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Tools and methods to establish a feed-forward loop from operation to design of large ships and buildings.

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ABSTRACT

Purpose: This study compares ways to transfer knowledge from the operation stage to the design stage in construction projects of large ships and buildings. Previous studies show that integration of operational knowledge in design of new buildings is important to ensure a high performance of the buildings, though studies show that it is difficult to establish such a feed-forward loop in practise. Comparatively little research has been carried out in knowledge transfer in construction projects of ships.

Methodology: The study was done in three steps. First, five practitioners experienced in ship construction projects, as either ship owners or ship designers, were interviewed to gain insights into the integration of knowledge from the operation stage. Secondly, a literature review was conducted for insight on knowledge transfer in building design. Finally, a workshop with five other practitioners representing both the building industry and the marine industry was held to validate the findings.

Key findings: The analysis identified similarities and differences between the shipping and building industries with respect to knowledge transfer from operation to design. The findings are divided on two aspects: A) General conditions and B) Practical tools and methods. The study furthermore investigated two approaches to knowledge transfer; a technocratic approach and a behavioural approach. The study identified examples of both approaches. Some tools and methods were used by both the shipping and building industries, e.g., project reviews by operational staff and commissioning. Other tools and methods were only used in either building or ship projects and could potentially be adopted by the other type of project.

Impact: The study informs practitioners on ways to establish a feed forward loop from operation to design of either buildings or large ships. Furthermore, the study points at several important aspects of knowledge transfer from operation to design to be further investigated by researchers as well as practitioners.

Keywords: Operational knowledge, building design, ship design, construction projects, knowledge transfer

1 INTRODUCTION

The European Commission (2017) has set ambitious goals to reduce energy consumption and greenhouse gas emissions among the member states. Improving new buildings, renovating existing buildings and optimising building operation towards being more sustainable are among the essential measures to achieve such goals (Thuvander et al., 2012).

The operational stage of buildings is by far the most important, when it comes to use of energy and limited resources. In a literature review, Maslesa et al. (2017) concludes the operating energy for non-residential buildings accounts for 80-90% of the total environmental impacts. Decisions made in the design stage have a crucial role on the environmental performance of facilities in operation (Valle Kinloch and Junghans, 2014).

Researchers have identified the design stage as the stage that has the most influence on the future operation of the facility. When the facility is in the operation stage, it is difficult or impossible to change the design to improve the performance (Rasmussen et al., 2017). To consider the operational phase in early design phase, it is necessary to bring in experience and knowledge from facilities already in operation. A feed forward loop needs to be established to ensure that building projects are built by use of experiences from former projects (Jensen, 2009; 2012). However, studies (Jensen and Chatzilazarou, 2017; Rasmussen et al., 2014) show that even experienced building clients with internal operational division struggle with exploiting the knowledge they possess in the new building projects they develop.

Like buildings, ships are large complex physical structures designed and constructed for individual customers. Both types of projects are engaged with large complex physical structures, they are project based, and they go through similar life stages of conception, design, construction and operation. Besides, both type of facility have a long life span, where the operational phase is responsible for the main part of the whole life cycle cost as well as the whole life cycle environmental impact (Knotten et al., 2016).

The difficulties and complexity of knowledge transfer are confirmed by the rapidly growing theoretical field of knowledge transfer (Heisig, 2009). Two approaches to knowledge transfer have been widely discussed: 1) A technocratic approach focusing on knowledge codification and 2) a behavioural approach focusing on the people aspect (Alversson and Kärreman, 2001; Ahmed-Kristensen and Giovanna, 2015). Research within knowledge transfer from operation to design of building projects shows, that the practical tools and methods lacks input from the behavioural approach (Rasmussen et al., 2017).

This study investigates ways to establish a feed forward loop in the design process of buildings ships. The purpose is to bring new insights to research and inform practitioners about tools and methods used in practise to improve knowledge transfer from operation to design.

Two questions guide the investigation:

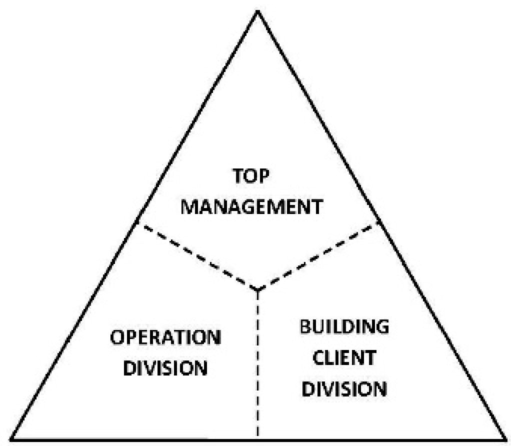
Q1: What are the similarities and differences between the design process of buildings and large ships to establish a feed forward loop from the facility operation to the facility design process?

Q2: Which tools and methods that support a technocratic or a behavioural approach regarding knowledge transfer can be adapted from ship building projects and applied to the design of buildings?

2 THEORETICAL BACKGROUND

Given the opportunity of improving building design though knowledge transfer, researchers have developed lists and categories of the various tools and methods available. For example, Rasmussen et al. (2018) created a list of 42 initiatives a building client can implement to enable transfer knowledge from building operation to building design. This list incorporated the methods for transferring knowledge identified by Jensen (2009; 2012), augmented it with additional tools from a literature review and case study. These were then distributed to a three-partite structure of buildings clients, consisting of Top Management, Building Client Division and the Operation Division, see figure 1 (Rasmussen et al., 2018).

Figure 1: The three-partite building client (Rasmussen et. al., 2018)



Other studies have created different classification systems. For example, Rasmussen et al., (2017) provide a list of “things to do” to transfer knowledge from Facilities Management (FM) to building design differentiated between “tools” and “awareness”. Tools are hands-on recommendations such as projects reviews and Life Cycle Costing. Awareness are more diffuse recommendations such as “more attention to FM” and “good communication”. Rasmussen et al. (2017) stresses the need for further investigation into the “awareness” aspects of knowledge transfer.

Previous research on knowledge transfer from building operation to building design does not apply much theory from the scientific field of knowledge management, including knowledge transfer (Rasmussen et. al., 2017). This implies a risk that previous research has not fully explored the complexity of the topic in relation to design processes. Similar to the categories of “tools” and “awareness”, this study investigates two different approaches to the phenomena of knowledge transfer. On one side a technocratic approach focusing on knowledge codification and on another side a behavioural approach focusing on the people aspect.

Alvesson and Kärremann (2001) distinguish researchers of knowledge transfer (KT) between those who are interested in the ‘technological side’, and those interested in the ‘people side’. They find the latter more widely emphasised in knowledge transfer theory. The opposite is the case, when researchers within FM or construction management investigate KT (Rasmussen et al., 2017). Ringberg and Reihlen (2008) presents a similar distinction, in the field of KT: *“Two major research approaches are dominant in the field, namely positivism and social constructivism” (p. 913).* They advocate for adding a third approach, the socio-cognitive approach, where not only social context and interaction, but also private and cultural mindscapes influence the transfer of knowledge. In contrast, the positivistic approach sees knowledge as 'an objectified asset' (p. 929), which can be directly transferred, for instance, using words.

Recently, some studies have applied knowledge transfer theory to research of construction management. Vianello and Ahmed (2012) investigate knowledge from service to design in the oil industry. Wong, et al. (2008) investigate knowledge transfer from maintenance to airplane engine design. Both studies are heavily based on theory from knowledge management and knowledge transfer. Vianello and Ahmed (2012) make a distinction between a technocratic approach and a behavioural approach in KT, "*The behavioural approach focuses on the behaviour of individuals and on the social relations and cultural factors (…). The technocratic approach focuses on the information systems which are designed to manage knowledge, for instance IT infrastructures, applications, databases and technical procedure*". Furthermore, the technocratic approach is dominant within the engineering field (Vianello and Ahmed, 2012).

3 METHODOLOGY

A cross-sectional study (Saunders et al., 1997) was employed using expert interviews (ships), literature review (buildings) and a workshop (ships and buildings).

Five interviews were conducted with representatives from the ship design industry between November, 2017 and February, 2018. The same interviewer conducted all interviews, and the interviews were held in the native language (Danish) of both interviewee and interviewer. Citations in this paper were translated by the interviewer.

The interviewees were chosen for their experience in integrating operational knowledge in design, and were been chosen with the purpose of getting the widest possible picture as a maximum variation sampling (Bryman and Bell, 2003). Collectively, the set of interviewees had experience with ferries and other large ships as both clients and designers. Table 1 shows how the experts were divided on branch and working areas. Snowball sampling (Bryman and Bell, 2003) was used. All interviews were held at the interviewees' respective workplaces.

The interviews were in-depth, semi-structured (Bryman and Bell, 2003), and based on a protocol. The interviews had an explorative nature (Saunders et al 1997) and the interview protocol included a list of open questions that the interviewer used as a checklist during the conversation. The interviews were between 34 and 76 minutes in duration (Table 1). All interviews were audio recorded and transcribed. Atlas.ti software was used for coding. Two of the five interviews were conducted, transcribed and coded, before moving on to the following three, allowing for the evaluation of the process and adjustment of the interview guide and the transcription style.

Table 1: Distribution of interviewees and duration of interviews

Role	No.	Interviewee	Interview time
Ship designers	1.	Naval architect, self-employed consultant.	58 min.
	2.	Naval architect, owner of ship design company.	76 min.
Ship owners (building clients)	3.	Former head of new ship division at shipping company. Now head of research centre.	66 min.
	4.	Head of new ship division at shipping company.	57 min.
	5.	Head of new ship division at shipping company.	34 min.

For the matter of building projects, a literature review of previous research on ways to transfer knowledge from operation or FM to design was conducted. Findings of the review along with the researchers' own experiences as practitioners served as basis for comparison.

Preliminary findings were presented and discussed at a workshop held in March, 2018. The validation workshop included five other practitioners: three from the building industry and two from the shipping industry.

A thematic analysis was done (Saunders, 1997) where themes arose from data.

4 FINDINGS

Findings of similarities and differences are divided in to A) General conditions and B) Practical tools and methods. Practical tools and methods includes both examples of a technocratic approach and a behavioural approach to knowledge transfer. The list of tools and methods used only by ships (B2) includes examples, which potentially can be adapted by the building industry. However, the list of general conditions shows that a large number of conditions are similar (A1), but an even larger number are different (A2). For both lists, only a few items are elaborated further in this paper due to word limitations.

4.1 General conditions

General conditions are the conditions related to the context and the specificity of the two industries, for instance in terms of products, competences, markets, technology, regulation etc. Table 2 presents the findings from the interviews for general conditions; distributed on A1) Similarities, and A2) Differences.

Ships are often built in series of e.g. ten identical ships built in a row. Buildings are occasionally built in series, examples are housing complexes with identical units built in a row.

Table 2. General conditions

A1: General conditions, similarities: • The three partite client. • Shared goal and team spirit (between building client and operation) is important. • Challenged by different focal point when design team and operational staff work together. • Limited learning from operation to design within series. • Limited use of IT based tools to store and transfer operational knowledge to design. • The cost of operation stage is by far larger than construction cost.
A2: General conditions, differences: • Overlapping competences in ship design • Naval architects are engineers with a background from technical universities or similar • Building architects are "artists" with an aesthetic focus from academies of fine arts or similar. • Public building clients for large ships are rare • Ships are mobile and built at locations independent on where they are going to be used • New ships are decided with strong business case focus • Ships are in general more alike (more possibility to learn across series) • Different professions do the first design sketches in a new project.

Three-partite client

The three-partite client identified in relation to buildings is also recognized in the ship owner companies. The three parties in ship owner companies, like building owner companies, hold different competences. The new building division primarily employs naval architects and engineers, whereas operation division primarily employs staff with a non-academic background such as navigators and machine engineers. Having in most cases both builders and operators internally, offers a great opportunity to bring knowledge and experience together, described by one interviewee:

"I actually think we are quite privileged here. Where we sit, our operating division is 20 meters away. And we have a morning meeting every day at 9, where we all get up and in just 5 minutes; 'What happened over the night since yesterday?' And if there have been any operating problems on a ship, I always have "big ears." And then I will go ask further (…) and especially, if it is concerning some of the ships I've helped build, that's even more interesting." -Head of new ship division, ship owner.

Shared goal and team spirit

While being co-located has its advantages, the interviewees furthermore emphasize the importance of having a shared goal and team spirit. The interviewees are aware that operational staff and design staff have different foci:

"There are a lot of discussions here when you bring in operational staff… they typically have this perspective that it (the ship) must be reliable... most of them are not much concerned about the overall budgets and the return of investment and profit margins of the company. A captain, who does not arrive at the harbour on time, or a machine engineer, who (…) cannot start an engine, it is so heavily present in an operational division … therefore the focus of their side is very much on reliability, maintenance and safety aspects." -Former head of new ship division, ship owner.

Private versus public clients

With only a few exceptions, large ships are owned by private companies. The opposite is the case for buildings, where many large projects have public clients (e.g., hospitals and university facilities). In contrast to public clients, private clients are not obligated to make national or international tenders. They are free to choose whoever they find most fit for the task, regardless if it is competitive. This can help the private ship owners establish long-term relations with design companies or shipyards. Trust and good experience are mentioned as factors influencing the choice of the design company.

4.2 Tools and methods

The term 'tools and methods' covers specific procedures that are used to support communication, collaboration and decision-making in the design process in the two industries. Table 3 presents B) Tools and methods; distributed on B1) Similarities, B2) Only or mostly used in design of ships, and B3) Only or mostly used in design of buildings

Table 3: Tools and methods

B1: Tools and methods, similarities: • Reviews of the design on different stages by operational staff. • Workshops with different stakeholders, including operational staff, on different stages • Key numbers (measurements) for parts and interior. • Commissioning • Case studies or study trips for stakeholders for inspiration on different aspects of the design. • Total Cost of Ownership/Life Cycle Cost is important, but with short pay-back time
B2: Tools and methods, ships only (mostly) • On-boarding operational staff to the design team. • On-boarding design staff to operation (the design managers board a ship for a week or two) • Captains report. • Survey among operators of ”problematic suppliers” • Extensive model testing during design • Classification (Certification schemes)
B3: Tools and methods, buildings only (mostly) • Environmental Life Cycle Assessment (LCA) • Iterative design process. • 5 year guarantee period

As shown in Table 3, some of the tools and methods are used in both ship and building design process, but some are used differently in the two types of projects.

Commissioning

Commissioning is an example of a method that building projects have adopted from ship building. However, commissioning of ships consists primarily of testing functionality and performance of the new built ship. The commissioning process starts around three months before the shipyard hands over the ship to the owner. In building projects, commissioning – at least ideally - starts already in the early stages by setting up exact and measurable demands. Thus, commissioning serves as an example of the need of transformation if a tool from one sector is transferred to the other.

On-boarding operational staff

On-boarding operational staff to the design team is definitely not a common method in design process of buildings according to the workshop participants from the building sector. In contrast, it is according to the interviewees a very often the case in design process of ships. They are full time employed in the project along with designers and engineers. One of the ship owners gives this description:

“On the project we are doing out in China now, we have hired a machine engineer and a captain from the fleet. They have agreed to approve drawings and discuss with the designers, etc., and in that way, getting their operational experience in to the project. It will typically be a full-time assignment here (...) it's a really good set-up, because they've participated, let's say in the basic design stage and now they're also present at the shipyard. (...) it's not getting any better. (...) they have spent approximately two years (...). Afterwards, they either have to return to the sea or move on to another project.“ -Head of new ship division, ship owner.

On-boarding design staff

On-boarding design staff to operation is the opposite situation. The design manager or part of the design team boards an existing ship of the ship owner typically for a week or two.

"Then there may be a small shipping company down in Italy where you go on board for 14 days or a week on the ship and talk to people on board and that's typically the project manager, the designer who will do the project or the one who is going to write the specification." -Ship designer.

A variant of the on-boarding method is a shorter visit, where design staff study a particular important design issue, described like this:

"*You can take for example the mooring system, which is a very good example, right? The mooring system is important for several reasons (…). So we got into the field and studied, how it was done now. And we had someone taking pictures of it and filmed it, measured the time (…). And then you could show it to some people and do some workshops and like saying ... What's this? What's happening? How can we improve this process?*" -Former head of new ships division, ship owner.

'On-boarding' are rare examples of tools, which draws mostly on the behavioural approach, and are as such interesting to the building sector to notice.

5 DISCUSSION AND CONCLUSION

The analysis identified similarities and differences of knowledge transfer from operation to design in ship projects compared to building projects. The three-partite building client was very similar in the two industries and the need to create shared goals and vision between the design team and the operation team is also recognised in both industries. Commissioning is an example of a tool from ship projects being transferred to building projects, but the need of translating the method or tool to fit the new context became clear.

The participants of the workshop representing the building industry suggested that the financial investment in the design process is possibly larger in ship projects than building projects. Their experiences are that the design process in general is kept at a very low cost. This would obviously be a barrier to adopting the two on-boarding methods. However, Lavikka et al. (2017) provide an example of on-boarding of FM-staff in a building project both during design and construction with a case study of a successful building project of a medical centre in California. They argue that an important reason for the success was that the head of the on-boarded FM staff had experiences from both building projects and building operation. All the interviewees from ships had a background involving both design and operation suggesting a stronger overlapping of competences in ship projects.

At the workshop, it was also suggested that ships are closer to the core business of the ship owners and clients than buildings are for most building owners and clients. This is particularly the case for corporate and public real estate. The similarity to ship owners and clients is probably greater for commercial real estate, where buildings are seen as investment objects.

Technical or behavioural approaches

The study aimed to investigate how the two approaches to knowledge transfer are reflected in tools and methods used in ship projects. In building projects, tools and methods to transfer knowledge from operation to design are strongly influenced by the technical approach, and it was examined if this was also the case for ships. The study does not give a clear answer to this question, although the list of tools and methods clearly includes both a technical and a behavioural approach.

On-boarding of operational staff to the design team is an example of a behavioural approach. Long-term on-boarding allows for establishing a shared goal and team spirit, mentioned as important by the interviewees. This can be challenging in technical-oriented tools like the captains report, where the sending and receiving parties do not necessarily meet face to face. From the interviews it is unclear how the reports are stored, transferred and applied to new building projects.

Research methodology
Neither the list of general conditions nor the list of tools and methods are exhaustive. The interviewer found that it was difficult for the interviewees to describe what they actually did to transfer knowledge, illustrated by this citation:

"Before you came, I thought that I wouldn't be able to say a lot about this subject. I also made a brief brainstorm with my colleagues, and we did not come up with much… but now having talked to you (author comment: for 47 min) it is clear to me, that we actually do a lot. And that we are actually good at it, too…" -Head of new ship division, ship owner.

The expert interviews were effective for outlining and exploring the issue, and provided some insight into the general conditions as well as tools and methods that are used for transferring knowledge in the shipping industry. However, it is difficult to obtain deep insights into knowledge transfer through this method alone. Even if knowledge transfer is something that people do as part of their daily work, their knowledge about it is mostly tacit.

Further research
Further research into knowledge transfer should also incorporate observational data on specific cases, as well as interviews with people while they are working on a specific project. This would supplement and validate the current findings, and would lead to greater robustness in understanding the process of knowledge transfer within the shipping and building industries. It would thereby present even more opportunities for applying general conditions and tools and methods from one industry to the other.

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