finally in step 3 the degree or level of Value Added Management (VAM) is assessed using the definitions as illustrated in Figure 6.
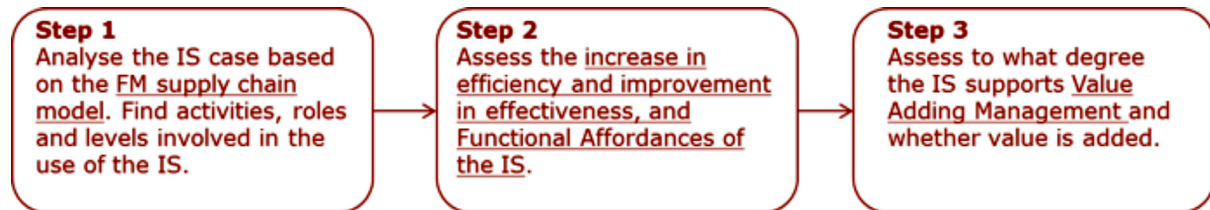
Figure 5 Three main steps in assessing the value of IS supporting FM

5   CASE STUDY OF IS IMPLEMENTATION

In this section the IS implementation case (case E in Table 2) is introduced and used to exemplify the IS assessment method,. The organisation is a large airport in Europe. The specific IS was put into use in 2013 and is intended to support the cleaning processes in the organisation. The IS delivers information about the frequency of use of specific intensely used rooms in the facilities of the airport. Sensors detect when a person enters into one of these rooms, and the system can thereby keep track of how many people have used each room.

Furthermore a use response system has been installed in each of the rooms, enabling users on their way out of a room to report back about their experience of using the room; whether it was Good, OK or Bad. If responding "Bad" the user is asked to report back which specific issues caused the bad experience.

Data from the sensors and from the use response system is presented on a monitor in a simple way to the dispatcher of the external cleaning company. The dispatcher's role is to coordinate the cleaning process based on the information on the monitor. When a specific number of persons have passed the sensor in a room a field on the dispatchers monitor turns from green to red, and if a specific percentage of users of a room find the experience of using the room bad another field turns from green to red. In each case the dispatcher can then send cleaning personnel to this specific room to see whether cleaning is necessary. If a user reports back about a specific issue that needs to be improved, the dispatcher can then also send personnel to the room to deal with the issue.

Before the IS was implemented and taken into use, cleaning in these rooms was done on a regular basis, e.g. every two hours. Whether there actually was a need for cleaning or whether specific issues needed to be handled, was not part of the cleaning procedures. As a consequence of implementing the IS, cleaning in these rooms is now mainly demand-driven; based on use frequency and user experience responses.

The external company in charge of cleaning these rooms are, according to their contract with the airport organisation, required to use the IS. There are no explicit SLA or KPI sections in the contract between the cleaning company and the airport, but the contract requires the cleaning manager from the cleaning company to send out cleaning personnel when and where it is needed, based on information from the IS, and to respond to specific issues reported by users. The KPI related part of the contract requires the cleaning company to deliver cleaning according to normal standards.

As part of an international benchmarking of airports, users of the airport have the last seven years been asked quarterly about their experience of using the facilities, including their experience with the level of cleaning in these rooms. In general the satisfaction level has increased every year. The introduction of this IS and the change in procedures may have contributed to the increase of the satisfaction level, but also refurbishments and other improvements of the rooms during the same period may have had an impact.

The introduction of this IS and the changes in the work procedures, is aligned with and contributes to the goals and strategies defined by the top management, which includes aiming at being seen by users as the best airport organisation in Europe.

Using the case described above, it is in the following shown how the proposed three step method (see Figure 5) can be used to assess the value added by implementing IS supporting FM into an organisation.

5.1 Analysing the IS case using the FM supply chain model (Step 1)

This analysis refers to Figure vi using numbers in brackets. The IS reports frequency of use detected by sensors, and level of experience and issues reported by users (1). On the Supply side the information from the IS is used by the dispatcher (2) from the external cleaning company (3) to manage the cleaning, including the cleaning frequency. As mentioned the SLA (4) related part of the contract (5) between the cleaning company and the airport requires the cleaning manager from the cleaning company to send out cleaning personnel (6) when and where it is needed, based on information from the IS, and to respond to specific issues reported by users. On the demand side the manager responsible for cleaning at the airport (7) monitors the cleaning based on information from the IS, supplemented with occasional inspection rounds in the facilities (8). By use of surveys (8) the user's (9) experience of the facilities is investigated quarterly. As mentioned the surveys, in regard to cleaning, show an increase in the satisfaction level among the users. The use of the IS to support the cleaning business process is aligned with the strategy of improving cleaning and thereby contributes to reach the goal, set by the top management, of being the best airport (10).

5.2 Assessing effectiveness, effectiveness and the Functional Affordances of the IS (Step 2)

Cleaning frequency is now based on use frequency and issues reported back from users through the IS. Cleaning is not as earlier done at regular intervals; it is now done when needed.

The quality of the cleaning (the output in Figure 2) has, according to the cleaning manager, improved since the introduction of the IS. Therefore the effectiveness of the cleaning has improved. At the same time the experienced level of cleaning (the outcome in Figure 2) has increased according to the quarterly survey results. The improvement in effectiveness has led to improvements in the output (and outcome), thereby leading to added use value (See Figure 2).
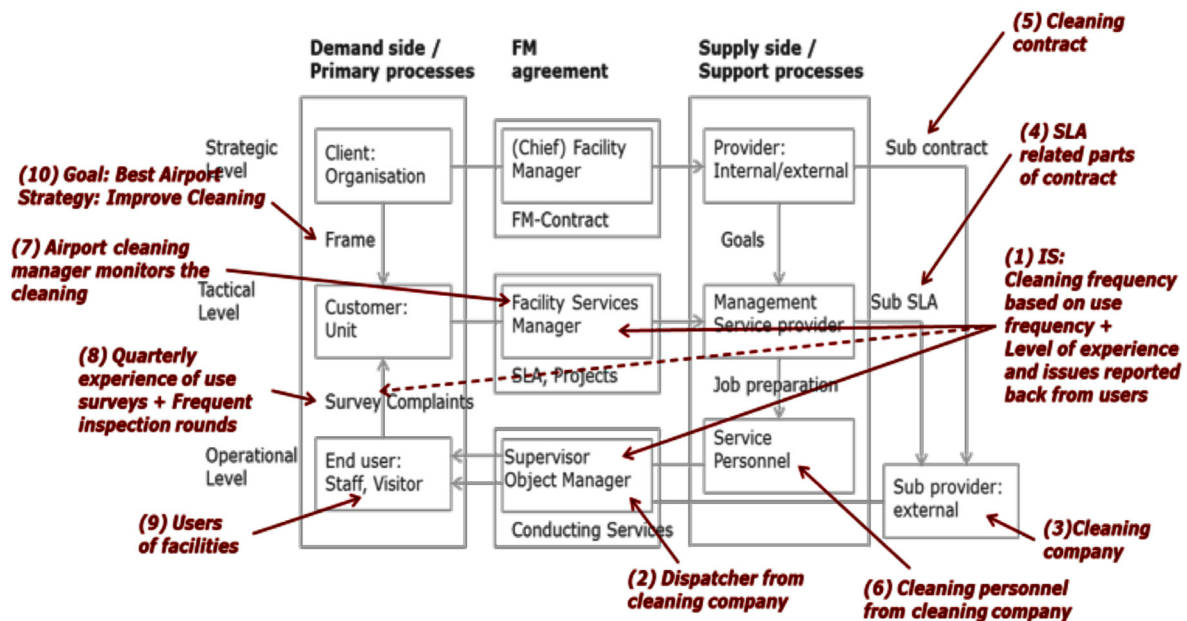
Figure 6 Analysing the IS case using the FM supply chain model **(**Based on CEN**,** 2011)

Since the IS was introduced the frequency of cleaning has dropped while the level of cleaning has not dropped. The <u>efficiency of the cleaning has therefore been improved</u>. The airport pays the cleaning company the same for the cleaning, compared to before the IS was introduced. The cleaning company may have reduced their cost as a consequence of increase in efficiency and thereby achieve an <u>added exchange value,</u> but this is not the case for the airport (the client).

A functional affordance of the IS which have increased efficiency is the delivery of real time user frequency information on the monitor. This functional affordance has made it possible for the dispatcher to send out cleaning personnel when a certain number of persons have used a room. The functional affordance of the IS which has improved effectiveness is the delivery of user response information on experience of use and on specific issues. This functional affordance has made it possible for the dispatcher to send out cleaning personnel when specific issues must be dealt with. The fact that the cleaning manager hired by the airport uses the IS to monitor the cleaning process, can be seen as a functional affordance which has improved interoperability; the IS facilitates sharing of data about the cleaning process.

5.3 Assessing how the IS supports VAM and whether value is added (Step 3)

The IS supports effectiveness. It delivers information so the cleaning manager better can initiate the right cleaning, thereby <u>improving the effect of the cleaning</u> (added use value). The IS also supports efficiency. The cleaning manager can better initiate cleaning when it is needed, and thereby <u>reduce the resources spent on cleaning</u> (added exchange value). Supporting both efficiency and effectiveness in the management of the process, the IS therefore supports Value Adding Management. See Figure 7.
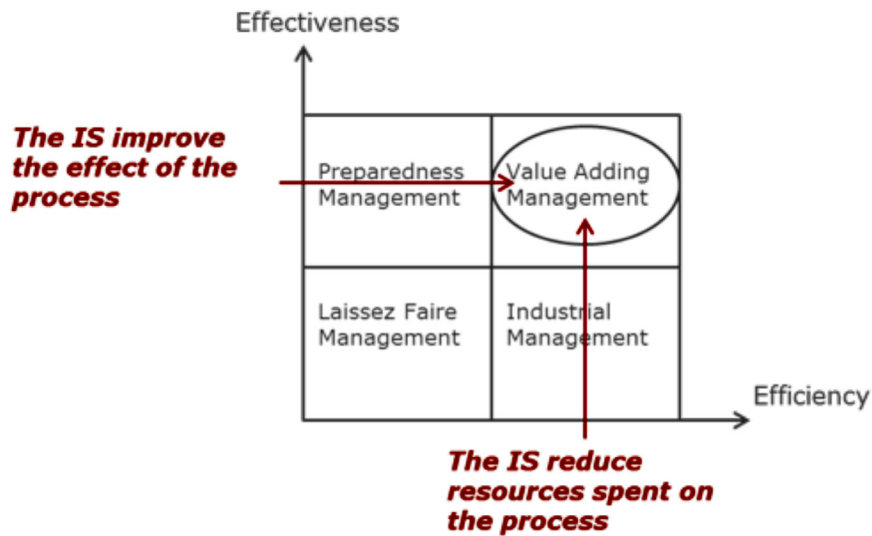
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Figure 7 The IS from the case supports both Efficiency and Effectiveness in the management of the process. Therefore the IS supports VAM. **(**Based on Jensen and Katchamart**,** 2012**)**

6 DISCUSSION AND CONCLUSION

Based on the FM supply chain model (CEN, 2011), this paper analyses how a specific IS supports the management of a specific operational process (cleaning). Based on this analysis it is accessed to what degree the IS supports increase in efficiency and improvement of effectiveness. Furthermore the potential Functional Affordances of the IS which are used to achieve these improvements are defined. Finally it is assessed whether the IS supports Value Adding Management (VAM) of the process.

This analysis cannot stand alone. It does not include an assessment of the quality of the management, the work process or the IS. This analysis only helps clarify whether the basic managerial and technological elements needed to achieve VAM are present.

VAM as described by Jensen and Katchamart (2012) includes the two classical business process related dimensions effectiveness and efficiency. When including the IS perspective, interoperability as a third dimension could be included. IS can support interoperability as an element in the management of a process. Interoperability can, e.g. reduce time spent to search for information and can therefore be seen as a dimension increasing efficiency.

Because of the way the cleaning process is organised the potential of the functional affordances of the IS can be exploited. The IS contributes to added value because the dispatcher actually use the information offered by the IS, and because the cleaning work process is organised so that this information can be used. The functional affordances of the IS were seen as useful in this specific context in the strive for VAM. In future cleaning contracts the airport could obtain a share in the potential cost reduction gained by implementing the IS. This could be done by redefining the SLA in the contract.

This paper illustrates that a well organised management setup is required to gain value from IS. It is also illustrated that implementing IS includes both organisational and technological changes. The system keeps track of the state of the cleaning and can be used by the demand side to monitor the quality of the delivery of cleaning.

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The system described in this paper is being further developed. For inspections rounds a tablet based inspection report system is being developed, including testing different types of tablets for the purpose. Furthermore is has been considered to equip the cleaning personnel with tablets, so that information from the IS can be sent directly to the cleaning personnel and thereby obviate the dispatcher role.

The use of the IS as described definitely adds value to the secondary process cleaning. Because of the increase of the user experience of the cleaning level, which is aligned with the strategy of improving cleaning in order to become the best airport, the use of the IS also adds value to a primary process of the organisation.

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Employee's preferences for services and facilities offered in serviced offices: results of an empirical study

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ABSTRACT

Purpose and theory: Serviced offices are popular, offering many services and facilities to attract tenants. As research showed that most business centres occupy similar buildings, services are important to differentiate. They are also an important reason for choosing a specific serviced office. All kind of organizations (from freelancers to large corporates) use them and their characteristics are likely to influence how they value different services. This study identifies which services/facilities are perceived as most important by which types of end-users.

Approach: Data were collected through a questionnaire among 137 end-users in 13 serviced offices in the Netherlands. With principal component analysis 31 services and facilities could be reduced to six independent factors and four additional services. Multiple regression analyses was used to determine effects of user characteristics (employee demographics, job characteristics and reasons for using serviced offices) on perceived importance of each service/facility (factor).

Findings: Results showed that age and educational level influence importance of services/facilities, especially interactive ones (e.g. workshops). Organizational characteristics had little effect on perceived importance. The reasons for using serviced offices showed expected effects on importance of services, e.g. those using the office to work in a certain atmosphere found interactive facilities more important.

Originality/value: So far, research on effects of user characteristics on perceived importance of services/facilities has focused largely on single-tenant offices and large corporates. Serviced office owners and operators can use the insights obtained from this study to differentiate their product offer from the rest and aim for specific tenant market segments.

Keywords: Serviced offices, user preferences, services and facilities, co-working.

1   INTRODUCTION

Vacancy rates for office space in the Netherlands and many other Western European coun-tries have increased dramatically since the start of the economic downturn. New Ways of Working further increases office vacancy, as the average number of square meters per FTE is decreasing that way (Lokhorst, Remøy & Koppels, 2013). Furthermore the labour market has become more flexible recently. Both the number of employees with a flexible labour contract and the number of freelancers have increased substantially over the last ten years (CBS & TNO, 2015). These developments have caused landlords to convert vacant single-tenant of-fice buildings to business centres to offer a variety of smaller floor areas to multiple tenants. These business centres offer more flexibility with shorter lease terms (e.g. monthly).

Weijs-Perrée et al. (2016) identified four different types of business centre concepts in the Netherlands, namely regular business centres, serviced offices, co-working offices and incu-bators. Regular business centres are the oldest type. They simply offer office space with few or no services and facilities to those that are too small to afford their own office. Business incubators specifically focus on supporting start-ups and have been used mainly as an eco-nomic development tool. They have been the subject of many academic studies (e.g. Hackett & Dilts, 2004). Serviced and co-working offices have surfaced more recently and are upcom-ing. They generally offer a large range of services and facilities and so far scientific research on these concepts remains scarce. This is surprising, as specifically this market is growing strongly without the necessary insight in user preferences to offer what is really demanded.

Most business centres are quite similar with regard to physical aspects and should thus differ-entiate themselves with characteristics like services, contract types or social spaces (Weijs-Perrée et al., 2016). Gibson & Lizieri (2000) showed that the access to support services is an important reason for tenants to choose for a serviced office. Moreover, 40 percent of the ten-ants indicated that the available services were in the top three of selection criteria for a specif-ic serviced office (Gibson & Lizieri, 2000). Serviced offices therefore continuously adapt their concept, services and facilities (Laterveer, 2011). But end-users of business centres are likely not homogeneous and it is expected that end-users with varying characteristics do not value these services and facilities to the same extent. Business centre operators could use such variations to differentiate their product offer and attract specific tenant segments. As up until now no studies have been conducted on this subject, this paper aims to give insight in service menu differentiation possibilities, by exploring how user characteristics influence to what extent services and facilities are considered important. Although a distinction between serviced offices and co-working offices exists, it is hard to see this in practice. The main dif-ference lies in the intention of operators of co-working offices to stimulate collaboration and interaction between tenants (Kojo & Nenonen, 2014). Many serviced offices apply a hybrid concept, also offering co-working space in part of their building. Therefore this paper focuses on serviced offices and includes hybrid variations with co-working concepts.

The next section reviews existing literature on serviced offices, the characteristics of their users and the services and facilities that are offered. Next the approach and results are dis-cussed of a survey among 137 end-users of 13 serviced offices in the Netherlands on im-portance. Last, a conclusion is drawn and recommendations are given for practice and for future research.

2 SERVICED AND CO-WORKING OFFICES

There are multiple overlapping markets for serviced office space, defined by quality of space, location and occupier (Gibson & Lizieri, 2000). The sector is relatively fragmented and operators vary in terms of their scale and scope (Dabson & McAllister, 2014). There seems to be a distinction between a few large, often international, operators that have a mix of large corporate and SME tenants and multiple small operators that focus on a more local market of SMEs, start-ups and freelancers (Peltier, 2001; Troukens, 2001; Dabson & McAllister, 2014). Due to the diversity of the market it is hard to generalise about the serviced office sector. The different types of tenants will likely have different needs regarding the offered services (Troukens, 2001).

Peltier (2001) showed that large and small serviced office operators do offer different products, aligned with their diverse tenant target groups. Large serviced office suppliers operate on a multinational scale in order to serve their corporate clients. Generally they are located on prime locations in grade-A buildings and offer a sophisticated set of products and services. Consistently, their clients expect to pay a premium for the offered product and services, compared to regular office space. On the other hand, small serviced office suppliers operate on a local or regional level, are located in ordinary adequate offices and offer a limited number of products and services. Their clients are willing to compromise product for cost and consequently expect to pay less compared to regular office space (Peltier, 2001). This lower price for the space and services can be offered because they can procure a large range of services at discounted rates, due to scale advantages and existing relationships with suppliers (McAllister, 2001).

The business model of serviced offices is funded based on the same principles as other forms of outsourcing, namely the conversion of fixed costs to variable costs and the transfer of risk to another party (Dabson & McAllister, 2014). Instead of the fixed costs associated with regular long-term leases and facility contracts, serviced offices offer products with flexible contracts that can be classified as variable costs. As corporate real estate managers see a lack of flexibility in real estate as a very important risk (Bartelink et al, 2015), leasing space at serviced offices could help to reduce this risk. Tenants also benefit from the advantage of a 'one-stop-shop', which means that the search costs that clients may incur in procuring office equipment and facility services when they would lease regular office space are reduced substantially (Dabson & McAllister, 2014).

The concept described as co-working offices (Weijs-Perrée, 2015) or co-working spaces (Kojo & Nenonen, 2014) is a more recent development (Deijl, 2012). The upcoming of new information and communication technologies made it possible for people to work outside of the traditional office environment. Furthermore, many freelancers and employees that worked at home felt the need to interact, socialise or collaborate with others. For users of co-working offices the immaterial benefits of co-working (e.g. knowledge sharing, collaboration and interaction with others) are not just a side-effect but the main reason to work in this kind of office space (Döring, 2010). Co-working is mainly practiced by small enterprises and freelancers. Therefore it is likely that the more flexible labour market and higher number of freelancers have contributed to the increased popularity of this type of office. The popularity of the co-working phenomenon may be an important reason why many serviced offices have integrated a co-working concept in (part of) their office space.

Van Meel & Brinkø (2014) mention that co-working offices differ on multiple aspects from serviced offices, e.g. on business model, target group, spaces, work mode, and management. However, as mentioned earlier, during the past decade in the Netherlands several commercial landlords have converted their vacant office buildings to serviced offices that often (partly) apply a co-working concept. Those serviced offices have a for-profit business model and offer private office space, but they also offer flexible open plan workspaces, organise networking events and have hosts instead of help desks (examples can be found on www.tribes.world). Furthermore these serviced offices have a broad tenant target group that consists of freelancers, SMEs and large corporates that operate in varying sectors. Thus, although a distinction between the two types of offices is justified, it is observed that (in the Netherlands) there are many business centres that apply a hybrid concept. Therefore, this study uses a definition of serviced offices that is only partly based on Dabson & McAllister (2014, p.4, underlined words are added/changed by the authors):

"a serviced office is a <u>fully furnished office</u> space within a building that is let, sub-let or licensed to third parties on a serviced basis. The services will tend to comprise all of the building services and a menu of business support services. It is an umbrella term that includes..." <u>hybrid forms of serviced offices and co-working offices</u>.

3   OFFICE USERS AND SERVICES AND FACILITIES

Serviced offices are used by a broad spectrum of organisations, employees and freelancers. Laterveer (2011) differentiates ten types of users of serviced offices based on a literature review: starting businesses; businesses that enter a new market; freelancers; virtual workers; flexible corporate employees; flex workers between appointments; organisations that need temporary office space; project teams; meeting teams; and video conference users. Although it has not been tested empirically and additional user types might exist, his typology provides an overview of users that have also been mentioned in previous studies (e.g. Dabson & McAllister, 2014). Moreover, his study provides valuable insights in relevant characteristics on which serviced office users differ from each other.

A serviced office manager has to deal with two levels of office users, namely companies, often referred to as tenants or occupiers, and the end-users, the people who work at these companies. For freelancers this is the same person, but for larger organisations it is not. Although this paper focuses on the importance of services and facilities for the end-user, some basic organisational characteristics (e.g. primary activity and size) are also relevant to define the end-users more completely.

A literature review on office user characteristics resulted in a list including three organisational characteristics, four demographic characteristics, seven job characteristics, and eight different purposes for using the serviced office. The purposes distinguished were based on the studies of Laterveer (2011) and Dabson & McAllister (2014), as they are considered a relevant characteristic for this research as well.

Weijs-Perrée et al. (2016) created a comprehensive list with services, facilities and spaces in business centres. It was complemented with services and facilities mentioned by Peltier (2001) and Gibson & Lizieri (2001) and those that were found on websites of serviced office operators. This resulted in 31 services and facilities, which includes among others building related services and facilities (e.g. cleaning and maintenance); food and drinks related services and facilities (e.g. catering); work related services and facilities (e.g. secretarial ser-

vice); non-work related services and facilities (e.g. gym, childcare); and all sorts of spaces and areas (e.g. conference room, outdoor area). All user characteristics and services and facilities are visible in the conceptual model presented in Figure 1.
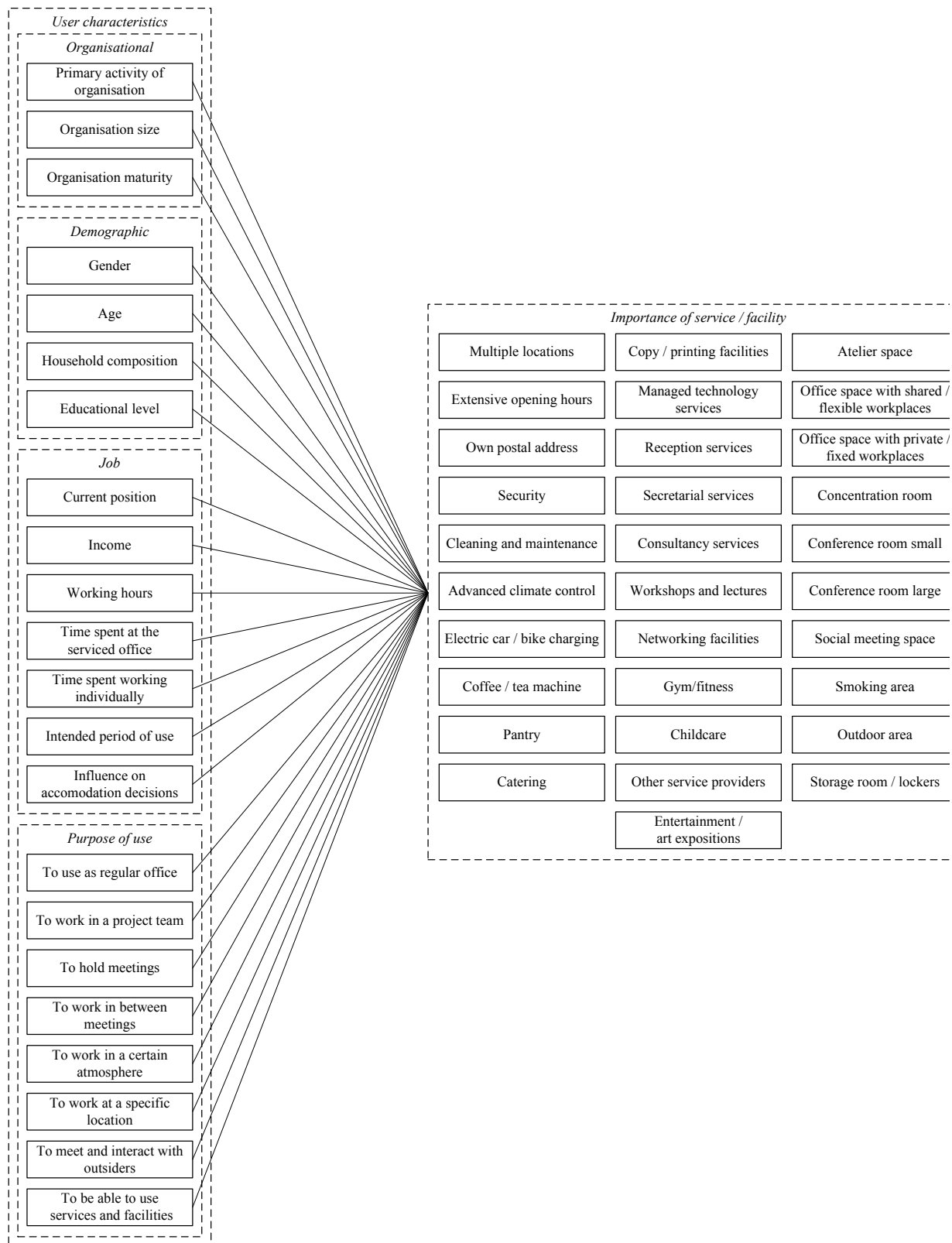

Figure 1 Conceptual model.

4   SURVEY, SAMPLE AND REDUCTIONS OF VARIABLES

A questionnaire was used to record demographics, job characteristics and purpose(s) for using serviced offices. It also included self-stated rating scales for measuring importance of 31 services and facilities on a 5-point scale ranging from very unimportant (1) to very important (5). In general respondents find this type of questions easy to answer and they provide more stable weights than other direct methods (Bottomley, Doyle, & Green, 2000; Gustafsson et al., 2004). The questionnaire was distributed physically in serviced offices in June 2016, but users also had the possibility to fill it in online. In total 137 respondents that work in thirteen serviced offices spread across the Netherlands filled in the questionnaire. Although it was not possible to obtain a randomly selected sample group, it has been attempted to include end-users of a diverse range of serviced offices. The respondents work 40.5 hours a week on average, 65 percent of the sample group is male and the age ranges from 17 to 63 years (average = 40.0).

Principal component analysis was used to reduce the data on importance by combining the 31 variables into a more limited number of factors (see Table 1). This resulted in a reduced list of six factors defined as linear combinations of in total 22 variables.

Four services and facilities were left out of the factor analysis due to a lack of correlation with other characteristics (which are multiple office locations, offering of an own postal address, catering and outdoor area for breaks). These services plus the identified factors are used in a regression analysis to find effects of user characteristics on perceived importance of services and facilities (factors). Associations are first explored with bivariate analyses. Only those characteristics that significantly relate to a service/facility (factor) were entered into multiple regression analyses to identify effects, as the sample was too small to include all variables and an effect is not likely when there is no bivariate effect in the first place.

5   RESULTS

An overview of the results of is presented in Table 2, in which the bivariate analyses results are shaded and the multiple regression analyses results not. When possible, the type of effect is indicated as well with + (positive effect) and – (negative effect). Overall, the proportion of the variance that is explained by the regression models is quite small (3.5% to 13.6%). This indicates that the known user characteristics explain only a very small proportion of the total variance of perceived importance of services and facilities.

It is striking that only three associations were found between the organisational characteristics and the importance of services and facilities. This is surprising because literature on serviced office users up until now mainly focussed on organisational aspects. Moreover, other studies mention a division of the market between major international operators and small local operators that cater the needs of respectively large corporate organisations and small businesses. The results of this study do not indicate that employees of these small and large organisations have varying preferences regarding services and facilities.

Demographic characteristics also only have a small effect on the importance of services and facilities. Previous research on single tenant office users did find effects of age on end-user satisfaction. In this sample only two categories of services and facilities are associated with demographic characteristics. It was found that users with a lower income and users with a lower educational level consider supportive services and facilities relatively more important

(e.g. reception, consultancy services, atelier space). Interactive services and facilities (e.g. networking events) are considered more important by users with a yearly income below € 30.000 and users that use the serviced office because of its atmosphere.

Table 1 Rotated component matrix (PCA) for importance of services & facilities

PCA with varimax rotation converged in 7 iterations (N=137)	Factors Services & Facilities					
	building related	amenities	technology	supportive	interactive	rooms & spaces
Security	0,575	0,132	0,185	0,103	-0,125	-0,046
Cleaning and maintenance	0,744	-0,127	-0,097	0,087	0,129	-0,048
Advanced climate control	0,631	0,106	-0,138	-0,019	0,083	0,126
Electric car / bike charging	0,303	0,469	0,336	-0,001	0,108	0,164
Gym / fitness	0,057	0,639	0,067	-0,033	0,213	-0,076
Childcare	0,069	0,780	0,110	0,042	-0,040	0,079
Other service providers	-0,047	0,800	-0,005	0,222	0,008	0,080
Entertainment / art expositions	-0,047	0,650	-0,154	0,206	0,278	0,025
Copy / printing facilities	0,037	-0,031	0,693	0,221	0,216	0,075
Managed technology services (e.g. LAN, phone)	-0,142	0,129	0,792	-0,009	0,088	0,041
Reception services	0,074	-0,083	0,423	0,422	-0,013	0,370
Secretarial services	0,267	0,099	0,144	0,798	-0,017	-0,078
Consultancy services	0,119	0,156	0,228	0,743	0,197	-0,224
Workshops and lectures	0,038	0,235	0,159	0,246	0,756	0,119
Networking facilities	0,099	0,095	0,128	0,089	0,820	0,062
Atelier space	-0,321	0,330	-0,107	0,491	0,211	0,180
Storage room / lockers	-0,080	0,077	-0,039	0,569	0,097	0,308
Social meeting space	-0,066	0,188	0,114	-0,081	0,504	0,485
Office space with shared / flexible workplaces	-0,217	0,028	-0,005	0,093	0,054	0,673
Concentration room	-0,051	0,031	-0,061	0,107	0,307	0,667
Conference room small	0,308	-0,081	0,084	-0,048	0,049	0,708
Conference room large	0,173	0,248	0,325	-0,045	-0,155	0,697

Total variance explained 58,7%

Table 2 shows that job characteristics particularly affect how important users consider an outdoor area. Income and time spent at the serviced office are both identified as negative predictors, but no logical explanation comes to mind. The importance of an own postal address shows the most associations, especially with job characteristics and the purposes of use. It is a relevant service to offer, as it is considered more important by those users that can influence accommodation decisions.

The results also show logical effects of the purpose of using a serviced office on perceived importance of services and facilities. Respondents that use the serviced office as a regular office find technology and an own postal address more important, while users that work in a project team find shared workspaces and rooms relatively important and attach less im-

portance to a postal address. Respondents that use the serviced office to hold meetings find rooms and spaces (e.g. meeting rooms), catering and an outdoor area relatively more important, while people that use the serviced office to work at a specific location find multiple office locations more important. And respondents that use the serviced office for its services and facilities find the amenities (e.g. gym, childcare) and an own postal address relatively more important. Although many associations were found, it is surprising that no relation was found between the usage purpose 'to meet and interact with outsiders' and the importance of interactive services and facilities.

Table 2 Overview of results of bivariate and multiple regression analyses

		Importance of … services & facilities									
		Building related	Amenities	Technology	Support	Interactive	Rooms & spaces	Multiple locations	Own postal address	Catering	Outdoor area
	Variance explained by model (%)	7.4	4.4	7.3	10.6	13.6	5.4	3.5	10.3	6.1	9.3
Organis.	Primary activity of organisation			**						**	
	Organisation size	*									
	Organisation maturity										
Demograph.	Gender										
	Age					+*					
	Household composition										
	Educational level				-**	-	+**				
Job	Current position	**							*		
	Income			-**		-**					-**
	Time spent at the serviced office (hours)						-*	+*	+		-*
	Time spent working individually (hours)										
	Intended period of use										
	Influence on accommodation decisions		**		*	-			+		
Purpose of use	To use as regular office			+					+*	+	
	To work in a project team						+		-		
	To hold meetings						+			+*	+
	To work in between meetings										
	To work in a certain atmosphere					+**					
	To work at a specific location							+**			
	To meet and interact with outsiders										
	To be able to use services and facilities		+						+**		

*Significant at 90% confidence interval
**Significant at 95% confidence interval
**Significant in bivariate analyses only

6 CONCLUSION AND RECOMMENDATIONS

This exploratory study indicates that user characteristics significantly influence how important services and facilities are considered to be by end-users of serviced offices, especially job related characteristics and the purpose of using a serviced office. However, the regression models only predict a small proportion of the variance of the importance of studied aspects, thus further research is needed to confirm the exploratory results. Although the results of this study do not offer direct tools that can be used to differentiate service menu's from competitors, the results of the analyses do indicate that job characteristics and reasons for using a serviced office are likely more relevant for differentiation strategies than organisational and demographic characteristics.

Because this study focuses on importance, it was possible to gather data on users' opinions on services and facilities also of those that are not offered in their serviced office, in contrast to studies that measure satisfaction of end-users with aspects of the current office. Consequently the research gives insight in the relevance of less common services and facilities (e.g. atelier space; concentration rooms; secretarial services; consultancy services; gym/fitness; childcare).

Although it was attempted to include end-users of a diverse range of serviced offices, the selection of the sample group is not random. Combined with the small sample size of 137 respondents this negatively affects the external validity. Also the proportion of the variance that is explained by the regression models is quite small. This means that there are likely other aspects that also affect the user's opinion on the importance of services and facilities. For further research it is recommended to gather data from more respondents and include personality characteristics. Furthermore, this study explored the effect of the purpose of use on users' opinions on importance of services and facilities and showed some promising results. Elaborating on this subject, further research could be conducted on serviced office users' motives, activities and needs, both on organisational and end-user level. Conjoint analysis would be an appropriate, more advanced method to study importance rating.

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The Role of FM in Disaster Resilience: Integrating the Sendai Framework into Disaster Risk Management

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ABSTRACT

As future cities become larger and ever more densely populated the impacts that natural and manmade disasters (e.g. flood, heatwave, earthquakes etc.) have on the resilience of city communities will become more extreme. The Sendai Framework for disaster risk reduction was adopted by the UN in 2015 as the global framework through which stakeholders involved in managing pre and post disaster planning can seek to reduce the impact of such events on communities. However, whilst the Framework provides general guidance and identifies 4 priority areas for action (understand the disaster risk, strengthen disaster governance to manage risk, invest in disaster risk reduction to improve resilience, enhance disaster preparedness and build-back-better) it doesn't provide any practical tools to allow stakeholders to address these areas. This paper presents a theoretical mapping between the Sendai Framework and Built Asset Management strategies through which pre-event mitigation and post-event disaster recovery plans can be developed and integrated in business continuity planning. The paper outlines a Resilience Assessment and Improvement Framework that will be used in the EU H2020 LIQUEFACT project. Once validated through the LIQUEFACT project the Resilience Assessment and Improvement Framework will allow Facilities Managers in both public and private sector organisations to evaluate their exposure to a range of natural and manmade disaster events and to assess the potential of a range of mitigation and adaptation techniques to reduce their vulnerability and/or improve their resilience to a disaster event. This in turn will aid community resilience and enhance speed of recovery.

1   INTRODUCTION

This paper provides a description of a desk based study to outline a resilience assessment and improvement framework (RAIF) that can be used by built assets owners and/or managers to assess the antecedent vulnerability, resilience and adaptive capacity of their built assets (buildings and infrastructure) to disaster events; particularly Earthquake Induced Liquefaction Disaster (EILD) events, and develop and evaluate alternative adaptation measures to reduce vulnerability and/or improve resilience at the built asset and community level. The RAIF is an enhancement of the risk/resilience framework developed by Jones et al (CREW, 2012) to extreme weather events. In particular the risk/resilience framework has been enhanced and refined to reflect the latest disaster risk reduction guidance provided through the

SENDAI Framework; best practice extracted from other earthquake risk reduction frameworks; and the specific EILD risk framing approaches used by various existing protocols and software tools. By extension the framework can also be used by EU, national, regional and local decision makers to assess vulnerability, resilience and adaptive capacity of urban communities to EILD events. The RAIF represents the first output from the LIQUEFACT project.

2 THE LIQUEFACT PROJECT

Recent events have demonstrated that EILDs are responsible for significant structural damage and casualties with, in some cases, EILDs accounting for half of the economic loss caused by earthquakes. With the causes of Liquefaction being substantially acknowledged, it is important to recognize the factors that contribute to its occurrence; to estimate the impacts of the EILD hazards; and to identify and implement the most appropriate mitigation strategies that improve both building/infrastructure and community resilience to an EILD event. The LIQUEFACT project adopts a holistic approach to address the mitigation of risks to EILD events in European communities. The LIQUEFACT project sets out to achieve a more comprehensive understanding of EILDs, the applications of the mitigation techniques, and the development of more appropriate techniques tailored to each specific scenario, for both European and worldwide situations.

3 VULNERABILITY, RESILIENCE, ADAPTIVE CAPACITY AND RISK

Vulnerability, resilience, and adaptive capacity are concepts from the biophysical and social realms that are increasingly being applied to the understanding of the complex relationships between communities, the built environment, and the drivers that may affect change. Whilst there is considerable debate over the precise definitions of the terminology (Gallopín, 2006), the UNISDR defines:

- **Vulnerability** as *"the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard"*. Vulnerability is considered as the principal component of risk (Hewitt, 1983) which encompasses physical, social, economic, and environmental factors and the effect that these have across geographical, social and temporal scale.
- **Resilience** as *"the ability of a system, community or society exposed to hazards to resist, absorb, accommodate and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions"*. Resilience is both the capacity of a system to react appropriately to moments of crises that have not been entirely anticipated, and its ability to anticipate these crises and to enact, through planning and recovery, changes in the systems that will mitigate their effects (Aguirre, 2006). Therefore, the resilience of a community is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need.
- **Adaptive Capacity** as *"the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.*[8] Adaptation can occur in an autonomous fashion, for exam-

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[8] This definition addresses the concerns of climate change and is sourced from the secretariat of the United Nations Framework Convention on Climate Change (UNFCCC). The broader concept of adaptation also applies to non-climatic factors such as soil erosion or surface subsidence.

ple through market changes, or as a result of intentional adaptation policies and plans. Thus adaptive capacity can be considered as the capacity of a system to adopt mitigation measures (physical, social, economic, environmental etc.) to potential disaster events.

The UN International Strategy for Disaster Risk Reduction (UNISDR, 2009) defines

- **Risk** as *"The combination of the probability of an event and its negative consequences"*.

In this context the term risk extends beyond a single measure of the impact of an event to encompass a range of *"... potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period"*. Thus disaster risk reflects the concept of disaster as the outcome of continuously present conditions of risk and comprises different types of potential losses which are often difficult to identify and quantify. Thus, whilst in its simplest form risk may be expressed as:

$$R = H\,V\,E$$

Where:
  Risk (R): the combination of the probability of an event and its negative consequences
  Hazard (H): the probability of an event occurring
  Vulnerability (V): the characteristics of a system that make it susceptible to the damaging effects of a hazard
  Exposure (E): all the elements of the system that are subject to potential loss

The metrics required to measure vulnerability and exposure are complex and need to reflect the inter-relationships between the characteristics of the system (or indeed systems) and multiple potential losses and as such a single measurement of risk is not meaningful in a disaster risk context. Establishing a measure of risk is further complicated when one considers the relationship between vulnerability and resilience. Resilience is related to vulnerability; the more resilient a system the less vulnerable it is to the impacts of a hazard. Given the relationship between resilience and vulnerability the risk formula may therefore also be expressed as:

$$R = H\,\frac{V}{Re}\,E$$

Where (in addition to the definitions above):
  Resilience (Re): The ability of a system, community or society exposed to hazards to resist, absorb, accommodate and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions

Given the above, when considering the theoretical requirements of the RAIF the LIQUEFACT project perceives risk as a multi-dimensional (e.g. vulnerability, coping capacity, exposure of persons and assets etc.) construct that needs to be assessed across of range of scales rather than as a single measure at a single scale. In essence the RAIF must accommodate all the impacts that a disaster event may have on the performance of built assets from both the physical and business perspective as it is the combination of these that effect the wider resilience of the system (economic, political, social and business effects) and the community.

4 SENDAI FRAMEWORK FOR DISASTER RISK REDUCTION

There have been many attempts at producing guidance on how to reduce disaster risks and improve community resilience. The latest such guidance, the SENDAI Framework for Disaster Risk Reduction 2015-2030[9] (UN General Assembly, 2015), is a 15-year non-binding agreement that was adopted at the Third United Nations World Conference on Disaster Risk Reduction, held from 14 to 18 March 2015 in SENDAI, Miyagi, Japan.

The stated intention of the SENDAI Framework is to support a ''… substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries.'' To this end the SENDAI Framework encourages countries to adopt a concise, focused, forward-looking and action-oriented framework for disaster risk reduction that considers a wide spectrum of small-large scale, frequent and infrequent, sudden and slow onset disasters caused by natural and man-made hazards. The SENDAI Framework is based on (but not limited to) the following guiding principles:

- Disaster risk reduction is a shared responsibility between government, authorities, sectors and stakeholders. It requires all-of-society engagement;
- When managing disaster risk consideration should be given to protecting people, their health, property and livelihoods, as well as productive, cultural and environmental assets;
- Disaster risk reduction depends on coordination mechanisms within and across sectors and with relevant stakeholders; and requires empowerment of local communities;
- Disaster risk reduction requires a multi-hazard and risk–informed decision making based on scientific information complemented with local knowledge that contextualises the information to local circumstances;
- Disaster risk reduction is more cost-effective than post disaster response and recovery and a "build-back-better" philosophy reinforces future risk reduction.

When developing implementation plans the SENDAI Framework suggest that national states should focus on 4 priority areas for action.

- **PRIORITY 1: Understand the disaster risk**
  A holistic understanding of disaster risk in all its dimensions is essential to support effective risk management. Using relevant and reliable data (nationally and locally) will provide base-line information on vulnerability, adaptive capacity, exposure and hazard characterisation which will allow primary and secondary impact scenarios to be modelled and the effectiveness of coping strategies to be evaluated. The scenarios can also provide a mechanism to communicate the disaster risks to central planners and the wider community.

- **PRIORITY 2: Strengthen disaster governance to manage risk**
  Develop clear vision, plans, guidance, command, control, and coordination activities within and across sectors that engage all the stakeholders in disaster risk management. In developing the systems consideration should be given to publicly and privately owned criti-

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[9] See http://www.unisdr.org/we/coordinate/SENDAI-framework for full details.

cal infrastructure as well as to households, communities and businesses. Whilst systems can be designed centrally they should be enabled locally with local authorities empowered to act at the local level.

- **PRIORITY 3: Invest in disaster risk reduction to improve resilience**
  Public and private investment in disaster risk reduction is essential to enhance economic, social, health and cultural resilience of people, communities, countries and their assets. Effective mechanisms should exist to promote disaster risk transfer (e.g. insurance, risk sharing and retention, financial protection etc.) for both public and private assets and in particular critical infrastructure assets including appropriate design standards; building materials; and maintenance and refurbishment strategies. With regards to business resilience, effective understanding of the integration of disaster risk management into business models, including the supply chain, is critical if livelihoods are to be protected.

- **PRIORITY 4: Enhance disaster preparedness and build-back-better**
  Pre-planning is essential for an effective recovery, rehabilitation and reconstruction following a disaster event. This phase also offers an ideal opportunity to build-back-better by integrating disaster risk reduction into development and reconstruction projects. To prepare for disaster events requires contingency plans and programmes to be developed and tested routinely across the community. These plans need to consider forecasting and early warning systems as well as communication systems and channels. Policies to improve the resilience of existing critical infrastructure should be developed and implemented as part of routine refurbishment. Logistics required immediately after a disaster event should be stockpiled and a distribution system established for their release immediately following a disaster event.

One of the pivotal strengths of the SENDAI Framework is that it recognizes that the State has the primary role to reduce disaster risk but that responsibility should be shared with other stakeholders including local government and the private sector including community organizations and businesses. However, whilst the SENDAI framework provides the high level strategic guidance needed to drive improvements in disaster risk reduction it doesn't provide operational guidelines on how to deliver improvements at a local policy or building level. In particular it doesn't provide an action-oriented framework that relevant stakeholders at all levels can use to identify disaster risks and guide mitigation investment decisions to improve community resilience. This is particularly true in the facilities management field where the SENDAI principles need to be integrated in disaster management and business continuity plans and maintenance and refurbishment strategies if the impact of disaster events on critical built assets and businesses is to be reduced and community resilience improved.

5   RESILIENCE ASSESSMENT AND IMPROVEMENT FRAMEWORK

The RAIF is based on the risk/resilience framework developed by Jones et al (CREW, 2012) in the CREW project. The CREW project developed and tested a 6 stage adaptation framework that was integrated into a built asset management model that would allow building owners/managers to identify and programme interventions (physical and social) to improve the resilience of their built assets to extreme weather events. Whilst the stressor behind the disaster risk associated with the LIQUEFACT project is different to that used in the CREW project the general theory supporting the adaptation framework is similar. The underlying theory is based on Cutter's (2008) Disaster Resilience of Place model (Figure 1) in which antecedent conditions, including coping response and absorptive capacity, directly affect

speed of recovery and system resilience. The LIQUEFACT project has re-interpreted the adaptation framework developed in the CREW project to reflect the expectations inherent in the SENDAI Framework and the specific characteristics associated with EILD events. To this end the RAIF draws together two main activities; a risk-based assessment of the antecedent conditions that affect building and community resilience pre event and a resilience improvement framework that will allow alternative mitigation options to improve building and community resilience to be evaluated against a range of post event scenarios. The RAIF is show in Figure 2.
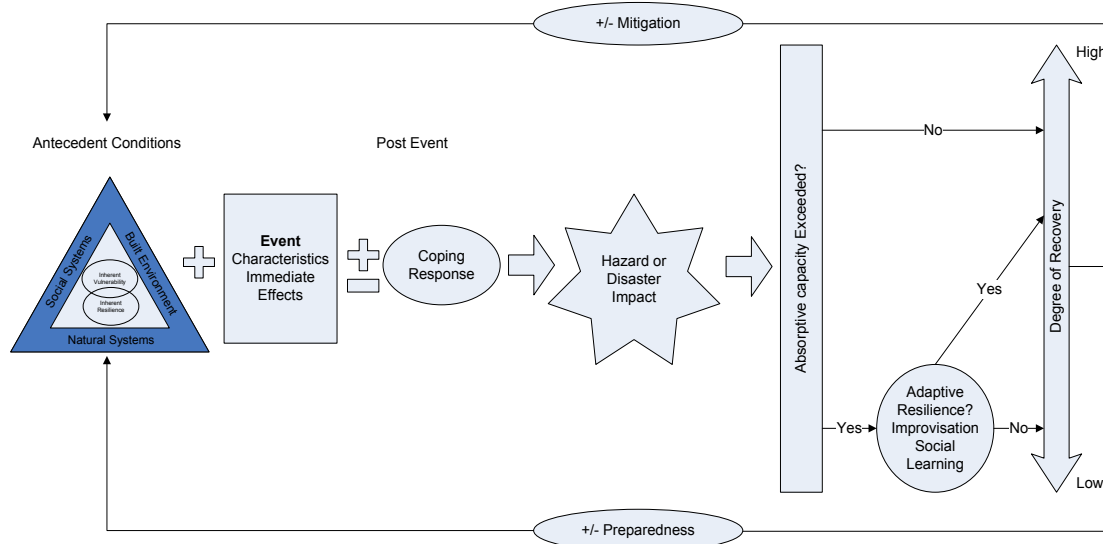
Figure 1 Schematic representation of the disaster resilience of place (DROP) model
(Source: Cutter et al, 2008)

Stage 1 – Antecedent Condition Analysis: The first stage of the RAIF requires an assessment of the vulnerability of an asset (e.g. individual building/infrastructure asset, portfolio of buildings/distributed infrastructure assets, town/city wide buildings/infrastructure, regional wide buildings/infrastructure, state wide buildings/infrastructure assets etc.) to an EILD event. The first stage of this assessment is to identify whether the asset is located in a geographical area likely to be affected by an EILD event. For each built/infrastructure asset identified as at potential exposure to an EILD event the level of hazard is evaluated by considering the probability of an earthquake hazard and the susceptibility of the ground to liquefaction. The level of hazard will be classified using qualitative labels ranging from "Very Low" to "Very High" that express the level of likelihood of the ground below the asset to liquefy for any given earthquake characteristic.

In order to assess how an individual building/infrastructure asset is likely to be affected by an EILD hazard an assessment needs to be made of the potential impact of liquefaction on the integrity of the building/infrastructure assets on the site. This in essence will be an assessment of the inherent level of vulnerability/resilience of a building/infrastructure asset topology to a potential EILD event. For buildings, for example, the vulnerability/resilience is likely to be a combination of construction and foundation type. The level of vulnerability/resilience will be classified using qualitative labels ranging from "Very Low" to "Very High".

This analysis will provide asset managers and other stakeholders with an assessment of the range of exposures that their asset(s) are likely to be susceptible to and their inherent vulnerability/resilience to these exposures.

Stage 2 - Impact Assessment: The hazard-exposure and vulnerability/resilience scores from stage 1 will be used to assess the level of risk to building/infrastructure asset(s) which in turn will be used as the basis to assess the loss of functionality of the building/infrastructure asset(s) immediately following disaster event. The loss of functionality will be made on a case by case basis using the expert knowledge of the facilities manager and building users to interpret the impact that any given level of risk will have on functionality and performance. It is currently assumed that the loss of functionality will be categorised using qualitative labels ranging from "minor cosmetic damage" to "major structural damage" with the loss of performance being a further qualitative statement contextualising the impact of the loss of functionality.

Stage 3 - Community Impact Scenarios: The impact of the loss of performance of individual building/infrastructure assets on the resilience of a community following an EILD event will be assessed by integrating the performance outcomes identified in stage 1/2 of the RAIF (above) into a FCM (stage 3 of the RAIF) that describes the complex relationships (physical, social, organizational, economic etc.) that constitute a communities resilience to disaster events.

The resilience modelling component of the RAIF seek to identify and investigate all the factors that influence the vulnerability, resilience and adaptive capacity of an urban community to an EILD event. Unfortunately, because of inter-relationships and interdependences between resilience indicators (resilience, vulnerability and adaptive capacity are in essence concepts and as such cannot be measured directly) and the uncertainties that these place on quantitative measurements, resilience in absolute terms is difficult to measure.

The uncertainties associated with the resilience assessments can be accommodated by applying the FCM (Stylios, Georgopoulos, & Groumpos, 1997) to the development of resilience models. The RAIF will use FCM to define inherent vulnerabilities (physical, social, environmental, economic etc.) at the sub-system level (e.g. health care, transport etc.) to provide a resilience assessment of each sub-system to an EILD event. The RAIF will then combine the sub-system FCMs to provide a resilience assessment at the overall community level.

Stage 4 - Mitigation Options: Once the baseline assessment of the resilience of the sub-systems and community to an EILD event has been established and the required improvements in resilience have been defined the ability of a range of mitigation actions to achieve the required improvements can be evaluated. This analysis requires a range of mitigation actions to be identified (both physical and operational) and the effect of each on the level of performance of individual buildings/infrastructure assets to be evaluated using the impact assessment matrix outlined in Stage 2.

Two types of mitigation actions need to be considered; those that seek to reduce a building/infrastructure assets vulnerability/increase its resilience; and those that seek to reduce the hazard level. The former are likely to be building level interventions; the latter are likely to be ground level interventions. The vulnerability and resilience of the modified building/infrastructure assets will be remodelled (stages 1-2) and the impact on resilience (stage 3)

re-assessed. Mitigation options will be ranked according to their impact on the sub-system level and on their contribution to improving overall community resilience.

Stage 5 - Improvement Framework: Once the mitigation options have been identified a cost/benefit analysis will be calculated for each specific sub-system component. The cost/benefit analysis will need to consider both direct and indirect costs (e.g. physical, loss of revenue during refurbishment period, etc.) and benefits (e.g. to the organisation, community, etc.) and extend the analysis across geographical and temporal scales (e.g. consider the inter-relationships between multiple similar assets, consider the implications of delaying refur-bishment until later in a building/infrastructure life cycle).

Once the cost/benefit analysis has been completed for all sub-system components, considera-tion will need to be given setting intervention priorities and sequencing of work. The adaptive capacity of all stakeholder groups to fund and manage the retrofitting of mitigation interven-tions will need to be assessed (e.g. availability of capital, governance requirement, legislation etc.) and priorities set for both the mitigation interventions to be enacted (it is very unlikely that sufficient adaptive capacity will be available to adopt all the mitigation actions suggested by the FCM model) and the timescales over which they will be programmed (e.g. retrofitting of buildings/infrastructure mitigation interventions are likely to be programmed periodically over the assets normal refurbishment cycle – up to 30 years in some cases).

Stage 6 - Built Asset Management Planning: once priorities have been set, detailed built asset management plans can be developed. These plans require detailed design solutions to be developed for each mitigation intervention and all financial and legal conditions to be ad-dressed before contracts are let. Once implemented, the performance of mitigation interven-tion against the performance specification detailed in stage 4 is monitored through detailed simulation or in response to an EILD event.

Once assessments have been completed for an individual built assets they can be combined across the whole built asset portfolio (e.g. healthcare assets) and then these can be combined with other sub-systems (e.g. Transport) to assess the resilience of a community to the com-bined stressors associated with a disaster event.

6   CONCLUDING COMMENTS

Improving the resilience of communities to natural and manmade disaster events is complex activity that requires all the stakeholders involved in the community to work together to re-duce the vulnerability and improve the resilience of individual system components across the range of community systems. In particular those responsible for the critical built assets and infrastructure that the community will rely on immediately following a disaster event (healthcare, utilities, transport, industry etc.) need to be aware of not only the impact that a disaster event may have on their assets but also how a loss of performance of their assets may affect other parts of the community and hence to inhibit the ability of the whole community to recover from the event. In this context Facilities Managers have a key role to play in both preparing for a disaster event and managing the consequences of such an event. Facilities Managers need to better understand the hazards and risks that a disaster event may pose to their organisation and be able to assess the impact that loss of performance within their or-ganisation may have on the wider community in which they function.

Figure 2 Resilience Assessment and Improvement Framework (adapted from the CREW Adaptation Framework, 2012)
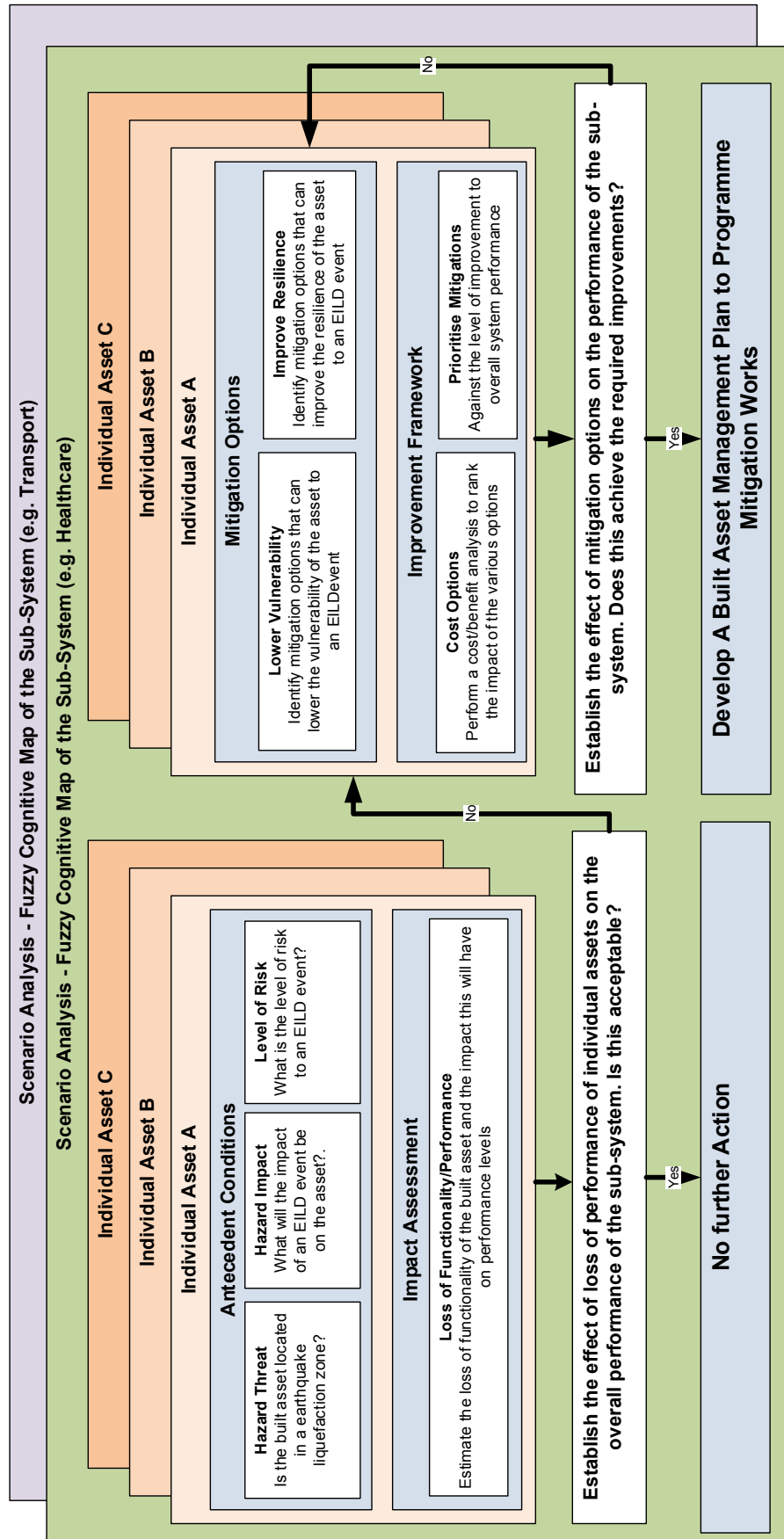
Whilst at present most disaster management and business continuity plans are focussed on the former, few (if any) address the latter. This is the major challenge that the SENDAI Framework presents to Facilities Managers; how can organisations extend their disaster and built asset management strategies beyond the immediate business level to the wider community level? This paper has outlined a new theoretical Resilience Assessment and Improvement Framework which addresses this challenge. The RAIF integrates the risk reduction guidance contained in the UN SENDAI Framework into a built asset management framework that Facilities Managers can use to assess their organisation's vulnerabilities and resilience to disaster events and integrate these into a wider assessment of community resilience. Over the next 36 months the LIQUEFACT project will develop and test the practical toolkits needed to operationalise the RAIF in the context of EILD events.

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Out of the Shadows: Influencing Train Passengers' Perceptions and Satisfaction by Increasing Visibility of Cleaning Staff

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ABSTRACT

Purpose: Traditionally, most cleaning activities take place in the evening or during night-time. In the Netherlands, day-time cleaning is becoming increasingly popular. It is however unknown how day-time cleaning affects perceptions and satisfaction of end-users. An experimental field study was conducted on trains of Netherlands Railways (NS) to determine how the presence of cleaning staff affects perceptions and satisfaction of train passengers.

Design/methodology/approach: Data were collected on the trajectory between station Amsterdam Amstel and station Utrecht Centraal in the fall of 2015 during off-peak hours ($N = 1,113$). In the experimental condition ($N = 482$) two cleaners collected waste and performed minor cleaning activities during the journey. In the control condition ($N = 631$), no cleaners were present.

Findings: It appeared that the presence of cleaning staff positively influenced train passengers' satisfaction. In addition, a positive and significant relationship was found between the perception of staff, cleanliness, comfort, atmosphere, satisfaction, and the presence of cleaning staff.

Practical implications: Perceived cleanliness is an important indicator of actual cleanliness for managers of facility services. Due to rapid technological developments cleaning service might be robotised in the near future. However, this study highlights the added value of the presence of cleaning staff to the primary service process.

Originality/value: No experimental field study focussing on the effects of day-time cleaning on perceptions and satisfaction of train passengers has previously been undertaken.

Keywords: Cleanliness, customer satisfaction, perceptions, rail, day-time cleaning

1   INTRODUCTION

Cleaning of offices, school buildings, airports, and trains most often takes place in the evening or during night-time, out of the sight of end-users (Ueno et al., 1984). There are several reasons to perform cleaning activities in the evening or during night-time. Most importantly, productivity of cleaning staff is assumed to be higher and end-users are not disturbed. It is however unknown if and to what extent day-time cleaning affects perceptions and satisfaction of end-users. This study aims to bridge this gap by reviewing current literature and performing field experiments on trains of Netherlands Railways (NS). The main research question is: "to what extent does day-time cleaning influence perceptions and satisfaction of train passengers?"

2   THEORETICAL FRAMEWORK

2.1   Service experience
Service research generally distinguishes three factors that influence the service experience, namely: the service processes, the environment, and the people present (staff and customers) (e.g., Bitner, 1990; Turley & Milliman, 2000). Firstly, service processes are time bound and efficiency is essential; how smoother the service process runs, the more satisfied customers will be. Service processes are essential to railway operators such as NS: punctuality is key to train passengers (Van Hagen, 2011). Secondly, the environment in which the service is produced and consumed simultaneously can have a lot of impact on perceptions of service satisfaction and quality (Bitner, 1992; Mari & Poggesi, 2013). Train passengers will have greater confidence in the business processes (e.g. punctuality) when the trains and train stations are clean, safe, and well planned. Lastly, perceptions and satisfaction of customers are influenced by other shoppers and staff. Moreover, the presence of others in the service environment influences how the service is experienced: presence of too many or too few other customers may result in negative feelings (Eroglu, Machleit, & Chebat, 2005). Also the presence of sufficient and well-trained service employees is positively related to perceptions and satisfaction (Turley & Milliman, 2000).

2.2   Presence of staff
Service employees are critical in the service delivery process (Gutek, 1999; Vilnai-Yavetz & Rafaeli, 2011). They also communicate a firm's ideals and attributes to customers, representing it in their appearance and behaviour. Previous research indicated that the presence of service employees positively influences perceptions of service quality (Baker, Grewal, & Parasuraman, 1994) and customer's attribution and satisfaction in case of service failure (Bitner, 1990). In general, most research focusses on the presence of service employees in a retail environment (e.g. cashiers, sales people). The effect of the presence of cleaning staff and day-time cleaning could be considered as underexposed in service and facility management research. The qualitative studies of Whitehead, May, and Agahi (2007) and Whatley, Jackson, and Taylor (2012) are to the knowledge of the authors the only studies evaluating the effect of cleaning staff on perceptions. In both studies, the presence of cleaning staff and more specifically the appearance, behaviour, and attitude of cleaning staff were identified as 'social cues' that positively influence perceptions of cleanliness. Besides a number of positive implications for customers, previous research indicates that cleaning staff may benefit from day-time cleaning as well.

2.3 Implications of day-time cleaning for cleaning staff

Sociologists (e.g., Dutton, Debebe, & Wrzesniewski, 1999; Emerson & Pollner, 1976) refer to the work of cleaners and janitors as "dirty work". Dirty work refers to work that is experienced as heavy and odious by the individual and colleagues. Ueno et al. (1984) researched the effect of consecutive night-shift work on health conditions among cleaners of the Shinkansen Super-Express trains. It appeared gastrointestinal disorder, general fatigue, and depression was more common among cleaners working night-shift hours compared to cleaners who worked during day-time. Moreover, night-shift cleaners indicated that they had too little time to rest, enjoy social events, and pursue studies outside working hours. The close relationship between the type of "shift systems" and different medical and social problems was widely demonstrated by several scholars in different industries (e.g., Costa, 1996; Hansen, 2001; Kogi, 1976).

In contrast, cleaners who work during day-time experience a better work life balance and face less medical and social problems compared to cleaners who work during night-time (Ueno et al., 1984). Moreover, interaction between cleaners and customers is considered to be one the main advantages of day-time cleaning. Previous research stated that the experience of employees in the service environment is correlated with the experience they create for their customers (e.g., Parish, Berry, & Lam, 2008; Schneider, Ehrhart, Mayer, Saltz, & Niles-Jolly, 2005). Although the main focus of this paper is on the effect of day-time cleaning on perceptions and satisfaction of customers we expect that there is a cyclical relationship between day-time cleaning, job satisfaction and customer satisfaction. Day-time cleaning positively influences job satisfaction, more satisfied employees create more satisfied customers, and satisfied customers positively influence the "quality" of the employee-customer interaction.

2.4 Hypothesis formulation

Following previous research the expectation was that the presence of cleaning staff would positively influence satisfaction *(H1)* and perceptions of staff *(H2)* (Baker et al., 1994) and perceptions of cleanliness *(H3)* (Whatley et al., 2012; Whitehead et al., 2007). Following research of Van Hagen (2011) we expect that the presence of cleaning staff serves, as other environmental stimuli (e.g. music, scent) as a positive mood inducer. Therefore we expect that people experience more pleasure and subsequently have more positive perceptions of comfort *(H4)*, trip speed *(H5)*, and atmosphere *(H6)*.

3 METHOD

This study was carried out in trains of Netherlands Railways (NS). NS is the major railway operator in the Netherlands by daily handling more than a million passengers. NS outsourced its cleaning activities to Hago Rail Services. The contract is considered to be the largest cleaning contract of the Netherlands.

3.1 Participants and procedure

The goal of this field experiment was to determine if the presence of cleaning staff influenced perceptions and satisfaction of passengers. Data were collected on the trajectory between station Amsterdam Amstel and Utrecht Centraal in the fall of 2015 (N = 1,113) during off-peak hours. Approximately 63% of the participants were female, average age was 34 years (M = 34.4, SD = 16.9). Travel motives were distributed as follows: 26.8% school/education, 20.4% commuting, 20.3% leisure, 13.7 % business travelling, 14.3% visiting family or friends, 4.5% other. The journey between Amsterdam and Utrecht is approximately 35 kilometres and takes

20 minutes by train. In the experimental condition (N = 482) two cleaners in neat clothes collected waste and performed minor cleaning activities during the journey. If needed, cleaners provided travelling information to the train passengers. In the control condition (N = 631), no cleaning staff was present. Data of the experimental and control condition was gathered on the same days. Surveys were collected during the journey by experienced research assistants.

3.2 Measures

The survey contained approximately 40 items about passengers' satisfaction with the service and questions about passengers' perception of staff, cleanliness, comfort, trip speed, and atmosphere. In addition, background information about the passengers' gender, age, and travel motive was collected. The survey was conducted in Dutch, items were translated to English. An overview of the composite variables, corresponding items, and Cronbach's alpha was presented in Table 1. Except for one item of the comfort construct, all constructs were considered to be reliable. The survey data was analysed using IBM SPSS Statistics 22.

Table 1 Overview of constructs, items, and Cronbach's alphas

Construct	Items	Cronbach's alpha	Mean	SD
Perceptions of staff	The staff is visible during the journey, I think the staff is attentive, I think the staff is professional (*1 = totally disagree, 7 = totally agree*).	.872	6.20	1.85
Perceptions of cleanliness	I think the interior of the train is clean, I think the interior of the train is well maintained (*1 = totally disagree, 7 = totally agree*).	.858	6.31	1.30
Perceptions of comfort	I experience the comfort as pleasant, the train furniture meets my needs, I am able to spend my time pleasantly in this train (*1 = totally disagree, 7 = totally agree*).	.724	7.06	1.25
Perceptions of trip speed	My train ride is smooth and without problems, This train brings me quickly to my destination, This train runs right on time (*1 = totally disagree, 7 = totally agree*).	.807	7.76	1.64
Perceptions of atmosphere	I think this train is colourful, I think it is cosy in this train, I think the scent in this train is pleasant, I think the exterior of this train looks appealing (*1 = totally disagree, 7 = totally agree*).	.709	6.20	1.21
Satisfaction	What do you think of the service of NS? (*1 = poor, 10 = excellent*).	-	7.20	1.03
Gender	What is your gender? *(male, female)*	-	-	-
Age	What is your age? *(open)*	-	34.41	16.95
Travel motive	What is your main travel motive? *(commuting, business travelling, school/education, visiting family or friends, leisure, other motives)*	-	-	-

4 RESULTS

The manipulation check confirmed that staff was evaluated as more visible (the staff is visible during the journey) during the experimental condition (M = 5.6, SD = 2.29) compared with the control condition (M = 4.8, SD = 2,38; F (1, 1035) = 32,44, p = < .001). It was expected that the presence of cleaning staff would possibly influence perceptions of staff, cleanliness, comfort, trip speed, atmosphere, and satisfaction. Analysis of Variance (ANOVA) were performed for each dependent composite variable. Results are presented in Table 2. It appeared

that the presence of cleaning staff positively influenced perceptions of staff (5.9 in the control condition versus 6.5 in the experimental condition), perceptions of cleanliness (6.1 versus 6.5), perceptions of comfort (6.9 versus 7.3), perceptions of atmosphere (6.1 versus 6.3), and satisfaction (7.1 versus 7.4). No significant relationship was found between the presence of the cleaning staff and perceptions of trip speed (7.8 versus 7.7). No differences were found for gender, age, and travel motive.

Table 2 Overview of results

	F	df	p	Adjusted R^2
Perceptions of staff	24.65	1, 796	**.00**	.029
Perceptions of cleanliness	20.23	1, 999	**.00**	.019
Perceptions of comfort	27.75	1, 1097	**.00**	.025
Perceptions of trip speed	1.03	1, 1090	ns	.000
Perceptions of atmosphere	5.38	1, 1027	**.02**	.004
Satisfaction	17.59	1, 1103	**.00**	.015

5   DISCUSSION

The main aim of this study was to examine to what extent day-time cleaning influences perceptions and satisfaction of train passengers. The results show that the presence of cleaning staff during the train journey significantly influences satisfaction *(H1)*, perceptions of staff *(H2)*, cleanliness *(H3)*, comfort *(H4)*, and atmosphere *(H6)*. No significant effect was found for perceived trip speed *(H5)*. The presence of cleaning staff had the most impact on perceptions of staff and comfort. The effects persisted, as showed by two additional measurements performed six and twelve months after the initial measurement (data not shown). Based on these results, the expectation is that day-time cleaning will become a dissatisfier, just as the onboard Wi-Fi which was introduced several years ago.

The current research has several limitations. First, trains between Amsterdam and Utrecht are crowded during peak hours. Therefore, the effect of day-time cleaning was only evaluated during off-peak hours (9AM till 4 PM). This may limit the generalizability of the findings. Second, cleaners participating in this study were volunteers who received hospitality training. The expectation is that participating cleaners were most suitable for day-time cleaning. Not all cleaners felt comfortable by performing their work while customers are around. Finally, the explained variance (adjusted R^2) could be considered as low since there are many different variables related to the individual (e.g., mood, expectations), physical (e.g., spatial layout, design, lighting) and social environment (e.g., behaviour of others, appearance of staff) that influence perceptions and were not included in this study.

6   PRACTICAL IMPLICATIONS

An increasing amount of NS trains are currently cleaned while being in operation. The present study indicated that it is a misconception that train passengers are disturbed by the pres-

ence of cleaning staff. Passengers are more satisfied, and have more positive perceptions of staff, cleanliness, comfort, and atmosphere. Moreover, day-time cleaners indicated to feel healthier and have more fun at work since they are openly appreciated by train passengers. In addition, day-time cleaning reduces work-load in other phases of the cleaning process. During the night, cleaners are able to use their time more efficiently since bins are emptied and minor cleaning activities are performed during the day. As a consequence, day-time cleaning leads to a reduction of the turn-around time of trains during the day.

Implications were identified for the FM industry. For many corporate and in-house facility managers, perceived cleanliness is an important indicator of actual cleanliness. However, this study demonstrated that perceived cleanliness is not only influenced by actual cleanliness but also by the presence of cleaners. Other studies also demonstrated that the physical environment influences perceptions of cleanliness as well (e.g., Moon, Yoon, & Han, 2016; Vos & Van Hagen, 2015; Whitehead et al., 2007). Moreover, workplace technology is rapidly developing. It is not unlikely that cleaning services will be robotised in the near future. Therefore, it is important that providers of cleaning services are aware of the fact that their employees can be an important contributor to the primary service process. Lastly, as previously mentioned switching to day-time cleaning may require additional training for cleaning staff.

7   FUTURE RESEARCH

Future research could consider the effect of day-time cleaning on health, social well-being, and job satisfaction of cleaning staff. Furthermore, the long-term effects of day-time cleaning on perceptions and satisfaction are unknown. It may be hypothesised that day-time cleaning may become a dissatisfier on the long-term since customers take day-time cleaning for granted.

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Keyword Index   Chapter

The 16th EuroFM Research Symposium is organized as part of the European Facilities Management Conference EFMC 2017 in Madrid, Spain, 25-28 April 2017.

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