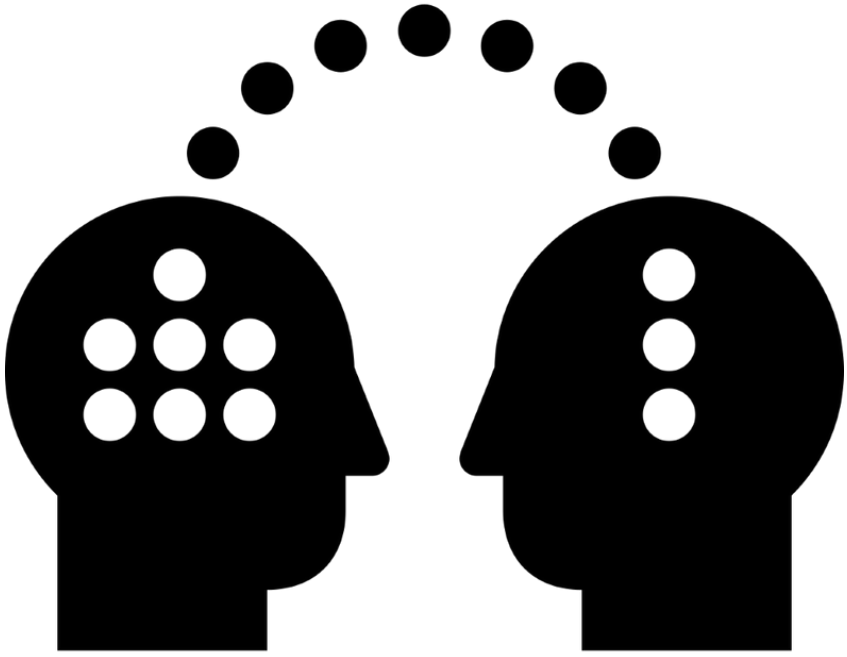
CHALMERS
UNIVERSITY OF TECHNOLOGY



What we think we know

Knowledge transfer between actors in a construction project

Master's thesis in the Master's Programme Design and Construction Project Management

ISABEL BUSTAMANTE MOLINA
OSCAR KAUFFELDT

DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING
DIVISION OF CONSTRUCTION MANAGEMENT

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2022
www.chalmers.se

MASTER'S THESIS ACEX30

What we think we know

Knowledge transfer between actors in a construction project

Master's Thesis in the Master's Program Design and Construction Project Management

ISABEL BUSTAMANTE MOLINA
OSCAR KAUFFELDT

Department of Architecture and Civil Engineering
Division of Construction Management

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2022

What we think we know
Knowledge transfer between actors in a construction project

Master's Thesis in the Master's Program Design and Construction Project Management

ISABEL BUSTAMANTE MOLINA
OSCAR KAUFFELDT

Examensarbete ACEX30
Institutionen för arkitektur och samhällsbyggnadsteknik
Chalmers tekniska högskola, 2022

Department of Architecture and Civil Engineering
Division of Construction Management
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone: + 46 (0)31-772 1000

This publication has been produced during Isabel Bustamante's scholarship period at Chalmers University of Technology, which was funded by the Swedish Institute.

Department of Architecture and Civil Engineering
Gothenburg, Sweden 2022

Cover:
"Knowledge Transfer" by Duke Innovation Co-Lab, Public domain (Co-Lab, 2013)

What we think we know
Knowledge transfer between actors in a construction project

Master's thesis in the Master's Program Design and Construction Project Management

ISABEL BUSTAMANTE MOLINA
OSCAR KAUFFELDT

Department of Architecture and Civil Engineering
Division of Construction Management
Chalmers University of Technology

ABSTRACT

Over the last decades, attention to the creation and maintenance of knowledge in the construction industry has increased. The fields of knowledge management and organizational learning have shed light on how knowledge is transferred between different projects. Far less attention has been put towards solving the issue of transferring knowledge between different phases and agents within the same project. In the complex setting of construction projects, with its interdependent stakeholders, the type of knowledge needed varies wildly depending on the project phase. Understanding needs to be shared in order to align project participants' work and move towards the project's goals. To do this, we must study what happens to knowledge within projects.

This thesis takes a critical look at the creation, transformation, and transfer of knowledge within construction projects, to identify how and why knowledge is lost. It is an exploration of what happens to knowledge when the project transitions from early to detailed design. It looks at the interaction between actors with different perspectives, disciplines, and interests, and over a long-time span. The thesis draws rich data from a case project, using project documentation to frame the project's knowledge infrastructure and an interview study to complement it.

Our findings show three mechanisms affecting knowledge loss in construction projects. First, that different perspectives among project participants are linked to misunderstanding. Second, that project changes inflict losses by overwriting previous design ideas. Changes are nearly inevitable, as requirements and personnel are changed, and, as such, the project must be flexible and adaptable to lessen knowledge loss. And third, that the reasoning behind decision making carries actionable knowledge, and a failure to document or otherwise transfer this knowledge can have severe implications during redesign and implementation of design changes. By analyzing why knowledge is lost, the thesis contributes with new insights into the driving forces behind knowledge loss within construction projects.

Keywords: holistic framework of knowledge management, knowledge creation, knowledge transfer, knowledge transformation, project knowledge management, shared understanding

Table of contents

Preface

This master thesis has been conducted at the Master's Program Design and Construction Project Management at Chalmers University of Technology, at the department of Architecture and Civil Engineering, the division of Construction Management.

The study was conducted during the spring of 2022 in close collaboration with a large consultancy company in Sweden, who provided us with access to a Case Project and graciously participated in out interviews and answered any questions we had. We thank you for your time and enthusiasm.

We would like to thank our supervisor at Chalmers University of Technology, Rikard Sandberg and for the guidance and feedback he has provided throughout our thesis work. His advice and questions have inspired and spurred us on.

Finally, we give our thanks to all faculty members at the Master's Program Design and Construction Project Management, and special thanks to the director of studies, Martine Buser, for an educational and fun two years. Without the time and effort put in by you all, this study would not have been possible.

Gothenburg, June 2022
Isabel Bustamante Molina & Oscar Kauffeldt

1 Introduction

Most construction activities are organized in a project form, as this mode is viewed as flexible and adaptable to the unique and situation specific conditions of designing and constructing a building (McKinsey & Company, 2020). The construction industry is therefore highly project based, and its practice is often viewed from a project management perspective (PMI, 2021). New projects bring together a new set of people and often have a large degree of independence from the organizations they represent, only answering to demands on return of investment and free to decide on design specifics (Dubois & Gadde, 2002). However, this loose coupling, independent and temporary nature of projects also means a lack of centralized support that a permanent organization could offer. While each new project starts from scratch, both the construction project's organization and the buildings themselves vary little between projects (Kadefors, 1995).

The industry is subject to strong institutionalization to meet coordination and communication needs in complex settings, which come from the high degree of interdependent tasks and uncertainty (Kadefors, 1995). Institutions, or the standardization of knowledge and skills, decrease the need for specification and documentation (Kadefors, 1995). Organizational research in construction should therefore focus on the practice and performance of project management, but also on the effects of the set of institutions which the project operates in (Kadefors, 1995).

Knowledge is a key resource for organizations, and it is needed to achieve common organizational goals (Demarest, 1997). Knowledge informs participants about tasks and activities that should be performed and how to fulfil them. The need and use of knowledge changes and shifts throughout a project's lifetime (Lindner & Wald, 2011), as the project adapts to its organizational environment and the institutions that govern work practices (Kadefors, 1995). "An organization knows something if just one person knows it, the organizational culture and structure enable that knowledge to be used effectively" (Duhon & Elias, 2008, p. 5). People factors (e.g., social forums, organizational culture and learning) are just as important as systems (e.g., information technologies, organizational routines and processes, and infrastructure) for the spread and effective sharing of knowledge with the organization participants (Duffield & Whitty, 2015).

Value comes from the use of knowledge. Knowledge that cannot be put to use does not provide benefit to the project. To promote the spread of knowledge among project participants, there should be awareness of the mechanisms of knowledge transfer; the managerial, institutional, and informal ways that knowledge spreads. For individual projects, knowledge is transferred between different project stages or groups (e.g., transferring design intent to contractor), but knowledge can be lost during this transfer (Cheng, 2009). Understanding how knowledge is created, transferred and transformed to be made available for use is essential to the value-creation of the project. Together with the reception and acceptance of knowledge (Essén, et al., 2022), these three interactions are cornerstones in knowledge transfer theory (Demarest, 1997; Duffield & Whitty, 2015; Yang, et al., 2009). To learn what happens to knowledge in projects, we must examine the interfaces of construction projects where knowledge is created, transferred and transformed.

1.1 Background

In this study we examined the transition of a project from early to detailed design phases. Projects evolve significantly between conception and finished building. As the project enters the detailed design, the goal and focus of the design work shifts from idea generation and schematic design towards enabling construction processes. Along with this shift, the project's work environment realigns towards this new goal, and the type of knowledge needed to progress the project changes as well. Thus, previous knowledge gets transformed and transmitted to new recipients, and new knowledge gets created to be used in its new context. There are theories of the mechanisms for categorizing (Cook, 1999; Spender, 2008), developing (Nonaka, et al., 1996; Yang, et al., 2009), sharing and distributing (Berg, et al., 2012; Duffield & Whitty, 2015) knowledge, yet this rational approach to knowledge transfer is not as effective as hoped, and project participants often report that their knowledge is forgotten, ignored, or not put to use in later stages in the project (Saini, et al., 2018; Sun, et al., 2019; Essén, et al., 2022).

Although project-based organizations may have knowledge transfer systems in place, these are often ineffective (Swan, et al., 2010). Knowledge is clearly being lost or discarded within projects despite efforts put into promoting knowledge transfer between actors (Swan, et al., 2010). The project team therefore must revisit and solve the same issues several times, often with different outcomes depending on the stage in the process and the people involved. The result is delays and rework, at the expense of the contractor or the client (Saini, et al., 2018). To decrease this loss, we must better understand the dynamics of knowledge transfer that take place within a construction project and examine its practices.

1.2 Aim

The overriding aim of this thesis was to explore the roles of the individual and organization regarding the dynamics of creation, transformation and transfer of knowledge. This aim allowed us to critically examine the practice of knowledge transfer in construction projects. We took a structural view on knowledge, rather than a managerial one. The focus was to look for the movement of knowledge and the project conditions that enable this movement, rather than the movers of knowledge. Also, we explored some of the mechanisms by which knowledge is transferred, and for what cause or by whom that transfer is initiated. We considered that looking for what happens to knowledge when a construction project moves from one stage to another was a way of studying the interactions that govern knowledge transfer in projects. The goal was to contribute to knowledge transfer literature by highlighting under what conditions knowledge is not transferred and the mechanisms that could occur with this.

The thesis is directed towards managers and leaders within construction projects that are interested in understanding what happens to knowledge when it is transferred between actors and stages in a construction project. Learning more about how the transfer of knowledge is limited or enhanced by certain knowledge transfer systems and communication patterns, could provide valuable lessons for what to promote or avoid when setting up the project. The intended outcome of the research was therefore to find if knowledge is lost because of project knowledge transfer infrastructure, and if so, why this loss occurs.

1.3 Research questions

To fulfil the aim, an explorative and abductive approach was chosen, using semi-structured interviews for the backbone of the study. Project documentation was also used for background information about the case project. This approach allowed for a broad probing of the project system and people involved in knowledge transfer within the project.

The questions that guided the research were the following:

> *Supportive research questions: How do agents interact with the knowledge that gets transferred from early to detailed design in practice? What happens to knowledge when it is transferred from early to detailed design?*

The supportive questions allowed the exploration of what happened to knowledge within the case project. The intended contribution was to characterize the conditions that may or may not affect failures of knowledge transfer. Answering this question provided us with a framework that enabled analysis of the causes and dynamics of why knowledge is lost.

> *Main research question: Why is knowledge lost when a project transitions from the early design phase to the detailed design phase?*

The main research question needed the knowledge gained from the supportive research questions. The intended contribution was to pinpoint the causes for knowledge loss due to the particular conditions presented in this project stage. Answering the main research question enabled us to fulfil the aim of the thesis.

1.4 Scope and limitations

This thesis was centered around a case study of a hospital construction project in Sweden and focuses on the interaction between client and contractor. The case project used a Design-Bid-Build (DBB) contract type. In this type of contract, the client was responsible for the entire design of the building. Therefore, to study the design phase, the interaction between client and consultant was the most relevant and interesting. No data from projects using other types of contracts was used.

Throughout the thesis, the concept of knowledge that we used was focused on practice (Cook, 1999), where data becomes information through the lens of meaning, and knowledge is information contextualized (Spender, 2008). While we drew heavily from the field of knowledge management in our study of knowledge transfer, we did so with the understanding that management of knowledge, in the classical term, is only one of several mechanisms by which knowledge is transferred (Styhre, 2009; Spender, 2008; Kadefors, 1995). Our focus was on knowledge transfer as a mechanism, how knowledge is created (Yang, 2003), transformed and transferred so that the right people know the right things (Yang, et al., 2009). Here management can play a role of creating the conditions for those mechanisms to function, but it is secondary into understanding the conditions that impact knowledge transfer in a project organization.

Knowledge management between different construction projects, such as horizontal and vertical cross-project knowledge transfer mechanisms (Zhou, et al., 2020) was not part of the main scope, nor organizational learning (Swan, et al., 2010), nor the nation-wide institutional aspects of project organizing (Kadefors, 1995), nor the reception and acceptance of knowledge (Essén, et al., 2022). While these are interesting lenses, they

draw away from the focus of what goes on ‘inside’ a project. Although, some theory from these fields was used to compare to knowledge transfer mechanisms.

Further, we made a distinction between the managerial aspects of knowledge management (e.g., the day-to-day operations and leadership) and infrastructural aspects (e.g., knowledge management databases, organizational charts and communication lists, meeting structure, official communication within and between projects etc.) (Wiig, 1997; Demarest, 1997). The infrastructural aspects of the project knowledge management are the organizational infrastructure, both social and technological, and have to do with how the project is set up. They decide the conditions which project participants work within (Duffield & Whitty, 2015).

What was meant when referring to knowledge? The thesis looked at what knowledge about the project is needed in order to perform the work satisfactorily and transfer it onto the next stage. There are two parts to this type of knowledge: 1) knowledge about the scope and limitations of project participants’ role in the project, and what is expected of them, and 2) knowledge about the larger project context, how their work interacts with others and how their role fits into the larger picture. For the purposes of the thesis, professional knowledge was left out of the scope, i.e., the knowledge that participants possess about their profession, that lets them perform their job but is not about the project.

2 Theoretical framework

Knowledge is a complex concept that is part of the daily life of every human being. Organizations have knowledge transfer practices that allow them to improve their performance (Swan, et al., 2010). The following section intends to explain the different types of knowledge and uses distinct models to break down and analyze knowledge creation and knowledge transformation as a way of understanding knowledge transfer and its implications. Furthermore, it explains how knowledge transfer works in practice and what its enablers and challenges can be according to theory.

2.1 Knowledge definition

Knowledge, what is it exactly? There are many different perspectives on what knowledge is and is not, both in a popular and academic sense (Wiig, 1997). As mentioned before, in communication and cognitive sciences, it is held that data becomes information through the lens of meaning, and knowledge is information contextualized (Spender, 2008). Thus, knowledge consists of data, meaning and context. Spender (2008) argues, however, that the framing of 'knowledge' obscures both the problem and solution, that it is "a marketing label for old intellectual products" (p. 167). Instead, Spender proposes that we center the discussion on the three constituent parts of knowledge so that we may use the collected knowledge from these other fields and apply them in the managerial context (Spender, 2008).

Other scholars argue that knowledge has further characteristics that make it a useful tool of analysis for managerial purposes, namely that knowledge can be differentiated according to whether it is internal or external (Demarest, 1997; Wiig, 1997). The problem that the knowledge-concept tries to solve is how to characterize those things which we know intrinsically, without being able to verbalize them, from those which can be formulated, stored and transmitted (Cook, 1999). There are various classifications of knowledge depending on its current form. Some authors like Styhre (2009), emphasize this difference as the distinction between the know-how and the know-what. They base this distinction in the expert knowledge and the local knowledge. For Styhre (2009), the expert knowledge is the one that is theory based, technically professional and explicit. This type of knowledge is equivalent to the know-what. Explicit knowledge can be codified, defined and documented (Saini, et al., 2018). On the other hand, the local knowledge is the one that is practice based, related to practical reasoning and also called tacit knowledge (Cook, 1999). According to Nonaka and Takeuchi (1995), tacit knowledge is the same as un-codified knowledge, which is embedded in individual or collective practices and held in non-language form. This type of knowledge is related to know-how and is characterized by being practical and generally based on face-to-face interactions.

Later work has led to an understanding of knowledge that incorporates the explicit and tacit knowledge characteristics and supplements them with the concept of emancipatory or affectional knowledge (Yang, et al., 2009). According to Yang et al. (2009), emancipatory knowledge is "'human beings' awareness and understanding about reality gained through personal familiarity, cognitive and mental processing and emotional affection" (p. 275). This facet of knowledge attempts to capture the pre-dominant, deciding, motivation of the person or group, arguing that the inter-personal social context is important to understand how knowledge is transferred, because it informs the tendency and willingness for knowledge transfer (Yang, et al., 2009).

2.2 Knowledge transfer

Knowledge transfer is defined by some authors as a social form in which individuals and organizations interact (Yépez & López, 2021). Other authors break it into several processes and consider it is the act of obtaining, organizing and distributing knowledge to the different units of an organization for the benefit of the last (Wiig, 1997). It is a process where one organizational unit or department passes its experience to another (Zhou, et al., 2020). Within the concept of knowledge transfer, Wiig (1997) considers knowledge transfer as a strategy that includes knowledge sharing and adopting best practices in organizations. When applied in the construction industry, firms that have established mechanisms for sharing and distributing knowledge have been considered as innovative firms (Styhre, 2009). Other authors break down the knowledge transfer process as assimilation, adoption, modification, transformation and diffusion, making it necessary for knowledge to be understood and knowledge to be transformed (Sun, et al., 2019).

While knowledge transfer can exist on its own, several authors consider it to be strongly related to knowledge management, where knowledge transfer represents an outcome of knowledge management (Yang, et al., 2009). Knowledge management within business organizations was originally considered to be the key to improving performance in terms of revenue (Demarest, 1997). Wiig (1997) defines knowledge management's objectives as "to make the enterprise act as intelligently as possible to secure its viability and overall success, to otherwise realize the best value of its knowledge assets" (p.8). This knowledge management's concept was developed in a time where the general intention was to make the performance of the organizations more effective (Demarest, 1997). But behind the definition of knowledge management being an asset for the organization, several authors break down knowledge management in a series of steps that describe the process that the knowledge goes through. Saini, et al. (2018) define knowledge management "as the process of capturing, distributing, and effectively using knowledge" (p. 16). Wiig (1997) and Demarest (1997) also talk about knowledge management existing through a process where knowledge is created, knowledge is maintained in a structured way, knowledge is transferred or disseminated and finally knowledge is used to create profit for the organization.

Nevertheless, some other authors consider knowledge management closely embracing learning practices, and thus state that in literature it has its overlaps with organizational learning (Spender, 2008). As such, organizational learning is about managing the creation of the organization's knowledge (Spender, 2008). From the organizational learning perspective, knowledge transfer is considered as a process of learning within the organization, jointly with other interrelated subprocesses such as creating and retaining knowledge (Argote, 1999). Yang, et al. (2009) consider organizational learning as a process that "reflects the dynamic relationships between the individual and the group" (p. 281) and has transferring and creation of knowledge as part of the process.

Further on, Yang, et al. (2009) consider knowledge transfer's relation with respect to knowledge creation and transformation from one facet of knowledge to another. Transformation of knowledge has been studied by several models, included the SECI models that analyze knowledge transformation mechanisms and revisited further by the holistic models of knowledge that complement the process with a deeper analysis of the interaction of knowledge (Zhou, et al., 2020).

2.3 Knowledge creation and transformation

Not all types of knowledge are immediately available to be transferred and understood. Spender (2008) highlights the traditional distinction between data and meaning and argues that "meanings are 'lenses' we put over the data we receive to bring that data into the world of our actions as 'information'" (p. 164). If the sender or recipient cannot attribute meaning to the data, it cannot be understood (Spender, 2008). An important knowledge management and knowledge transfer issue is therefore how to transform it into a form that is useful for the recipient, and many scholars have attempted to map how knowledge interacts and moves from one shape into another. A cornerstone in this research is the seminal work of Nonaka et al. (1996) on a Theory of organizational knowledge creation, presenting the SECI model and Knowledge Creation Spiral **Fel! Hittar inte referenskälla.**. The SECI model maps out the possible interactions between knowledge types and attempts an explanation of mechanisms that transform knowledge and thus enable knowledge creation, or learning. Socialization is the process of exchanging experiences within groups through participation in common activities to create new practical knowledge. Externalization is the process of converting the implicit knowledge of individual members through codification (i.e., documentation) to allow it to spread throughout the organization more easily. Combination is the process of transforming a set of explicit knowledge into a new set by combining them and is commonly held as the simplest form of transformation. Internalization is the process of making explicit and codified knowledge digestible to individual members of the organization. The knowledge creation spiral suggest that new knowledge can be created through mobilization of tacit knowledge by organizations and the facilitation of the four processes of socialization, combination, externalization, and internalization (McAdam & McCreedy, 1999; Nonaka, et al., 1996). Von Krogh et al. (2000) suggests that knowledge creation in the organization can be promoted by establishing organizational enablers, examining barriers, creating and enabling context. A five-step knowledge creation process emerged: 1) sharing tacit knowledge, 2) creating concepts, 3) justifying concepts, 4) building archetypes and 5) cross-levelling knowledge (Nonaka & Takeuchi, 1995; von Krogh, et al., 2000). The model relies on a paradigm of practice, where tacit knowledge attained through participation and practice as the source of new organizational knowledge (Yang, et al., 2009; Nonaka, et al., 1996).

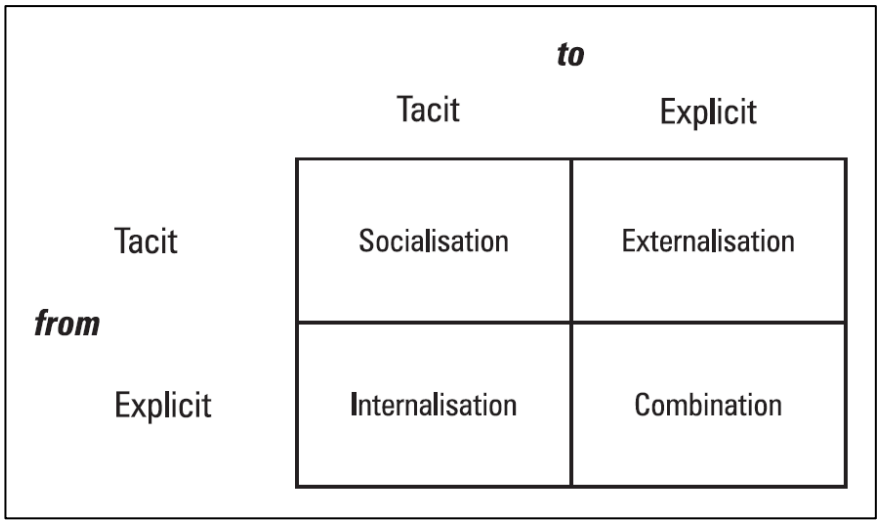


Figure 1 The SECI Model for Knowledge Creation (Nonaka, et al., 1996). *Image by McAdam and McCreedy* (McAdam & McCreedy, 1999).

Later scholars have criticized the SECI-model and knowledge creation spiral. Spender (2008) argues that the foundations of knowledge management are unsound, as the 'knowledge-concept' obfuscates the actual goings-on of the data processing within organizations. Arguing that knowledge-as-data, knowledge-as-meaning, and knowledge-as-practice are better conceptualized as data, meaning and information (Spender, 2008). Further arguing that management models building on the notions of knowledge are seen as too static for the highly dynamic context (i.e., organizations) that they are attempting to model. Yang, et al. (2009) argue that while the knowledge creation model "provides useful concepts and of the dynamic interactions between explicit and tacit knowledge" (p. 280), it fails to differentiate between individual and organizational knowledge and cannot, therefore, acknowledge separate knowledge characteristics at different levels in the organization.

Secondly, the knowledge creation model fails to realize that the process of externalization is not as simple as writing down one's best understanding of the subject. "Much tacit knowledge cannot be externalized and the learners have to participate in a community of practice to gain such knowledge … most professional schools require their students to fulfil practicum (i.e., to gain tacit knowledge) in addition to formal schooling (i.e., to acquire conceptual or explicit knowledge)" (Yang, et al., 2009, p. 280). Lindner and Wald (2011) describe the externalization process as the most difficult movement in the knowledge process, arguing that while explicit knowledge can be stored in documents and databases, tacit knowledge cannot. Tacit knowledge is rooted in the actions of project participants (Yang, et al., 2009).

The transformation of explicit and tacit knowledge is not so easy to portray in a generalized model. Authors like Berg, et al. (2012) agree that the most complex knowledge transformation process is externalization. As tacit knowledge is the practical related knowledge, some authors consider is difficult or impossible to transfer (Demarest, 1997). In some instances, according to Demarest (1997), this type of knowledge if it is not externalized, is not knowledge at all. They argue that knowledge must exist within a network and not solely inside the head of the knowledge holder. By not being codified and defined as explicit knowledge, it is considered not embodied which Demarest (1997) mentions as being "floating, held in memory or in the day-to-

day business practices of a small number of people but not formally encoded or available for dissemination or emulation" (p. 378).

Conversely, the internalization process is seen as a simplistic understanding of how people learn, and tacit knowledge gets created. Cook (1999) argues that "tacit knowledge is acquired on its own; it is not made out of explicit knowledge. Prior to being generated, one form of knowledge does not lie hidden in the other" (p. 385) . Yang (2003) states that "learning is an individual and social process as well. Few learning actions happen as exclusively individual activities" (p. 121).

Other authors, such as Duffield and Whitty (2015), Edmondson (2002), and Swan et al. (2010), see tacit learning coming from socialization as much as internalization. In other words, the step of internalization is not well defined and separated from the step of socialization. Some level of socialization is required for the learning of tacit knowledge. This can have implications for organizations and projects facing large quantities of explicit knowledge with no experience or practical knowledge of how to use it. Learning takes time (Yang, 2003). So, while the knowledge creation model is useful, it is important to be aware of the limitations of its processes.

To get around the limitations of earlier models, the idea of knowledge facets was introduced in models such as the Holistic Framework of Knowledge Management (**Fel! Hittar inte referenskälla.**) (Yang, et al., 2009) and the Holistic Theory of Knowledge and Learning (**Fel! Hittar inte referenskälla.**) (Yang, 2003). This idea differentiates between individual knowledge and that of the dominant knowledge within the group or organization, i.e., the collective knowledge that may be utilized. These models see the manifestation of explicit knowledge on the individual level as conceptual knowledge and on the organizational level as technical knowledge. Likewise, the tacit knowledge is believed to manifest as perceptual knowledge on the individual level, and collective practical knowledge of the organizational level. Further, the model absorbs the concept of affectual or emancipatory knowledge that was introduced by Boisot (1998) and defined by Yang, et al. (2009) as "the objectives and missions that guide our actions" (p. 283), and which dictates and filters what conceptual and perceptual knowledge that human agents spread. The emancipatory knowledge facet is described as "a set of patterns stored in memory that helps us make sense of the world" (Boisot, 1998), and according to Yang et al. (2009) "the alignment or misalignment of these aspects of knowledge with the values and guiding principles of organizational members ultimately decides the effectiveness of knowledge management" (p. 283). The emancipatory knowledge facet is described as manifesting as affectional knowledge on the individual level (e.g., mission awareness, sense of social responsibilities, ethical and moral standards), and as critical knowledge (i.e., the dominant affectional understanding of the group) on the organizational level. To manage knowledge effectively, managers need to understand what influences their willingness to exert effort in knowledge transfer activities, thus they need to be aware of the values, beliefs, and guiding principles of organizational members (Yang, et al., 2009).

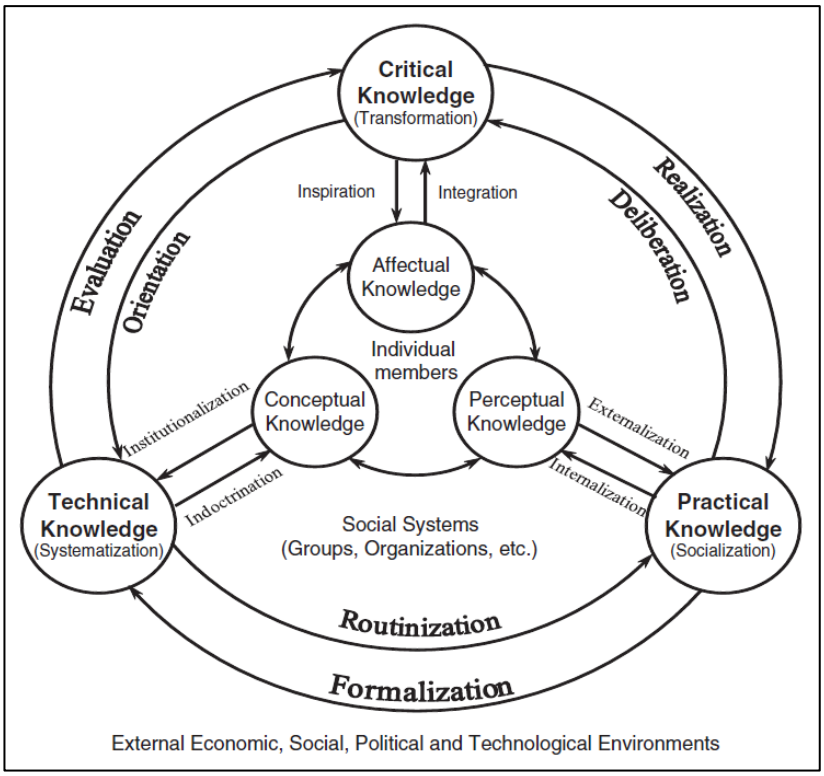


Figure 2 Holistic Framework of Knowledge Management (Yang, et al., 2009).

Further, these holistic models also expand on the mechanisms of individual learning and describe processes that allow learning through transformation between knowledge facets on the individual level, for example the processes of, validation/legitimization, materialization/interpretation, and conceptualization/contextualization (*Figure 3*) (Yang, 2003). These models consider the participation of learning and practice as part of knowledge transfer. Furthermore, the model suggests a two-part process for transferring knowledge between the individual and group level. For example, the step of internalization from the knowledge creation model is supplemented by socialization within the group. Also, Yang et al. (2009) suggest that the process for transferring explicit knowledge between the individual and group is different from transferring tacit knowledge. They suggest that institutionalization/indoctrination are more suitable descriptions of how the explicit knowledge is manipulated. Institutionalization is the implementation of routines to leverage knowledge created by individuals. Indoctrination is the process of making and enforcing formal requirements and regulations on organizational members (Yang, et al., 2009).

These models are much more dynamic and can respond to the changing organization. It allows several paths and angles of attack for managers to promote the transformation and transfer of knowledge. They realize that individual learning necessitates social activities and practice, and they account for the motivation and goal-orientation for knowledge transfer (Yang, 2003; Yang, et al., 2009).

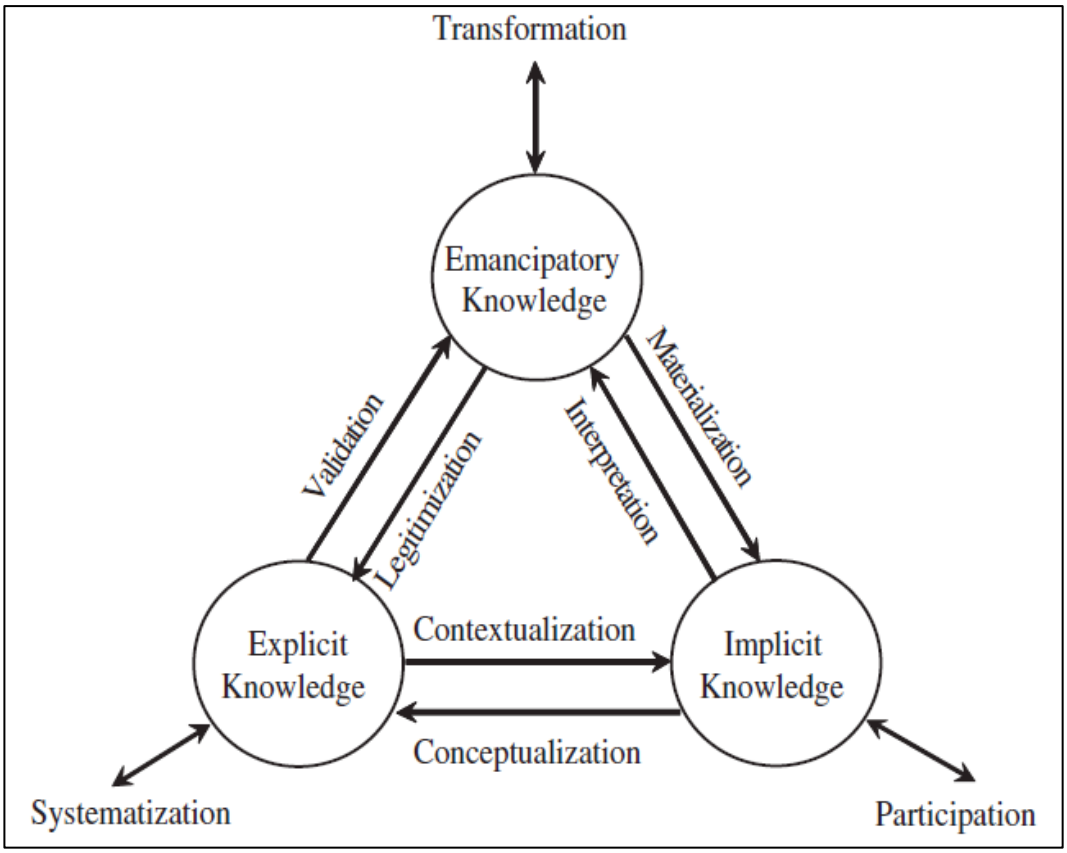


Figure 3 Holistic Theory of Knowledge and Learning: Dynamic Relationship of Three Knowledge Facets and Implied Modes of Learning (Yang, 2003).

2.4 Knowledge transfer in practice

2.4.1 Knowledge infrastructure

The knowledge management models described above explain how knowledge can be transformed and shared within an organization. Knowledge needs to have an ecosystem to exist in before being able to be transferred, used and managed. This can be also called the organization's knowledge infrastructure (Berg, et al., 2012). To develop these frameworks, authors like Lindner and Wald (2011) focus on both the formalized structures: organization and processes, and the informal structures: aspects such as organizational culture, informal communication, leadership and social capital. They concluded that these systematic processes facilitated the knowledge transfer between temporary and permanent parts of the organization.

From an organizational perspective, knowledge can be put to use only if the organizational culture and structure enables it (Duhon & Elias, 2008). "People learn by processing information using the human central nervous system. However, an organization does not have a central nervous system, so it needs to create analogous structures to enable its personnel to learn as one holistic group" (Duhon & Elias, 2008, p. 5).

Within the formalized structures there is the presence of systems and tools. These systems can include information databases, corporate intranet platforms, information integration software, building information modelling platforms (BIM), etc. Authors like Berg, et al. (2012), emphasize the importance of a good design of knowledge infrastructure where the knowledge is accessible, easy to find and thus, promotes knowledge transfer. The presence and development of these systems for knowledge and communication is important and enables knowledge transfer (Lindner & Wald, 2011). But authors like Bhargav and Koskela (2009) argue that for this knowledge infrastructure to work, the systems should be organized in a way that the retrieval of the information needed should be efficient and accessible for the participants in the project or organization. "It is not the mere availability of systems but their quality and usefulness which are essential" (Lindner & Wald, 2011, p. 887).

2.4.2 Enablers for knowledge transfer

Within the knowledge infrastructure, there exists enablers that promote transfer within an organization, or a project. Styhre (2009) mentions a study where the following aspects were identified as direct knowledge transfer enablers: organizational structure, communication and monitoring of strategy, process, culture, systems for learning and support of technology. Lindner & Wald (2011) concluded that knowledge mainly goes through the systems, processes and culture of an organization and that good management of these last has a positive effect on the knowledge transfer effectiveness in the organization. Bhargav and Koskela (2009) agree that the most important enablers are the cultural aspects but that they must be complemented by systems and processes. Included in the cultural aspects they analyze informal communication, motivation to share knowledge, trust between participants and promotion of top management. (Bhargav & Koskela, 2009). "Knowledge sharing happens more efficiently if there is a level of trust existing between employees" (Bhargav & Koskela, 2009, p. 901). The same happens between organizations, if the different organizations have worked with each other before and have some level of trust, it has been studied that knowledge transfer happens in a smoother way. In addition, Berg, et al. (2012) explains to have a further development with respect to knowledge transfer, the knowledge needs a

feedback system that closes the loop. Feedback exists to understand that the knowledge has been received and that message has been understood.

2.4.3 Challenges for knowledge transfer

Knowledge transfer in construction projects is supported by its knowledge infrastructure based on systems, intranets and platforms such as BIM. BIM and other integration information software were developed with the intention of producing better practices of knowledge sharing and knowledge transferring within their projects, to be able to deal with this level of complex knowledge (Yépez & López, 2021). But the barriers presented in the storage of information in the construction project industry are related to the fragmentation of the project nature and the disconnect that the project participants have (Yépez & López, 2021).

Bhargav and Koskela (2009) critique that even though several information managing platforms for collaborative knowledge sharing exist, these have transformed knowledge transfer practices. These technologies mainly address explicit knowledge and not tacit knowledge. Ghasabeh and Provitera (2018) agree with this but stating that "the processes of use and measurement of implicit knowledge, if not possible, are very hard" (p.5). Frequently, knowledge transfer in the construction context occurs at an informal level (Berg, et al., 2012). Styhre (2009) concluded when studying the practices of knowledge management into construction industry, that this tacit knowledge is a crucial part of the industry. The construction industry is characterized by what they call 'oral culture' and is a main part of the communication. They mention "while formal documentation is produced throughout the construction process, the communication in day-to-day work in architect offices, in design departments and on construction sites is primarily in the verbal form" (Styhre, 2009, p. 38). As mentioned before, knowledge is in the heads of the employers, Berg, et al. (2012) agrees, saying that this tacit knowledge is "rooted in the actions of the employees" (p.3) and it would be of great benefit if transferred to the organization as a whole. Since construction projects are in fact compounded by professionals with different experience and knowledge existing in the head of the members, therefore it is vital that this tacit knowledge gets captured and documented to be able to use it (Cheng, 2009).

Because of the temporary nature of the project, some authors like Swan, et al., (2010) argue that the temporary goals of the project get in the way of the motivation to record and transfer their knowledge for the benefit of the project. Meaning that the less motivation to transferring knowledge is a direct result of the focus only on their role inside the project. This produces the participants of the project to focus only on the acceptable outcome when under pressure instead of the optimal outcome (Swan, et al., 2010).

2.4.4 Project complexity

The project-based ecosystem in the construction industry is characterized for being fragmented and highly complex. (McKinsey & Company, 2020). Being fragmented refers to the various companies and stakeholders with distinct needs and expectations who interact in the same network. These temporary organizations usually have a rather short-term orientation in their way of working because they must focus on immediate deliverables" (Lindner & Wald, 2011, p. 878). This fragmented cross-functional network according to Lilly, et al. (2017) could lead to misunderstandings because of lack of same type of knowledge, failing to take account for all the details or filtering knowledge depending on the interests of the team. These conflicting goals could end

up hindering the knowledge transfer processes. According to Olander (2007) "stakeholders express needs and expectations about the project, which often conflict with one another, and it is unlikely that all stakeholder expectations will be met" (p. 277).

Project-based organizations' (PBO) main challenge within the knowledge transfer field is this temporary character of the organization and the time-pressured deadlines where the ultimate focus is for each participant to deliver their part of the project. This can cause the danger of not transferring the knowledge that was needed in the next stages and omitting the learning from better practices. Thus, creating the danger of reinventing the wheel (Pemsel & Wiewiora, 2013)

But going further into PBOs', to understand complexity in projects, PMI (2021) provides a framework of how it can affect a project's performance. The framework classifies situations into complicated and complex. Complicated is when there is a series of known unknowns, meaning the participant is aware that something could cause a problem. Complex is where there are unknown unknowns, and the cause-effect dependency is not obvious. This happens when the participant is not aware that something could cause trouble. It qualifies the project's complexity depending on its level of uncertainty (PMI, 2021). With this, Kim (2012) agrees with this classification and considers the unknown unknowns are when the risk is ruled by uncertainty. The ability to change an intended outcome comes from the knowledge about what its impact is going to be. Thus, when an unknown unknown is identified, it converts into a known unknown which reduces its level of uncertainty. The more unknown unknowns are identified, the more the performance of the knowledge transfer is improved (Kim, 2012). With this added complexity, the combination between a set of unknowns and the fragmented, temporary knowledge infrastructure in which they coexist, encompass the perfect scenario for challenging, in practice, the knowledge transfer within projects.

3 Methodology

The following chapter describes the way the research was conducted. First an explanation on the research approach and research design followed by the data collection process, the explanation of the sample selection and the method used to analyze the data. Finally, a chapter for the research's trustworthiness, the ethical and sustainability considerations and a critic of utilized method.

3.1 Research approach and design

A qualitative research method was selected to provide a better understanding of the topic. This qualitative research strategy is characterized by an analysis of spoken words and images and its interest on understanding the social world through examination (Bell, et al., 2022). Thus, according to Bell, et al. (2022), a qualitative method is suitable for interpretative findings where there is the need for explanations of social phenomena like the one in question. An interpretative research approach has a social constructivist view, which considers that event narratives are likely to change depending on the perspective, as a product of social interpretation (Schwartz-Shea & Yanow, 2011). The purpose of interpretative findings is to understand what the studied field is with support of its context. In addition, an explorative focus was intended to get a deeper understanding of the phenomenon. An explorative approach intends to provide a broad perspective on the subject and to have an open mind. Thus, allowing the researcher some degree of flexibility where the process can follow where the results are pointing (Alvesson & Sköldberg, 2009). Thus, the research evolved iteratively as more data was collected, and learnings were achieved.

Along with the qualitative and interpretative nature of the investigation, the research approach chosen was abductive, which allowed for flexibility and iteration. Even though it has also its similarities to inductive reasoning, where theory is the outcome of research, the latter was not selected because as Bell, et al. (2022) mentions, no number of empirical findings will necessarily develop theory. As the purpose of this research is to explain rather than create theory, an abductive approach was preferred. An abductive approach iterates between empirical findings and theoretical framework and allowed for the flexibility and open-minded study we were aiming for (Bell, et al., 2022). The abduction approach has a level of surprise that allows for exploring the subject in question (Bell, et al., 2022). Thus, the learning was done in an iterative way, where, when new findings came on the way, we returned to research about theoretical frameworks on the subject.

The research design was based on a single case study. A case study is a research strategy that is based on understanding the dynamics of a situation (Eisenhardt, 1989), in this case, focusing on a singular case. The analysis of a case helps to understand a complex phenomenon such as the loss of knowledge within construction projects. Thus, the intention is to explore the topic, rather than generalize it. In theory, case studies can be used to provide description about a complex project, theorizing and developing understanding (Eisenhardt, 1989). This approach is extremely useful when the area of study is not widely explored, and its research is in the early stages (Eisenhardt, 1989). A case study within social science gives back concrete context-dependent knowledge that is necessary to build up expertise (Flyvbjerg, 2006). Our intention was to explore the knowledge loss on a particular case on the construction industry to generate a deeper understanding and add value to the existing theory.

The selected case was a hospital construction project in Sweden handled by the Case Company. Since the aim of the assignment was to answer questions about construction projects in general, not about a singular project, the case study was used as a backdrop to explore the topic. The process of investigation in a case study is characterized by it being an iterative process. It allows the researcher to return to theory and to the research question (Eisenhardt, 1989). This gave us flexibility to adapt the direction of the research as the work progressed.

3.2 Literature review

The literature review was mainly done in two parts. First there was the initial literature review where we searched for theories and frameworks that would aid us into developing a deeper understanding of the subject. This investigation process was done on Google scholar and Chalmers library research databases. We started with research within the existing theory on knowledge management, knowledge transfer, organizational learning, and communication practices to create a solid base. In summary, the literature review was based on the following key words: knowledge management, knowledge management models, organizational learning, knowledge transfer models, knowledge transfer in construction projects, tacit knowledge transfer in construction projects, tacit knowledge sharing in construction.

Because of the abductive research approach and the research strategy based on a case study, the intention was to keep the mind open for any findings we may encounter during the data collection process. After this phase, a second literature review was done based on the discoveries of the interviews. This latest focused on project complexity, knowledge transfer in practice, stakeholder perspectives, decision documentation and knowledge transferred with understanding.

3.3 Sample strategy and case selection

After identifying the issue of knowledge transfer and its possible loss in construction projects, the company selected for the research was based on their interest on the topic and on their shared opinion about the existence of knowledge loss. The company had the intention of improving their practices and managing knowledge transfer in a better way in the future.

When exploring a topic with a case study, selecting the case is of crucial importance because it will determine the study (Eisenhardt, 1989). For a better understanding of the phenomenon, the case chosen was made with an information-oriented selection (Flyvbjerg, 2006). This means the selected case was based on the greatest possible amount of information that could contribute to the cause. Thus, an average case was not selected, the selected case was rather chosen because of its complexity and abundance of interactions. Another determinant into the selection of the case was the access to the information because of the confidentiality clauses. Complex construction projects usually have confidentiality clauses between companies that prevent the project's information from being of open access. Thus, we selected a hospital construction project that included the level of complexity desired to break-down the phenomenon of knowledge loss.

The selection on the sample of interviewees was a combination of purposive sampling and snowballing sampling. First, on purposive sampling, interviewees are selected depending on the relevance to the research (Bell, et al., 2022). Thus, this selection was done based on a mapping and analysis of the stakeholder's involvement in the project. The first step was to get a better understanding of what the role was of each company

involved and the interactions they entailed in the project; this analysis was based on the organizational charts found on the document database for the project. At the beginning, within each company, the interviewees were selected based on their recurrence in the organizational trees, participation in meetings and appearance on important documents.

The snowballing sample selection is when a group of people who is relevant to the research in question proposes other potential participants that are also relevant (Bell, et al., 2022). After every interview, the interviewee was asked to refer the next interviewee based on their opinions about involvement in the project and possible interaction with knowledge transfer.

The type of interviewees was classified into three groups. First, the design and project managers, responsible for the decision-making, then the assignment leaders who had decision power within their sections and, lastly the designers working more directly with the project. Together, it was a total of 12 participants with interviews between one and two hours long.

Table 1 Roles of interviewees in case project and number of interviews per group.

Group	Position	No. of interviews
1	Design and project managers	3
2	Assignment leader	5
3	Designer	4

3.4 Data collection process

One of the strengths of case studies is that they can use a combination of data collection methodologies, such as interviews, observations, document analysis and questionnaires (Eisenhardt, 1989). This characteristic contributes to the intention of this research of understanding an extremely complex phenomenon. Within the case study selected, a general understanding of the project was done by studying documents and information systems used in the project, and then later complemented by semi-structured interviews to project participants. Because the project phases in question happened in the past, the study focuses on the historic practice of knowledge transfer.

Before the selection of interviewees, a document and system study were done to get an idea of the relationship between the actors within the project and their involvement. The analysis of organizational documents, according to Bell, et al. (2022), can be used to build up the timeline of the project's events. Thus, the information systems studied were done by a historical analysis where we used the organization's documents to trace the history of the project. To prevent from the critics on historical document analysis, where some authors consider it could lead to a one-sided version of the facts (Bell, et al., 2022), the documents revised were mainly formal organizational documents. The latter were, formal meeting protocols signed by several project stakeholders, organizational trees, project introduction presentations and phase hand-over documents. This was done within the intranet of the company and the information integration system that they used, with the access granted by the organization. A general understanding of the project was also grasped through several informal conversations with the supervisor representing the Case Company. The data collection from this historic analysis phase is later explained in the description of the case study.

Interviews were conducted on a semi-structured manner to support the explorative research approach. In qualitative interviewing, the interest is on the participant's point

of view (Bell, et al., 2022). Thus, semi-structured interviews from past events can capture interactions and perspectives of the project based on what the interviewee considers as fact and important (Bell, et al., 2022). As our interest was to study knowledge transfer and knowledge loss in the project as the participants perceived it, this type of qualitative interviewing was appropriate. The interviews were conducted face-to-face either in the offices of the Case Company or at the interviewee's company. All the participants willingly participated and were eager to contribute to the study. The data collection closure was considered when saturation was reached, and the patterns found kept repeating (Eisenhardt, 1989). The interviews had a duration from one hour up to two hours depending on the level of interest of the participant. Since the interviews were semi-structured, there was a guideline of prioritized themes that should be acknowledged but the participants had freedom to expand on the topic. The total number of interviews conducted until reaching saturation was twelve. The interviews were recorded with the full consent of the participants.

The questions were based around three main sections. The first one was setting the ground for understanding how the project was organized and how the different interactions happened in the history through the phases. The next section was based on questions that had the objective of exploring what happened to the knowledge through the phases from the perspective of the interviewee, whether expectations were met or if there was something that could have made the knowledge transfer smoother. The last section was based on only one question with an explorative intention. If the interviewees had mentioned that they thought knowledge was lost, they were asked the main research question "why do you think is the reason why knowledge is lost through the early design and detail design phase?". The answers collected gave an interesting twist into the results of the interviews, all with the intention to explain more thoroughly the presented phenomena.

3.5 Data Analysis

For quality purposes, we did a verbatim transcription of the interviews immediately after each interview with the support of Microsoft Word's transcription software. After reaching saturation, all the interviews were analyzed based on a thematic analysis. Thematic analysis is a strategy method used to analyze data which identifies and selects main data from interviews (Bell, et al., 2022). Analyzing data is the heart of building theory and understanding from case studies, but it is both the most difficult and the least codified part of the process (Eisenhardt, 1989). Thus, we began by coding each transcript selecting themes based on their relevance to the questions asked and interesting statements and opinions contributing towards the study. Because of the relatively open style of this thematic analysis, and the quantity of selected themes, we decided to support it with an association technique called affinity mapping. Affinity mapping methods are used to organize, structure, and prioritize data by its relation (Alänge, 2009). This technique consists of three steps, where the first one is to explain each theme out loud to the work partner or team in question, and then group the themes into a first level grouping. The second step is to group the first level groups again, into second level groups. Lastly, by finding common associations between the second level groups, a third and final group is done. This form of grouping aids into identifying the trending patterns when there is a big amount of qualitative information. This meant in practice that, after having the themes detected on the interviews, they were grouped based on common patterns and recurrence. With this affinity mapping technique, we used the identified themes from the interviews to expose the recurring motifs of the findings and create a red thread with the main topics found. The recurring themes were

then used to structure the presentation of the results and aid us into ensuring the continuity in the paper.

3.6 Research quality and trustworthiness

Research quality and trustworthiness are characteristics that describe research done by following good practices. In qualitative research, some of the criteria characterizing trustworthiness are, credibility, transferability, and dependability (Bell, et al., 2022). Credibility is when there is congruence between the concepts studied and the researchers' observations (Bell, et al., 2022). In this case, by ensuring that we interviewed more than one person per organization, we decreased the risk of unique findings that may not show all sides of the story. With this, most of the observations were more trustworthy if they were confirmed by more than one source. We refrained from drawing conclusions based on individual observations. Furthermore, the questions asked to the participants during the data collection phase were open answer questions that allowed the interviewee to elaborate rather than to force them into a wanted answer. By this, we avoided asking leading questions and followed the explorative approach intended (Bell, et al., 2022). According to Alvesson and Sköldberg (2009), the explorative approach taken in this study asks of the researchers to be reflexive and critical to challenge the data and concepts found along the way, and thus, gives this type of qualitative research a strength.

Transferability is when the research can be externally repeated (Bell, et al., 2022). Transferability is an issue specially in case studies, but it can be strengthened by the author being descriptive with the surroundings and characteristics of the research needed to understand the social phenomenon. For transferability, because the social event is observed under specific characteristics that may not be able to reproduce exactly, the author must be transparent with the information and decisions taken at all phases. Thus, we followed a descriptive process of the data collection, the setup of the project and organization, and the views of the interviewees, to be as clear as possible. Dependability is the quality that is gained when the research is done by more than one observer (Bell, et al., 2022). In this case, the analysis and results gained a level of dependability due to the interviews being conducted and thematically analyzed by the two authors of this thesis. By having two members looking at the same aspects, the interpretability of the case is reduced (Bell, et al., 2022).

3.7 Method criticism

Case study research methodologies are highly criticized for not being fit for generalizing a theory (Eisenhardt, 1989). The result can be an explanation or theory that is very deep in its content, but it can lack overall perspective (Eisenhardt, 1989). Also, because of the qualitative research strategy chosen, this explorative research is hard to replicate (Bell, et al., 2022). This because the results would vary greatly depending on the context, company and project analyzed. However, the main concern of this research is not to develop generalizable theory but rather to explain, describe and break down a complex phenomenon. According to Flyvbjerg (2006), this theory cannot be formally generalized does not mean that it is not fit for contributing knowledge into the field. With this, the ultimate intention of this research is to contribute to the explanation of the complex phenomenon of knowledge transfer within stages of a construction project. And due to the highly explorative nature of the

research, the intention of the study was to add value to literature and aid future researchers on a similar field.

The intention was to study the practice of knowledge transfer, but since the project stages happened in the past, the study could be said to fall into positivism, where it is believed that the history will tell what happened in reality (Bell, et al., 2022). With historic study of documents and interviews about a past project, there is the risk of concluding erroneous assumptions that could be not entirely true. Nevertheless, this still gives a particular idea of the project and, as long as the researchers keep an objective approach, the particular views of the past can be confirmed or refuted (Bell, et al., 2022)

Furthermore, a limitation to relating the findings of this paper to previous findings was the scarcity of previous studies on knowledge loss within construction projects. There is extensive literature regarding knowledge transfer as knowledge being accumulated and shared with the intention of being utilized in future projects for the benefit of the organization. But through this research we have found a whole in literature regarding knowledge transfer and transformation with regards to knowledge transfer between stages of the same project and its multiple interactions with several stakeholders.

3.8 Ethical and sustainable perspectives

When setting the appointments for the interviews, every participant was informed of how the work was going to be performed and asked for consent to be recorded. They were informed that these recordings were only used for practical purposes of data collection. The interviewees were also informed about the privacy clauses of anonymity and confidentiality that guide this project. All personal and specific data was not published or used in the research but rather just the information from their experiences in the project. To ensure this anonymity, the interviews are not mentioned by name on the report, and neither are the specifics of the project. This anonymity plays an important part in the trustworthiness of the results, where the interviewees feel they can freely express their opinions without compromising further (Bell, et al., 2022).

Furthermore, this study contributes to more sustainable practices in the consultancy and construction industry by improving the performance of knowledge transfer and thus reducing the resources used in construction projects. If the knowledge transfer phenomenon is improved, construction projects could avoid re-work and miss understandings that waste not only human resources and economical resources but also material resources if the project goes into the production phase.

4 Project case description

To understand what happens to knowledge when it is transferred between stages of a construction project, the following section explains the set-up of the selected case and its actors' interactions. It contains the project's timeline and the project's organizational structure. It also expands on the project's knowledge infrastructure which includes the information systems, the project's documentation and the communication channels, including meetings and workshops. This information was gathered from the internal company's information database about the organization and the project.

4.1 Background

The case chosen for analysis was a major hospital project located in Sweden. Projects as such are characterized for being very complex and requiring major interaction and dialogue between different stakeholders (Olander, 2007). The hospital was meant to have cutting-edge technology, ensure functional care facilities, and satisfy the client's requirements and foremost, the necessities of the patients.

The vision was based on high quality and operative efficiency for the benefit of the patients. This was done by increased dialogue and collaboration between parties to achieve the best results. All through the project, this intent was widely communicated and maintained. The vision was intended to remind the participants to work with openness, dialogue, and cooperation towards a common goal.

4.2 Timeline

The project had an overall duration of 12 years from initiation to the ending of the construction and commissioning. The preliminary studies, planning and schematic design phases are a part of the early design phase. Thus, this report focuses on analyzing the interactions between the early design phase and the detailed design phase which happened from the years 1 to 6.

The preliminary studies phase is where the client sets the initial requirements and interacts mainly with the user. Is the phase where the feasibility studies are done, and the initial planning is delivered. The planning phase consisted in setting the initial plan for the project and analyzing the proposed solutions and designs. It is also the phase where the first proposal for time and cost happens. The following stage is the schematic design phase where the requirements are carried on and put into the initial drawings and design. The next stage is the detailed design phase, where all the information from previous stages looks reflected in a final design production with detailed drawings and specifications that will later be the guide for the construction phase. The construction phase bounces back to the detailed design phase in a somewhat iterative process for clarifications and modifications.

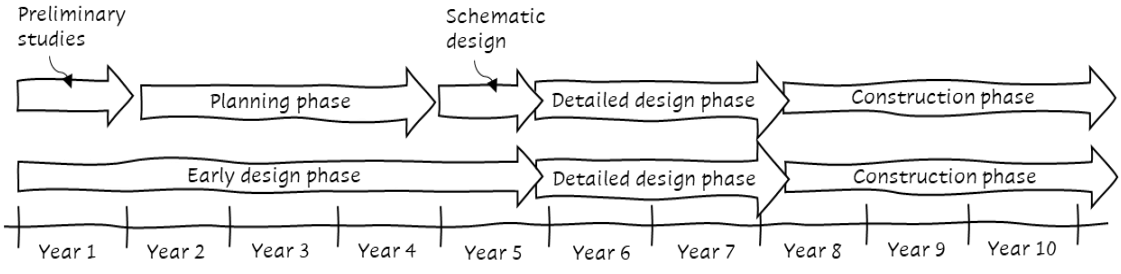


Figure 4 Timeline and project stages of the case project (own image).

4.3 Project organization

The project organization was divided into several stakeholders that collaborated during the long duration of the project.

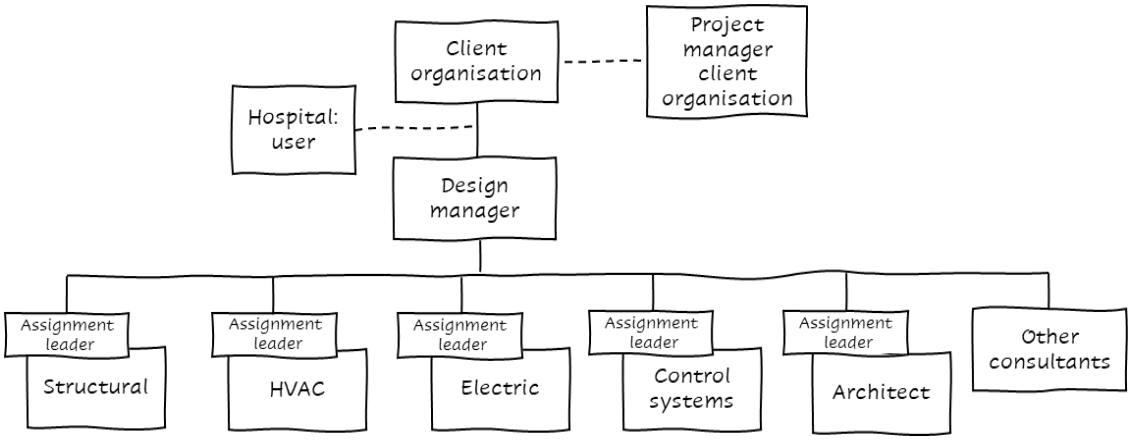


Figure 5 Project organizational chart including design disciplines (own image).

At the top of the chart there was the hospital and user, followed by the client organization. The client organization owns the building and is responsible for the investment, maintenance and repairs. The hospital is the healthcare operator, who runs the hospital, and thus, ends up being the user of the client. The hospital is renting the property from the client. Then the client is the actor that hires the consultancy companies to provide with the design and construction of the building.

In these stages of early design and detailed design, the next leadership role was occupied by design management who coordinated the rest of the technical disciplines: structural engineering, HVAC consultant, electric consultant, control systems consultant, architecture firm, environmental consultants, etc. It was a particularity of this project that the HVAC consultant, the electrical consultant and the control systems consultant were all sections of the same consultancy company.

Based on this, the organizational chart was compounded by three levels of order. The design manager and project manager on top, next the assignment leaders of each discipline and finally the design personnel for each discipline. The organizational chart was set up during the first initiation meetings and it was meant for promoting collaboration. The client organization worked closely with the hospital on the early phases to delimit the requirements, expectations, and intentions. The client and the user had common boards that answer to political decisions.

During the planning phase, the organization was represented by a project leaders group comprised by members of both the client organization and the hospital organization. Later, a project group (PG) organization was set to report to operations and to the client. This PG group was a management team compounded by the design manager, the project manager representing the client, and the representative leaders of the different disciplines. The head of information coordination was also a part of this group. The dynamic worked in a way that all the disciplines interacted in the same level, with their leadership representation on the main board.

4.4 Knowledge infrastructure

The knowledge infrastructure of the project sets the ecosystem of where the knowledge is going to exist and be transferred. The latter is characterized by the processes, systems, and communication channels.

Though some of the phase's activities overlap with one another, formal delivery reports were created after every phase. After the end of the planning phase in year 4, a planning report was created that contained a review of the proposed solutions, analysis of the program content and visualization of the project. It also included a proposal for time and cost. This document required collaboration of the client organization and the user. During the next phase, the schematic design phase, a delivery of drawings, specifications and detailed processes was done and finished with a system report. Both documents, jointly with the meetings and workshops allowed for a handover towards the detailed design phase. These documents where saved digitally in the project's integration information platform accessible for all project members.

The configuration of meetings varied depending on the phase of the project. During the planning phase, processes for how the meetings were going to be set up were elaborated. All meetings were held on-site in the respective offices. There were meetings specifically for the leader group and others for the rest of the disciplines. The meetings happened on a regular basis. During the planning phase, the meetings included the client organization, the user and the architect firm working in this phase. The architect firm working in this phase was not the same as in the preliminary studies phase. This is important to note because there is a transfer of knowledge between parties very early on the project.

The documentation of the project was done with formal protocols and drawing delivery processes. Midway through the early design phase, systems for information documentation were adopted such as BIM methodology, room function program databases and information integration software. The room function program database, further called RFP, is a database where the functioning and requirement of each room of the facility is documented in detail. This was a widely used tool in the interaction with the client and user. Moreover, the information integration software referred to as BIM integration platform was extensively used in the detailed design phase and towards the construction phase. All throughout the early design phase, the requirements were expressed and co-created in workshops. These types of workshops were done with the participation of the architect, the needed disciplines, the client, the user and in some cases, the patients. During the meetings regarding the RFP the requirements were discussed to project a solution. The objective of these workshops was the coordination of the technical system solutions based on the RFP. These workshops were generally done with the support of the BIM model to have a general idea of the design and geometry coordination.

5 Empirical findings

This chapter presents the empirical findings of the study. These are later used in the analysis chapter and compared to what can be found in the literature related to the subject. The information in this chapter is primarily based on the interview study, with some additions from project documents to provide a background to observations made by interviewees. Results are ordered in subchapters, starting with the project participant's views on the design process and their role in it, followed by the structural framework required for the project to capture and transfer knowledge between actors and phases.

5.1 Figuring out the design

The aim of the design phase is to produce construction drawings but getting there is a lot of work. To produce construction drawings from scratch, without reference, requires working at a level of detail which is far too great for the number of people and interest groups. Design changes made during the design stage have cascading effects that ripple through the project and cause more changes as other people adapt their work to fit new conditions. For this reason, many interviewees, especially on the design side, had a stated preference for keeping the level of detail low in the early stages. They had the opinion that the detailed design phase should consist exclusively of the production of construction documents, while most of the iterative and collaborative design work should take place in the early design phases.

> "In the early stages we mostly focus on 'are we able to fit everything in this volume of house?' Is it possible to build? If you had to be that precise in the beginning, you would have to redo everything later on. I think it would be too disheartening." (Designer)

The schematic design phase is better suited to exploring solutions and collaborative problem solving. In practice the early and detailed designs overlap, and some changes in the later stages are inevitable. This means that the transition between early and detailed design is not a hand-over, but rather different levels of detail of the same process.

> "The starting point was to create the greatest possible value per tax dollar. With that in mind, we designed the project by prioritizing what is most important for that aim. The most important activity in the project is clarifying what is value-adding or not. In the beginning, it is not about focusing on some building-technical detail, but what promotes good healthcare. We have formed the organization with that as our guiding principle." (Project Manager)

The first and most repeated observation during the interview process was that the value of the building comes from the hospital organization being able to use it. Since the hospital organization is renting the property from the client, the client gets the most value out of their investment into the building by having it designed in a way that maximizes the benefits to the hospital for the lowest lifecycle cost. Therefore, the overall goal of the design process is to optimize the design of the building to give the hospital the best possible conditions to carry out their operations. This includes both healthcare and facilities management. In practice, this means that all designing consultants must understand the needs of the hospital to carry out the design. For the purposes of the project, these needs are codified and documented as requirements and specifications. Requirements and specifications are a way for the hospital to define

certain functions that they want the building to have. It is then up to the designers to find a way of fulfilling these.

However, the process is not so simple. Hospital staff and designing consultants have different backgrounds and perspectives on how a hospital should function. Hospital staff are experts in how a hospital works. They might know how a room needs to look or what equipment it needs to have in order to treat patients, but unable to describe this in the same terms the designers require as input into their calculations. Even with professional operational developers in the client's organization, the depth and level of detail in their technical requirements was said to be insufficient for the complexity of the building design and its installations. While the client and hospital at large provided designers with technical requirements for some parts or aspects of the building, there were blank spots where no requirements and specifications were given. In those cases, the hospital and consultants needed to work together to translate needs and functions into technical requirements and design specifications. They did this to figure out what the design should be.

5.1.1 Complexity and project scope

The project's early design phase and detailed design phase took place over a period of six years and required extensive collaboration and interactions. During that time, the project suffered changes of personnel, advancement in technology, and updates in requirements. The project scope and requirements were set jointly between the client and the user of the hospital. The latter also depended to some degree on the whims of their politically appointed board of governors, whose goals at points seemed to differ based on ideology rather than project considerations. The difficulties of creating a functioning organizational structure were compounded by the design being carried out by different companies, representing different engineering and design disciplines, who had to collaborate and co-create towards the delivery of a common project. Some interviewees mentioned that the project ended up being so big the that organizational structure felt too small to handle such complexity. "The size of the project was an obstacle, there was so much history in it, it was so big" (Lead architect).

However, the project's goal was to achieve common problem solving. No single group or individual can fully or freely focus on one area. The work of designing a building requires collaboration and co-operation, which in turn requires negotiation and compromise. The different perspectives within the case project's organization are not just the regular fragmentation we typically see within the construction industry. Since this building is highly specialized and its value so connected to the operational efficiency of the hospital user, the client and user are heavily involved in the design process and part of the project organization. The strongest divide, however, was between the design and hospital side. The perspectives and goals of the designing part of the organization are fundamentally different from the healthcare and facilities management parts. Healthcare personnel work towards better results for the hospital's operations, and the goal of facilities management is to improve efficiency of maintenance and repair to keep the hospital up-and-running. Both have roles in the project to assist and collaborate with designers to achieve the goal of better operations. Even if hospital staff have a formal role in the project hierarchy, this is an advisory role.

5.1.2 How design requirements are set

Early in the design process, the amount and level of detail of design requirements are low, just as the level of detail of the design is low in the planning and schematic design

phases. At first, the issues addressed are broad and aimed at finding the scope of the project rather than preparing to create construction documentation. Thus, the need to specify technical requirements in the very early stages is less than in the detailed design. The work that the client, hospital, and design consultants do together moves from low to high detail as the project progresses through the stages. Eventually, the project reaches the schematic design phase, and the work shifts towards establishing technical solutions, such as capacity of installations or specification of rooms and their content. This step is meant to create knowledge about how the building should function to prepare for the following stage, the detailed design, where construction drawings are produced.

Requirements and design specifications as described by interviewees are not limited to demands on the design. Rather, they can be any request or ask that the client or hospital makes. What makes them requirements is that they come from the client or hospital. Again, the hospital's needs are what creates value. Thus, their requests, or needs, specified on a technical level are treated as requirement by the design teams.

The interpretation among consultants was mostly that requirements are treated as an input into the design work, coming from outside the project. Both consultants and the client organization view technical requirements as examples of acceptable solutions but are open to renegotiate them if better solutions can be found, if the underlying reasons for the requirements can be met.

Design requirements and specifications are set in two main ways. First, through the initiative of the client's or hospital's organizations. As they work to develop their own operations, they come up with standards and routines for buildings, rooms, and equipment that they are familiar with or would like to work with. These are specified in the project to ensure compatibility with existing practices, or to steer their operations according to some overall strategy. This method is essentially top-down as it comes from within and is sanctioned by the client's or hospital's organization. Second, in the case that the client or hospital do not have their own set of requirements going into the project, new ones are made in collaboration between them and the designing consultants through codification of existing practices. Essentially, the requirements are co-created between client and consultant or hospital and consultant.

5.1.3 Co-creating requirements and specifications

Co-creation occurred in the case project when there was a lack of pre-made requirements and the consultants demanded input about the intended outcome as part of the design process. The alternative is to design based on assumptions. However, both designers and client representatives pointed out that doing so is in general more costly and prone to changes, as the design then must be prepared for many different scenarios. Instead, the preferred method is for the designing consultant to discuss with a representative from the client or hospital how to best fill their needs within the parameters of the design issue. This can range in scale from large issues with major cascading effects such as deciding the number or location of operating theatres, to seemingly small issues such as the number of outlets with back-up electricity needed for medical equipment in a room.

In general, the need for co-creation of requirements comes up when the consultant needs clarification in some way. Usually if the way that the client or hospital has communicated a requirement is not the same type of information that the consultant needs, or information is missing. An example of the need for clarification is when, in

the case project, the HVAC designer asked for specifications of the expected number of people in a standard patient room. The representative from the hospital answered that the maximum amount of people would be around twelve people, even though the rooms were designed for only one patient per room. The designer found this a bit odd and alarming, as this was a much larger number of occupants than their preliminary calculations had accounted for, meaning that the dimensions of the entire ventilation system would have to be increased dramatically. After discussing the issue in more detail, the image became clearer. Most of the time the only occupant would be the patient and perhaps a visitor, and a few medical personnel. However, for a short time each day, the doctors would make rounds with their medical students, bringing the maximum occupancy to twelve people for about five to ten minutes per day. Since the time interval under this load was so short and because it was limited to one room at a time, the capacity of the ventilation system did not have to account for twelve people per room at the same time, rather a more average number per room but with the possibility of that many people in one room at a time. But the client didn't know this previously. They didn't know exactly what knowledge was needed to do the design.

The example above shows the importance of asking the right questions. Several interviewees from the designing consultants described scenarios where the questions for input asked to the client and/or user were too technical and specific, and thus could not be answered in the way expected. To benefit the design the most, designers need to understand the practical, day-to-day work of the client or hospital. What they do, how they do it, and importantly why they do it that way. This shared understanding of the work is repeatedly described as the foundation that lets the consultants design something aligned to the need of the client.

Another dimension of the co-creation dynamic is that the need of the client and/or hospital organization often calls for design that is flexible over time. For example, the technical installations such as water and electricity must be able to manage several different design loads if the equipment in an operating room gets replaced and updated. Or the use of a space might change if an office space is converted into a conference room. Whereas other spaces or equipment are more specialized and fixed, it is difficult to account for the exact use of the building during the design phase, as these might change together with the needs of the user. Therefore, the design must be made with such changes in mind. According to interviewees, this type of uncertainty about the needs of the user is the same as uncertainty about the functionality in principle. However, it deals with a different type of professional knowledge. It is not the practical knowledge of doctors and nurses, but the operational knowledge of the healthcare sector. Designers need to figure out trends in hospital operations to understand the long-term use of the building. The project must allow for variability through a flexible design. This ranges in complexity. The simplest case is adding an uncertainty marginal to the maximum expected output of a system to allow for increased demands over time, but not actually forecasting the changes. Other cases demand designing within an interval of outputs, such as the example with the ventilation above.

The challenge of the co-creation process is of course that designers are not experts in the fields for which they design buildings and installations. The client and the organizations they hire to design and construct buildings are specialists in their own fields. There is a limit to the level of insight that can be achieved between them. The project needs to find the right processes for knowledge exchange, so that the clients and hospital organization's thought processes are captured in the design work. It is uncertain beforehand what work practices should affect design choices or how. It is the job of the

consultant to extract the necessary work-practice knowledge from the client or hospital organization, and to decide how to adapt the design. The way that this challenge has been addressed in the project is to have representatives of the hospital organization to be part of the design group in the organizational chart. There have been design group meetings where hospital staff, such as doctors and nurses, partake in design choices and co-create requirements by sharing their knowledge and opinions on design choices. This way there is knowledge exchange, but it is focused on the design, bounded by the context of the meeting forum.

5.1.4 Accounting for changes and flexibility

Changes are constantly brought up by interviewees as a complicating factor for the entire design process. It is inevitable that the design will change, and that knowledge will be lost because of it. Finding processes that can deal with changes and the complexity they bring is paramount for the overall success of the project. The client sets design specifications based on their own best estimate of what technical systems they will need. The designer has an advisory role towards the client to help set the requirements right. This means that design requirements and design specifications can either be prescribed by the client directly or co-created with the design team. Often these two groups have different opinions of what will work best for the overall design Their different perspectives are based on their understanding of the users' needs and lead to different judgements on what solutions are best. Thus, design requirements are prone to change.

Changing the design to conform to new requirements is different from changes subsequent from adaptions or cascading effects of other changes. The requirements changing often signals a lost belief in the current design ideas and can be impactful for the entire project organization. These changes are especially prevalent in connection to change of personnel within the project or the represented organizations. When new perspectives are incorporated in the project, old decisions and solutions get revisited and revised. If the history and reasoning behind decisions are lost, then such re-evaluations can cause significant design rework. The project managers brought up that a balance must be struck between accepting the insight that new perspectives bring, while maintaining progress and forwards momentum in the project.

A universal observation was the importance for designers of understanding the way that the users work, not only what they need. The intent of previous design choices is lost as changes are implemented without insight or knowledge of the considerations that led to that choice. The reasoning for why something is designed a certain way, its history, is especially vulnerable to this. The risk is that functionality can be lost if re-design is done thoughtlessly. An example given was that a faucet and sink in an operating room might be placed close to the entrance so that staff can wash their hands going into the room, avoiding contamination of the operating theatre. The functionality of the faucet and sink comes just as much from its existence as from its location in the room. The functionality is lost if the location is changed so that the faucet and sink is away from the door. Thus, when changes occur the reasoning behind design choices is as important as the design choice itself.

Regarding this, interviewees highlight the importance of understanding the allowable deviation in design requirements. What can be changed or not, and how much can it be changed while maintaining its function. The better the reasoning behind decisions is understood, the less uncertainty there is, even about design boundaries. Then the design can fulfil the need of the user better.

The need for maintaining the reason behind a decision taken was one of the most repetitive observations between the interviewees. As mentioned before, one of the motives behind its importance is preserving its functionality, but there are other justifications for its importance. The consciousness of the consequences of taking a decision has also its significance. The Assignment Leader from the Control and Systems team mentioned that every decision has a series of dependencies behind it. He explained this with the example of moving a pillar. After the decision was taken, the team that moved it excused themselves to the design team by saying: "we didn't think that you were affected when we did this change, so we didn't tell you". The complexity in this case is to be aware when making the decision of changing something, how this is going to affect the decisions taken previously. And when it is going to eliminate the why it was designed like that in the first place. The important thing is to consider, "if a decision is taken, what else is going to downstream from it, and that must be the most complex thing to visualize" (Assignment Leader Control and Systems).

To figure out the best way to finish with the design stage, some interviewees proposed having the right level of detail in each stage. This meant increasing importance of the issues regarding biggest impact in the project, leaving the next of the design decisions to the following stages. One of the design team members mentioned that it was important to have the right level of detail in the first interactions with the client in the early design stage and ask the right questions. "It is not relevant to ask the client if the monitor is on that wall or on the other, it is way too early, and it does not affect the cost". The interviewee mentioned the importance of asking specific questions that have an impact on the project cost. And rather know the right decisions that need to be made, but at the same time acknowledge the challenge of this prioritization and the continuation in the next phases.

5.2 Formal knowledge infrastructure

There are several ways that knowledge can be transferred, and the project uses different communication channels to share different types of knowledge. For example, meeting forums allow for socialization and common problem solving, requirements must be specific and precise, whereas policy documents can be broader but concise and easy to internalize. Not every type of message can be sent using emails, or every detail showed in drawings. These concerns came up repeatedly during interviews. Interviewees showed concern that how knowledge is transferred or communicated matters just as much as what is being shared.

The project's knowledge infrastructure sets the conditions for how knowledge is shared in the project. One of the project managers specified that this includes pathways, processes, and systems for sharing written information, forums for verbal exchange and platforms for visual exchange. It was recommended that the infrastructure be built to allow transfer of different types of knowledge, not just relying on drawings for example. Several designers described that the flexibility of this infrastructure was important, that an over-reliance on a fixed set of channels for knowledge transfer runs the risk of becoming heavy handed. They warned that this would lead to project participants avoiding those systems in favor of more streamlined approaches by going through un-sanctioned sources. This would make oversight more difficult and increase the risk of issues "falling through the cracks". Furthermore, it was said that the infrastructure must be able to facilitate the spread of knowledge to the right people, regardless of if this requires participation or if it is simply notifying someone of a change or occurrence. The case project was seen as too large for one person to know everything, and so

connecting the right people is important. “In smaller projects you can keep the entire history in the project manager’s head, more or less. That is impossible with this level of complexity. … So, I built a group of people [to run the project] and tried to make it as complete as possible” (Project Manager).

Conversely some interviewees, especially the designers, highlighted that not everyone needs to know everything. Oversharing knowledge is burdensome and slow, and the participant must then sort through the relevant information. Thus, an approach of simply sharing everything was not advised. According to the Design Manager and Project Manager, the key thing that the project’s knowledge infrastructure needs to do is to facilitate the exchange of knowledge and ideas, and store relevant (actionable) information. Otherwise, knowledge is lost or never gets spread to the right people.

5.2.1 Project hierarchy and network

The challenge that the organizational hierarchy is trying to solve is to create structured connections to guide interactions within project and in its interface with stakeholders outside of the project. This resulted into a network of several companies passing knowledge in between them.

The project managers described that the organizational hierarchy, as a structure, is a way to combine the desires of the client organization and the resource needs of the project in the most general sense. The hierarchy is a way to structure the network of people involved in the project. It informs the flow of information and need for collaboration. It sets up groups consisting of representatives and forces them to navigate the towards a common solution for their various special interests. The hierarchy dictates what types of issues are addressed by whom. Each group has different responsibilities and goals, and different mandates to make decisions that affect the project. The connection between groups govern how they interact. What knowledge about the project is needed depends on the type of issues that are addressed in each group in the hierarchy, which in turn informs how routines and practices need to be set up to deliver said knowledge to the correct people in the project organization.

For the design process, a structured network allows designer and client to solve issues together. Many times, the designer cannot make design choices by themselves. Clarification or co-creation is necessary, lest they have to resort to design based on assumptions. Knowing whom to ask is as important as what to ask. The organization needs to be clear and known by all participants. Also, it is important that the design organization and client organization have corresponding roles in the project, so that there is always someone to ask and always someone responsible for an active issue. “Sometimes the solution depends on knowing who to ask or getting a hold of them. It is often like that in the beginning of a project, that you don’t really know who’s in charge of what” (Designer).

One critique against this approach was the effect that the project hierarchy had on the time needed for decision-making. Urgent and relevant questions sometimes were not properly addressed in time, as the hierarchy created distance between where the problem-solving took place and where the mandate lied to decide a solution. Some of the interviewees attributed this to, what they considered, a lack of project and design managers lower down in the organizational hierarchy.

5.2.2 Vision, policy, and guidelines

The project's vision and goals were described as the foundation for the entire knowledge infrastructure. These are supposed to encompass the intended outcome and establish direction. The idea is that the vision and goal should guide all work done in the project. By giving all project members a common ground to work from, everything flows from the vision.

"We started, as all organizations do with, 'what are our vision, our mission and our goals?' … It can affect quite a lot, a small sentence like that, if we work towards it and embed it in the organization. All the people who have the detail knowledge might think twice when running into issues and reconsider their approach. Each time that happens, the vision has an impact. For the patients" (Project Manager).

Other parts of the project's guiding structure include things like strategy and policy documents. For example, an information management strategy detailing the level of detail of the building model and the responsibilities of the BIM-coordinators. Or, a meeting plan detailing the frequency of recurring meetings, who is responsible for organizing it, who takes notes, what types of topics should be discussed and such. To be effective, the managers say that these general documents need to be overarching and non-specific. Because they always apply in every situation, they should be easily digestible and clear. They should inform the project's priorities and guide rather than dictate in order to be helpful in many diverse situations, in small ways.

5.2.3 Documentation of the design process

The project's progress is formally shown through documentation. It is the way that the project prevails throughout the years and how the design reaches the construction phase. The formal documentation of the project is divided into phase-reports (one per design phase), meeting protocols with recording of the decisions made in meetings, construction drawings, design requirements and RFP database.

A consensus among interviewees was that documentation is important. Further, they highlight that the project needs to be documented in a structured way for every discipline to be able to do their job. One incident in the project highlighted this. During the initial phase of the project the architect held interviews with the hospital user to establish how the hospital works. However, this was before the implementation of RFP. Thus, these interviews were not documented in an actionable way. Therefore, a second set of interviews were needed in the schematic design phase, repeating the work already done, and risking leaving out some important information from the previous stage.

The goal of documentation was said to be to record the work and ideas done behind a design solution. This could be for example inputs for design calculations, or technical requirements on which the design was based. One of the assignment leaders of the technical disciplines mentioned the importance of documenting the work, to enable the design to prevail through the stages and throughout the years. Further, they argued that it is important to know "why a design was done that way". This could also be important if the design team changes personnel, for the next designer to be able to adopt the work where it was left.

Another observation was the importance of documenting decisions accompanied by its underlying reasoning. Decisions are the foundation for the work being carried out. These decisions must be documented with its reasoning in case of changes. The argument here was that changes demand re-evaluation of previous design choices, and

then the project history, context, and inputs are just as important. Therefore, they argue, that there is a need to document the reasoning behind decisions as well.

Even being aware of this importance of documenting reasoning behind decisions, they are not always recorded. The volume of decisions in a project of this size and complexity makes it difficult to store and organize the volume of information that would arise in a way where it is accessible and actionable. There was a tendency among most interviewees to caution against unnecessary administrative work, as it slows down the progress of the design phase, and therefore an avoidance of documenting those things that could not be demonstrated to bring value to the project. To this, the project manager from the client organization mentioned, "if you would want to know the reason for everything you have to go through a lot of documents and a lot of protocols" and you would never finish. Therefore, for a project of this complexity, there is the need to limit the documentation presented and the volume of detail depending on level of importance. To be able to know the level of importance is hard. The project manager from the client organization made a further reflection; everything that is actionable needs to be documented. They stated that, in the case of changes, if the reasoning behind old decisions is relevant for the decision-making process of new decisions, then the reasoning is actionable.

"No one person can remember everything themselves. It would be too complex. Documentation helps to remember by putting it on paper" (Project Manager). But the excessive volume of decision and choices makes it difficult to document all and to use it in the future. In this project, in the case of a newcomer joining the project, if the new member would want to know the reason behind every decision, and the entire documentation of the project, they would have to go through a big number of documents and protocols. It is unrealistic to expect this of project members, and unpractical from a project management perspective to put resources towards something so vague. It is hard to justify, especially regarding the levels of new information that are continuously created in the project, that the new project member would need to learn at the same time.

5.2.4 Systems and tools

During the early stages of the project, in the early design phase, the design knowledge was documented in the system report and according to an assignment leader "a lot stays between the lines". One of the particularities of this project is that a lot of the systems for information were adopted during the project's execution and thus, generated all type of confusions around it.

The RFP database contained the technical specifications for every room in the building and was not implemented from the beginning. This caused a series of inconsistencies with the technical specifications and requirements discussed in the first interactions with the client and users in the project. Some of the designers mentioned how different the early phases would have been if the project counted with this system from the beginning. The project did not have a technical standard specification system with the client either, so this meant an information absence from the beginning.

But there are a few comments about the performance of this system that meant that it did not have enough holistic reach. The lead architect explained this with an example of doors. The doors did not belong to any room and did not belong to the hallway either, thus the system left out the specifications for the interactions between rooms.

BIM was also implemented along the way. This required assistance and trainings for learning the knowledge of using the tool. Depending on the team member or designer, this new configuration of design work had different challenge levels. But most importantly, this technology system was implemented when the project was still designed to be based on protocols and formal handovers. With this, one of the assignment leaders mentioned that with the implementation of BIM, "they had an old process for a new system" and that was noticeable.

In general, the interviewees mentioned that they were aware that the information systems and platforms can be different all the time, and they will continue changing with the advancement of technology. But that the design process needed a more holistic system that could encompass the project as a whole. The problem they saw is that every time there was a new system, this meant registering the information of the previous program to the new one. The designers considered this change of systems to be a work-load increase, saying "it was demanding. It was a lot of work".

When asked about the knowledge infrastructure of the project, the interviewees, both designers and assignment leaders mentioned several different platforms. The daily routine of a designer meant to be aware of the information actualized in email, meeting protocols, their company's intranet, RFP, BIM, information integration platforms and Q&A with the other design teams, etc. Considering the daily amount of work a designer has, and with tight time deadlines, this amount of information platforms was described by the interviewees as overwhelming. There were evidently too many sources and platforms of knowledge. And this, combined with the enormous size of the project made the interviewees react with this type of comments. "There was an enormous amount of knowledge documented into a bunch of different platforms" (Project manager from the client organization).

5.2.5 Meetings and collaborative forums

The project communication was based on recurrent meetings. These meetings happened on a weekly basis and its assistant members were chosen depending on the organizational hierarchy. There were meetings that only the leader group and the client were part of. There were also meetings just of the leader group and other meetings with all the assignment leaders from the different disciplines. The result of these meetings was documented on what was called a meeting protocol. The main answer towards the way they communicated in the project was through meetings. But even though aware of their importance there were also complaints about how big meetings with all disciplines were ineffective. "Too many meetings, and too many people in the meetings; though later said "Yes, I think I got the correct information because it was so many meetings" (Designer).

The assignment leaders also mentioned as an issue that decisions taken in meetings between designers within the same discipline are very important, but the leaders of the project cannot attend all these meetings. Leaders cannot be aware of all of it. To this they recommended bringing up the right questions in the right meetings. This meant, no specific discipline, noncrucial, questions in big meetings with group leaders and no important project changing decisions in discipline meetings that are not taken into leader group meetings. With this, it was proposed to cut meetings into parts depending on the topics.

For very understanding of the content exposed in the meetings, depending on its importance, some of them were done with the support of the 3D model to identify the

different discipline clashes. The handover meetings were also done with the support of the 3D model and were open for commentaries and suggestions. The interviewees mentioned that this type of communication facilitated a better understanding of the project and worked towards team integration.

5.3 Human resources

The following section groups the results of the human resources perspective of the interactions that happens when transferring knowledge from stage to stage. Some of the elements mentioned were the recurring change of personnel, the different effects that leadership and responsibility had on the project, and the shared knowledge and understanding that resulted from these. Some observations in this section relate to the communication of design requirements and the way the project knowledge infrastructure was organized.

5.3.1 Change of personnel

One recurrent interview response was that knowledge was lost due to a continuous change of people. Staff change was said to cause discontinuity at several steps over the project's lifetime. One interviewee gave an example from the first contact between the client and architects. Because the schematic design phase is general, when the project moves into the detailed design, many of the requirements that were set earlier need to be revisited. And so, change is natural. However, in this example, when revisiting the design, both the client and architect representatives had been changed for different people. The client said "oh, what you have done in this room, it wasn't what was agreed previously". According to the interviewees, situations like this cause redesign and re-work. Different understandings of the requirements are set by different people. Some of the interviewees refer to this as "it is like starting over".

Despite its consequences, personnel get changed throughout the project. Between the early design phase and the detailed design phase there are 7 years of project history. According to one of the assignment leaders, the requirements change as the expectations change because with new people there come new, different, views to confront a problem. Early group knowledge gets modified by the addition of new staff that bring new ideas. In a way, it can be positive to come up with new ideas, but it also brings risk of re-opening of solutions and causing re-work. This situation was exemplified by one of the technical designers mentioning that it is a human reaction to have new people questioning an old solution due to different perspectives on functionality.

When there is a change of personnel, there is an attempt to transfer knowledge of the project to them so they can perform their job. Some of the interviewees, part of the designer consultant teams, mentioned that when they started out in project, the knowledge transfer needed for them to perform their job was done directly from one person to another. On certain occasions, the project handover to important key members was done with a crash course about the project supported by a 3D model. On other occasions, this knowledge transfer happens with the support of documents and protocols. One of the technical consultants pointed out that there is just as much knowledge of a 7-year-old project that one can pass to a newcomer in a few months. Similarly, the large scope of the project was also mentioned in relation to the importance of documenting the reason behind a decision, where if the personnel changes, the importance of the reason behind this decision will prevail, and the next person can act upon the last.

5.3.2 Knowledge and shared understanding

The professional knowledge needed for each discipline is different. In a complex project, such as the one presented in this case study, cross-discipline professional knowledge is required to co-create. These professional perspectives enrich the project with distinct expertise and critical evaluation such as the construction team questioning the design team about the best location for a crane early in the process, so they can plan for logistics.

In some instances, there was failure to maintain the reason behind a decision or design choice. As an example, the project manager for the client's organization mentioned a case where an actor changes a technical solution because they do not share understanding with each other, and thus the original reason behind the solution is lost. The reason why someone had chosen a specific technical solution is based on their professional knowledge and the interest that they represent in their role. Thus, it is important to document the reason behind decisions for a design because it is necessary for different teams to understand each other's perspective.

The project consisted of several companies and disciplines working jointly, thus some of the interviewees considered that communication was the largest challenge, they considered that establishing understanding was a key for success. This situation produced a need for coordination between disciplines.

Some interviewees mentioned that personal communication left room for having different understandings of the same information. On some occasions problems of misunderstanding arose even when not being aware of it at the moment of the interaction. For instance, an assignment leader of the technical design quotes: "I think it's quite often we don't have the same picture. We think we have it, but we don't" (Assignment leader).

When the project is a joint effort of so many different disciplines, achieving a shared understanding is complex. By having several companies, with different disciplines, and distinct interests, the project suffers a high degree of fragmentation. But behind this fragmentation there is the ultimate objective of the delivery of a functional project that all project members should share. The assignment leader for the architectural design mentioned the risk of every discipline looking at their own design, and their own results. But what the project members really should want is to see the whole result of the design. All the players need the holistic perspective of the project to do their job, but purportedly lack it at some moments.

Interviewees talk about the challenges of bridging the different perspectives within the project. Depending on the participant's professional background, discipline, employer, level in the project hierarchy, and formal role in the project. Even personalities are said to affect the perspective of the project participant in their respective collaborative groups. Perspectives are significant in the context of the design process as they affect the interests of project participants. Goals and priorities are not homogeneous, each group has its own set of responsibilities. Naturally the fragmentation of participants leads to different priorities as project participants focus on their own responsibilities above others'.

Feedback and repetition were repeatedly claimed to be an important tool to decrease misunderstanding between project participants. One strategy that was recommended was to repeat what was communicated to make sure that it was understood, and that the sender and the receiver have the same understanding. One-way information can be

misunderstood, on the other hand, repeating or confirming the information encourages a shared understanding.

The results of the interviews also pointed to a lack of feedback on the documentation and information systems. For example, after implementing the RFP database, there was no feedback on if it was used or not or whether it needed any further modification. One of the interviewees that was involved in the implementation of the system had no clear knowledge of whether it was still being used in the projects in the present date.

Leadership perspectives and responsibility

Based on the organizational structure analyzed previously, there were two roles of strong leadership that interacted throughout the stages of early design and detailed design. These roles were the design manager and the project manager from the client organization. The results of the interviews pointed out that there were two approaches towards the project that differed on perspective. The project manager was in favor of the application of BIM, thus supported the increase of flexibility and collaboration. This included a more iterative process between phases instead of definite stages. On the other hand, the design manager approached the project with the strategy of defined deadlines and formal protocols. By adopting the BIM system during the project, according to one of the assignment leaders, the project ended up having "an old process for a new system".

The project had some key people who occupied the top spaces in the organizational tree. They had most of the responsibility and had the capacity of impacting the project to a greater extent. Such positions were the Design Manager and the Project Manager from the client's organization. As an example, it was mentioned that the Design Manager "was everywhere and nowhere at the same time". This because every decision required the approval and responsibility of the person in charge.

This issue aroused a proposal from the assignment leaders of having more project managers that could answer questions that require mandate to sign-off on decision, and thus add agility into the project. Based on this, some of the participants also suggested that the ultimate intention would be to build an organization that does not depend on these key people. There is a need of having people that carry responsibility and take decisions in the project, and there is also need for clearly assigning these responsibilities.

It was also mentioned that by assigning only one design manager reflects ignorance of how big the project really was. As exemplified by the interviewees, lead times for decisions were long. This scenario creates a challenge, as described by the design team "it really feels like it's [the project] in some people heads, that if they were go missing, it would just all fall apart." The project becomes dependent on key people who have mandate and responsibility in the organizational structure. If they leave the project, there are serious consequences. With this said, some assignment leaders, those who were more closely tied to the project's leadership, mentioned that having a more holistic perspective of the project and overseeing it is not only the manager's task. They also mentioned that the project belongs to all those who co-create into it.

6 Analysis and discussion

With the support of theoretical frameworks of knowledge creation and transformation, the following section analyzes the results obtained through the case study and arguments its resemblances and contradictions. By understanding how knowledge was transferred during the stages of early design and detail design, we could explore the possible reasons for its loss. As a result, the main reasons of why knowledge is lost are attributed to the different perspectives that a project can have, the failure to pass through the reasoning behind the decision-making process and the added difficulty of having big amounts of knowledge distributed in multiple platforms.

6.1 Different perspectives and divided roles

The goal of the design process is to reach a point where construction can commence, which in practice is when construction drawings are finalized. The main instruments the designers need for completing the design phase are technical requirements and design specifications. These are types of explicit knowledge, also called documentation (Cook, 1999), that outline the boundaries and conditions that must be fulfilled to meet the needs of the hospital user, and thereby the client. In other words, the goal of the design process is to formalize the collective (group) practical knowledge of the hospital user's work into technical knowledge about how the building should be constructed to suit their needs (Hedlund & Nonaka, 1993; Yang, et al., 2009). The goal of the design process cannot be fulfilled, however, if the design requirements and specifications do not reflect the true intended use of the building.

Again, Duhon and Elias claim that for an organization to utilize knowledge effectively, it has to have the right culture and structure (Duhon & Elias, 2008). The expressed need from designers to extract knowledge about the needs and practice of the hospital user sets the stage for what type of culture and structure the project needs. The challenge posed by fragmented perspectives is one of how to incorporate the needs and work of the hospital users into the design process.

The project must promote the sharing of knowledge between groups and individuals that need what the other knows. The structure of the project must include the right people, the right culture and the right processes (Duffield & Whitty, 2015). With regards to differing perspectives, processes become especially important as "processes help to transform temporary knowledge into permanent knowledge by turning tacit into codified knowledge" (Lindner & Wald, 2011, p. 885). Knowledge is lost when designers and advisory project members, e.g., hospital staff, fail to understand each other's perspectives during the co-creation of design requirements. Their different backgrounds means that they possess different explicit knowledge (Cook, 1999) and that they often approach the design work with different goals and interests in mind.

We argue that the ordinary processes of producing technical knowledge (i.e., institutionalization of conceptual knowledge on the individual level, or orientation of critical knowledge and formalization of practical knowledge on the organizational level (Yang, et al., 2009)) are insufficient to bridge this gap. They are insufficient for the same reason that technical requirements or design specifications cannot be created directly through systematization (Yang, et al., 2009; Nonaka & Takeuchi, 1995) of the collective technical knowledge of hospital users: there is no common ground, no shared understanding of what needs to be systematized. Transferring knowledge between two groups of widely different backgrounds is not the same as within groups of similar backgrounds. The healthcare staff of the hospital user are experts in their fields but have

neither training nor experience of the construction design process. Conversely, designers know very little about how healthcare works in practice, or why they do what they do.

Spender's (2008) view, that meaning is required to interpret data, is important with regards to how knowledge is formed based on the backgrounds of different people. Different perspectives, i.e., different "lenses", change how knowledge is perceived. If there is insufficient overlap in perspectives, if the knowledge is not adapted to the receiver, then it has no meaning for the receiving party and is not actionable. Knowledge is lost because is not transferrable when the perspectives and considerations of project participants are too fragmented. The receiver does not perceive the information as information, they are not available to be informed. Thus, they are not receptive to the knowledge being transferred.

From the outcome of the case project, some level of shared understanding has been achieved. The designing organization did manage to co-create requirements with the hospital user. The hospital organization and client (i.e., owner of the hospital building) have different specialties despite having close relations and a common board of governors. While facilities management and maintenance are a part of the client's organization, healthcare activities are not. There is a gap between the understanding of what healthcare workers need for their organization to function, and what the client's organization needs to function. But both must function for the project to be successful. So how was common ground created? We argue that individual learning is required for the collaboration to be meaningful in groups of widely different backgrounds. Either the hospital staff have to learn about design considerations or as happened in the case project, designers had to learn about the needs and work of hospital staff. We see this when designers emphasize the importance of understanding how the hospital staff will work. Note, the use of the word "understand", not be "informed". They seek common ground. This is similar to Duhon and Elias's (2008) view that an organization only knows something if the structure and culture allows it to be put to effective use.

Much of the knowledge of the healthcare professional cannot, reasonably, be externalized without prior knowledge of how the knowledge will be used (Hedlund & Nonaka, 1993) (e.g., affectional/emancipatory knowledge pertaining to values, dependencies and priorities between different healthcare related activities), which is exactly the problem in the first place. Indeed, as Lindner and Wald (2011) and Cook (1999) explore, externalization is among the more difficult movements in the knowledge process: "Explicit knowledge may be stored, but tacit knowledge cannot" (Lindner & Wald, 2011, p. 3), or " that tacit knowledge is acquired on its own; it is not made out of explicit knowledge. Prior to being generated, one form of knowledge does not lie hidden in the other" (Cook, 1999, p. 385). Nor can the designer create tacit knowledge through participation in a community of practice as part of the design process. Construction designers are usually not permitted to practice medicine. Nonaka and Takeuchi's five-step knowledge creation model (i.e., sharing tacit knowledge, creating concepts, justifying concepts, building an archetype, and cross-levelling knowledge) is therefore not applicable in this project case (Nonaka & Takeuchi, 1995; von Krogh, et al., 2000). However, the Holistic Theory of Knowledge and Learning (Yang, 2003), and the Holistic Framework of Knowledge Management (Yang, et al., 2009) do provide a framework accounting for the dynamic relationship of different sets and facets of knowledge and modes of individual and organizational learning.

Learning takes place on the individual level but few learning actions happen as exclusively individual activities, learning takes place at the social level as well (Yang,

2003). While intuiting and attending can take place on an individual level, interpreting and experimenting involves groups, and in group activities learning happens through participation and socialization (Yang, 2003; Hedlund & Nonaka, 1993; Yang, et al., 2009).

The challenge for the case project is to create an environment where learning can take place between the two groups of designers and advisors. Project managers need to gather and connect the right people into collaborative networks and set up the collaboration with processes that allow the necessary type of exchange to take place, and finally to promote a sharing, co-operative culture (Duffield & Whitty, 2015). The interviews done in this study reflect these conditions. The project teams and hierarchy set up collaborative networks where different project issues, including design, can take place in different groups. There is a place for every question, but not every question needs to be brought up everywhere. Learning between designers and hospital users in the case project took place in several forums, e.g., design meetings, interviews, and reference projects. These all have distinct mechanisms for knowledge sharing and all allow for socialization as a learning method. Finally, the project set up the incentives for project members through the vision and goal, so that hospital users were free to focus on the functionality, but also encouraging questions and co-creation from designers, which interviewees call a prestige-less culture.

From our analysis, we see that Yang et al.'s (2009) holistic framework of knowledge management is incomplete. It does not account for the meaning aspect of knowledge, which is connected to the perspective and background of the agents participating in the knowledge exchange. Transferring knowledge requires that we ascribe meaning to data (Spender, 2008), and this meaning is informed by the agent's perspective. By labelling the knowledge exchange processes (e.g., socialization and internalization), the holistic framework obscures the limits of these processes. In the same way that we might not create new technical knowledge from systematization (combination) of two separate bodies of knowledge, there is a limit to the gaps in tacit knowledge that can be bridged by socialization (participation) and the other processes within this model.

We have seen models within organizational learning (Duffield & Whitty, 2015; Swan, et al., 2010) and individual learning (education) (Yang, 2003) that approach learning from a mechanistic or process-oriented perspective. While these models are useful, they are simplifications. We have yet to see a model that adequately combines the process-oriented understanding of transformation and transfer of knowledge, with an individual as well as an organizational learning perspective. If the challenge is 'how to set up an organization that promotes knowledge transfer', then an important step is to include education outside the agents own field of expertise in order to increase collaboration. Therefore, we argue that the field of knowledge transfer, seen from an institutional and infrastructural lens, could benefit from the inclusion of 'learning' practices from the organizational learning and educational fields.

6.2 Changing out the people in the project

An observation presented in the interview series was that knowledge is lost when people leave the project, but not in the transition between early and detailed design in the case project. All parties remained throughout entire design. In fact, most detailed designers were part of at least the schematic design and worked on the design even before the transition to the detailed design. However, we also saw that new people entering the project, or changing roles, is a common occurrence and something the project must manage.

Why is knowledge lost when people leave the project? We see multiple examples that knowledge retention within the project is poor. When someone leaves a project, they take a lot of knowledge with them. The managerial challenge is to get the replacement person proficient with the project's history so they can contribute. New people in the project lack the insight of the person they replace, and also bring in different perspectives and new ideas into the project.

A long-term project participant sits on a significant amount of project history and context. They most likely have participated in discussions and problem solving at some stage of the design process. They will be knowledgeable about considerations and thought processes that underly many of the decisions that they have been a part of making, regardless of if this is as an active participant in the design work or if they have a managerial or co-ordination role. Even if they have not had active roles in making decisions, they have likely been present for such discussions and have some semblance of not only what the current understanding of the project is, but how it came to be the way it is. As the new project participant enters the project, they have none of this background information. In the case project, there was a large amount of documentation in the form of review drawings, reports summarizing the design phase and meeting protocols detailing decisions made throughout the project. The project participant also had access to other participants. However, as noted by interviewees, this was not enough to get a full understanding of the project. They reported lacking a sense of the history of the project. It was only by working on the issues themselves that they (slowly) started feeling knowledgeable about the context and current affairs in the project. By participating in discussions and problem solving, they learned to make the same considerations as their predecessor had made.

Lacking the project's history, it is impossible to understand the full scope of the issues that are being solved today. The result of this can be that the design choices are made without understanding of others' interests and goals. Where they are coming from so to speak. Thus, increasing the risk of creating new problems by unknowingly ignoring the ideas, considerations and thought process that went into that design. This risk is potentially amplified by the tendency for new project participants to question old decisions, which was highlighted by interviewees.

So, what contributes to the lack of understanding for the project's history? If it can have damaging results, then why is it not addressed within the project? As much of the design work is performed by collaborating in multi-discipline teams, the challenge for the new project participant is reaching a level of individual tacit understanding for the project's history where they can articulate their knowledge in a group, organizational and interorganizational setting (Hedlund & Nonaka, 1993). The experienced project participant has possession of knowledge and experience in applying it, what Cook (1999) calls knowing and Hedlund & Nonaka (1993) call articulated individual knowledge. The new participant starts out with very little knowledge of the project and no experience of working in it. Even if the new participant has "expert knowledge" (i.e., theoretical, professional or explicit knowledge), they lack the "local knowledge" of the project (i.e., context, practice, interactive or tacit knowledge) (Styhre, 2009). The resources available to the project participant as they start familiarizing themselves with the project are overwhelmingly big, including documentation of different kinds, e.g., meeting protocols (decisions), drawings, and policy and strategic documentation. These are all explicit types of knowledge that the new project participant must acquaint themselves with. Only when they have possession of explicit knowledge can they internalize it, i.e., what Nonaka and Takeuchi (1995) call, "translate theory into

practice", thereby transforming it into knowledge that can be used in a group setting. Without it, they cannot engage with the project work as knowledge in use, "knowing", requires tacit understanding (Cook, 1999).

Knowledge is lost because the type of knowledge needed for effective team collaboration, i.e. tacit understanding of project design history (Hedlund & Nonaka, 1993), is fundamentally non-transferrable with the types of explicit knowledge carriers available to new project participants, e.g. meeting protocols and drawings (Nonaka & Takeuchi, 1995). Practice is required to internalize explicit knowledge. Meaning that there will inevitably be a learning period when new people enter the project.

The second mechanism at play in the educational process of new project participants is socialization. This is the process of transforming tacit knowledge into new tacit knowledge in others, i.e., nonverbalized, intuitive and unarticulated knowledge (Nonaka & Takeuchi, 1995). Socialization is described as the "everyday comradeship" between people in the same group. For the project participant, this is their co-workers and collaborators in their respective organizations and meeting forums. This explains the observation, that new project participants report to learn by participating. They absorb by observing and collaborating with others on common issues, such as problem solving.

Looking at the ways that practical knowledge manifests, according to Yang, et al.'s (2009) Holistic Theory of Organizational Knowledge, it becomes obvious that certain types of tacit knowledge are impossible to achieve for individuals. The practical knowledge facet manifests as shared experiences, shared understanding, customs, conventions, and routines. All of these are group characteristics. Furthermore, these characteristics emerge and evolve as part of group interaction, through negotiation and exchange of ideas, i.e., through socialization (Nonaka & Takeuchi, 1995). Thus, like with the transformation from explicit to tacit knowledge, new participants need time to get socialized into the shared knowledge of the project.

A more common-sense reason why educating new personnel is difficult could be the size and complexity of the knowledge being transferred. Several interviewees point out that the scope of the project is massive, both the time scale and the volume of the design work. Communicating all the history in a project this large would require a huge effort from the side of the leaving project participant in the case of sharing the project's history. And equally huge effort from the new project participant, having to get read up on the project before starting to work. That level of time and effort might not be available. The project has limited resources to distribute. Educational effort towards the correctness of project participants understanding of project history must be in relation to the risk of damage or loss of value that a lack of project history might cause. This is supported by interviewees stating that there is a limit to how much of the history can be communicated when changing personnel, and that, at a certain point it is a waste of time.

6.3 The reasoning behind decisions

In projects of this complexity, it is of extreme importance to carry through the reason behind the decisions taken to the next phase. When the decision passes through to the next stage without its background reasoning, there is the risk that the next designer misunderstands its importance and its functionality as seen in the example about the faucet and sink presented in the results. In that case, the positioning of the sink was done with a reason behind it, which did not arrive to the actor on the next stage. Thus,

it lost its original meaning and reason of being. If the reasoning behind a decision is not clear, when the decision "arrives" to next stage, it has changed its original meaning. These designs and solutions "arrive" to the next phase without its full content. Correspondently, losing the knowledge that was created in the previous phase.

The results pointed out that every decision has several dependencies behind it. For example, the Assignment leader of the Control and Systems group mentioned the case of the decision of moving a pillar. Because the designer had not stated the reason of the pillar's location, the next team in the next stage moved it without knowing its background. This resulted in decisions taken later that affected other previous decisions, creating a ripple effect. The better the reasoning behind the decision of design is understood, the less uncertainty there is and the clearer its importance becomes. If this reason is not transferred to the next phase, the knowledge that existed before is lost because it lacks the whole meaning of it.

Some of the interviewees proposed the application of a decision log which means trying to transfer this individual practical knowledge behind a decision as a codified knowledge. Some of the decisions were in fact documented into meeting protocols, but why was this not enough? Even though it is of great importance to document knowledge, in order for the reason and importance to be understood it needs to be transferred with the context behind it (Spender, 2008).

For this reasoning behind a decision to have its whole meaning, the transference of knowledge must be done entirely. This knowledge can be said to be compounded by two parts, the technical codified knowledge that is registered as the taken decision, and the practical knowledge or process that was the reason behind that decision. The reasoning for the location of the pillar was based on practical knowledge, thus, individual knowledge that has not yet been incorporated into the formal system to be transformed for the benefit of the project (Yang, et al., 2009). Berg, et al. (2012) argue that knowledge that has practical reasoning behind, considered as practical knowledge, can't only be communicated as codified knowledge, it needs to be accompanied by a practical background. In this case, when a decision is documented without its reasoning and registered in protocols, it resembles more theoretical knowledge on the organization level.

As seen by Berg, et al. (2012), most knowledge stored in codified bases has social processes behind it that promote knowledge transfer. They propose to establish knowledge transfer with the support of workshops or personal communication. For example, in the case study, this type of knowledge transfer was used when transferring knowledge to certain new joining members to the team, but it was not used for transferring design decisions or choices. Maybe if the decision was transferred by a socialization process (i.e., workshop, personal interaction) and accompanied by its reason, it would not lose its meaning. Yang, et al. (2009) explain in their holistic framework for knowledge that socialization allows the transfer of knowledge from being a singular person's experience to being useful for the rest of the members of the organization.

But if we want to go further into the questioning, why is this practical reasoning behind the decision not passed through? The answer, its importance was not known. This phenomenon can be related to the unknown unknown's project management concept by Kim (2012) where the risk of losing knowledge can be diminished the moment it becomes known due to decreasing uncertainty levels. The first step would be to identify the issue, as in this research, that it is of crucial importance to know that the reasoning

behind a decision must prevail until the next phase. Then the knowledge loss possibility becomes a known unknown that can be anticipated, and thus, mitigated. But this issue is not always so easy to identify and mitigate. When a project counts with this level of complexity, cause-effect dependencies when taking a decision are not so obvious. This literature phenomenon could explain why the importance of showing the reason behind the decision is not always known by the project members.

Stretching this issue further, part of the not knowing that it was important to document with its whole meaning is related to the previous analyzed phenomenon of fragmented project and lack of a holistic perspective of the project. This because, by having a narrow perspective of the project, and being subject to time pressure, the participants tend to ignore the dependencies of their work and their presence in the network that encompasses a project (Pemsel & Wiewiora, 2013). The goal of individual project members is to the deliver the momentary project, thus there is only the need for an only acceptable outcome, not an optimal (Swan, et al., 2010).

6.4 Unmanageable knowledge volumes

The results showed that, even when being aware of the importance of preserving this reasoning in previous choices, in a project of this size, the volume of knowledge was extensive, and thus it connected to its difficulty of being documented and its spreading into several platforms.

One of the crucial steps established by knowledge management practices for using and managing knowledge is that this latter needs to be captured or documented (Saini, et al., 2018). And thus, construction projects have a big interest into documenting the important knowledge about the project to be able to be used in the later stages. Organizations in the construction industry use several databases and platforms that store explicit knowledge (Nonaka, et al., 1996). These systems for knowledge and communication are important and facilitate knowledge transfer (Lindner & Wald, 2011).

The process of externalization allows knowledge to pass from individual to the organization more easily. The objectives of this platforms are that they must be organized and present knowledge in a way that is easily accessible (Berg, et al., 2012). Thus, the results pointed to the necessity of less platforms with a more holistic approach that has the ability to sum up all the knowledge in one place. Based on the interviews it was discovered that every department and company participating in the project had a different way to document and communicate knowledge. This made it especially hard to be able to collaborate throughout the years. As Yépez and López (2021) agree, the disconnection and fragmentation of departments in the industry is an obstacle for development.

Due to the slow advancement of construction in the aspect of technological implementations, the way information systems and knowledge management has been implemented has been somewhat unorganized (Bhargav & Koskela, 2009). Some companies adopt these systems with the hope of improving their practices, but this means in practice that this implementation is done as what can be called “firefighting” implementation, by only doing it when the industry asks for it. For example, in the project case, during the six years between early design phase and detail design phase, there was the implementation of three new systems while the project was on going. Some of the participants expressed discontent to these changes because the knowledge that was in the previous stages, within another system, was very hard to transfer into

the new system. This was discovered to be especially hard for the new coming members that entered the project and had to learn how the systems worked. As the example presented in the results, the Project Manager from the client's side mentioned that in the case of wanting to transfer the knowledge to a newcomer member, seven years of project history couldn't be transferred in one month. Even under correct practices, the volume of knowledge is so big, that is too complex to handle.

Apart from the implementation of new systems during the project, the results also revealed that the excess of different platforms and systems created confusion and could produce some knowledge loss. With this, authors like Berg, et al. (2012), emphasize the importance of a good design of knowledge infrastructure where the knowledge is accessible, easy to find and thus promotes knowledge transfer. As a way of trying to approach this issue, the interviewees suggest prioritizing knowledge transference to the right level of detail, where the large impact information is prioritized. They mentioned that it was a matter of bringing up the right questions in the right stages. When prioritizing the knowledge transferred between the stages, there is the hope of reducing the volume of knowledge that is shared and document, and thus the intention of reducing knowledge loss. In literature, platforms where all the prioritized information is available and easily accessible are demonstrated enablers for knowledge transfer (Bhargav & Koskela, 2009). Only considering the fact that the amount of knowledge is overwhelmingly big in these types of projects, it could be on its own a reason for knowledge loss. But if to this it combines the unorganized knowledge distribution, it creates the perfect combination for disaster.

7 Conclusions and recommendations

The section below outlines our conclusions towards the main research question of why knowledge is lost in construction projects summarized into three identified mechanisms, as well as implications for managerial work, implications for research and suggestions of future research in the field.

7.1 Conclusions to research questions

The following section answers our main research question. We list three mechanisms for knowledge loss and give our reflections on their relevance to the project's success. Recapitulating, our main research question was:

R*Q: Why is knowledge lost when a project transitions from the early design phase to the detailed design phase?*

The first mechanism concluded is that different perspectives and backgrounds among project participants could be linked to misunderstanding between them. If designers and clients fail to understand the needs of the other, then the effectiveness of their collaboration can be adversely affected. Perspective informs sense making and the meaning that is ascribed to data. Therefore, to create knowledge through collaboration requires some overlap between project participant's perspectives on the project and their role in it.

The managerial implication of this is that design teams need to internalize the technical demands of the hospital user and translate them into the design. Without a shared foundation of knowledge about the intended use of the building, knowledge exchange during collaboration activities lacks meaning, and no new knowledge can be co-created. Design teams must go through a process of learning about the needs of the client to collaborate effectively. This includes learning about the practice of healthcare work, what considerations that are made by the client and user, and what practices the building should support.

Our second mechanism concluded is that project changes inflict knowledge loss by overwriting previous design ideas. Changes are near inevitable. Two prominent causes of changes are that external requirements change, and that people leave the project. Both of these lead to new project expectations to fulfill and cause previous knowledge to become obsolete. New perspectives entering the project contribute to changes in expectations, understandings, and trigger reconsideration of old solutions. These mechanisms are promoted by the fragmented nature of the project, and from the unmanageable volumes of knowledge in large construction projects.

While avoiding knowledge loss is nearly impossible, the case project attempted to mitigate these losses by decreasing the occurrence of external change and loss of personnel. They also tried lessening the impact on the project by building in flexibility in the design and documenting decision making to ease the indoctrination of new personnel into the project. The managerial implication is that projects need to develop more flexible and dynamic systems that can adapt to changes while maintaining an overview of the project and uniting the different disciplines towards the project's goal.

Our third mechanism concluded is that knowledge is lost because the processes of knowledge transfer available in projects are unable to transfer project history. Misunderstanding or failing to acknowledge the reasoning behind previous design choices increases the risk that the design loses its intended functionality, and therefore

its value. To mitigate these consequences, it is necessary to be aware of the contextual dependencies that a decision can have, including dependencies on previous decisions taken.

Project history includes the reasoning for decision taken and carries actionable information about the project. It is largely a construct of the group, built from shared experiences, context, which is hard to externalize and difficult to contextualize for new participants entering the project. Participation and practice are the main processes for learning context. As such, new members operate with a knowledge deficiency until they learn the project's history.

8 Further research

Our research has been focused on the creation, transformation, and transfer of knowledge within construction projects, but is largely isolated from the wider context of project and knowledge management. There are several variables and perspectives that might extend our results or provide nuance to the discussions we have had on the topic.

It could have great managerial benefits to study more explicitly how managers can affect the conditions that impact the effectiveness of knowledge transfer in a practical setting by exploring how to mitigate knowledge loss mechanisms. It would also be of particular interest to compare the extent that knowledge transfer conditions can be impacted, versus how much of them are fixed due to external circumstances, such as institutional pressures (Kadefors, 1995).

We acknowledge that our research has not been exhaustive in identifying knowledge loss mechanisms. We have focused only on a few mechanisms. Further research is required to map out more knowledge loss mechanisms. For instance, by using observation we could explore implications of knowledge transfer in an ongoing project.

As for new perspectives, another angle of approach would be to research the effects that the type of contract has on knowledge transfer between project stages. A variable that could change the extent and severity of knowledge loss is whether continuity can be maintained between project stages. For example, if the consultancy company handles the early design, but the contractor continues with the detailed design and the construction. This could lead to a greater break between phases of the project and could increase the impact that the knowledge loss mechanisms identified in this thesis.

9 References

Alänge, S., 2009. *The Affinity Interrelationship Method,* Gothenburg: Chalmers University of Technology.

Alvesson, M. & Sköldberg, K., 2009. *Reflexive methodology: New vistas for qualitative.* 2 red. u.o.:u.n.

Argote, L., 1999. *Organizational learning: creating, retaining and transferring knowledge.* 2 red. u.o.:Springer.

Bell, E., Bryman, A. & Harley, B., 2022. *Business research methods.* 6:a red. Oxford: Oxford University Press.

Berg, S. o.a., 2012. Knowledge transfer within and across organizational boundaries - A case study in the construction industry. *Arcom,* pp. 3-5.

Bhargav , D. & Koskela, L., 2009. Collaborative knowledge management—A construction case study. *Automation in Construction,* Volym 18, p. 894–902.

Boisot, M., 1998. *Knowledge assets: Securing competitive advantage in the information economy.* Oxford, UK: Oxford University Press.

Cheng, M., 2009. *Research on the Knowledge Transfer in Construction Projects.* Beijing, China, IEEE.

Co-Lab, D. I., 2013. *Knowledge Transfer.* [Online]
Available at: https://thenounproject.com/icon/knowledge-transfer-27472/?fbclid=IwAR1aYXP07FquKFThX0e75shNC8LOsHiEYebFR84SDXrYroLOrZnNV2hYpAw
[Used 20 May 2022].

Cook, N. S. D., 1999. Bridging Epistemologies: The Generative Dance Between Organizational Knowledge and Organizational Knowing. *Organization Science,* Volym 10, pp. 381-400.

Demarest, M., 1997. Understanding Knowledge Management. *Long Range Planning,* Vol 30, No. 3(Elsevier Science Ltd.), pp. pp. 374-384.

Dubois, A. & Gadde, L.-E., 2002. The construction industry as a loosely coupled system: implications for productivity and innovation. *Construction Management and Economics,* Volym 20, pp. 621-631.

Duffield, S. & Whitty, J. S., 2015. Developing a systemic lessons learned knowledge model for organisational learning through projects. *International Journal of Project Management,* Volym 33, pp. 311-324.

Duhon, P. F. & Elias, J., 2008. Why it is difficult to learn lessons: insights from decision theory and cognitive science. *SPE Proj Fac & Const,* Volym 3, pp. 1-7.

Edmondson, A. C., 2002. The Local and Variegated Nature of Learning in Organizations: A Group-Level Perspective. *Organization Science,* 13(2), pp. 128-146.

Eisenhardt, K., 1989. Building Theories from Case Study Research. *The Academy of Management Review,* Volym Vol. 14, No. 4, pp. pp. 532-550.

Essén, A., Knudsen, M. & Alvesson, M., 2022. Explaining Ignoring: Working with Information that Nobody Uses. *Organizational Studies,* 43(5), pp. 725-747.

Flyvbjerg, B., 2006. Five Misunderstandings About Case-Study Research. *Qualitative Inquiry,* Volym Vol 12. No 2, pp. pp. 219-245.

Ghasabeh, M. & Provitera, M., 2018. Transformational Leadership and Knowledge Management: Analysing the Knowledge Management Models. *The Journal of Values-Based Leadership,* Volym Vol. 11. Issue. 1, Article 8.

Hedlund, G. & Nonaka, I., 1993. `Models of knowledge management in the West and Japan. *Implementing Strategic Processes, Change, Learning and Cooperation,* pp. 117-144.

Kadefors, A., 1995. Institutions in building projects: Implications for flexibility and change. *Scandinavian Journal of Management,* 11(4), pp. 395-408.

Kim, S. D., 2012. Characterizing unknown unknowns. *Project Management Institute,* Paper presented at PMI® Global Congress 2012(North America, Vancouver, British Columbia, Canada. Newtown Square, PA).

Lilly, V., Schröpfer, M., Tah, J. & Kurul, E., 2017. Mapping the knowledge flow in sustainable construction project teams using social network analysis. *Engineering, Construction and Architectural Management,* 24(2), pp. 229-259.

Lindner, F. & Wald, A., 2011. Success factors of knowledge management in temporary organizations.. *International Journal of Project Management,* 29(Elsevier), pp. pp. 877-888.

McAdam, R. & McCreedy, S., 1999. A critical review of knowledge management models. *The Learning Organization,* 6(3), pp. 91-100.

McKinsey & Company, 2020. The next normal in the construction: How disruption is reshaping the world's largest ecosystem. Issue McKinsey & Company.

Nonaka, I. & Takeuchi, H., 1995. *The Knowledge-creating Company: How Japanese Companies Create the Dynamics of Innovation.* Oxford: Oxford Univerity Press.

Nonaka, I., Takeuchi, H. & Umemoto, K., 1996. A theory of organizational knowledge creation. *International Jornal of Technology Management ,* 11(7-8), pp. 833-845.

Olander, S., 2007. Stakeholder impact analysis in construction project management. *Construction Management and Economics,* Issue 25, p. 277–287.

Pemsel, S. & Wiewiora, A., 2013. Project management office a knowledge broker in project-based organisations. *International Journal of Project Management. Vol 31,* pp. pp. 31-42.

PMI, 2021. *A Guide to the Project Management Body of Knowledge (PMBOK ® Guide).* u.o.:7th Edition. PMI.

Saini, M., Arif, M. & Kulonda, D. J., 2018. Challenges to transferring and sharing of tacit knowledge within a construction supply chain. *Construction Innovation,* Volym Vol. 19 No. 1, pp. pp. 15-33..

Schwartz-Shea, P. & Yanow, D., 2011. *Interpretive Research Design : Concepts and Processes.* ProQuest Ebook Central red. London: Taylor & Francis Group.

Spender, J.-C., 2008. Organizational Learning and Knowledge Management: Whence and Whither?. *Management Learning,* Vol. 39(2)(Sage Publications), p. 159–176.

Styhre, A., 2009. *Managing Knowledge in the Construction Industry.* u.o.:Taylor & Francis Editorial. .

Sun, J., Ren, X. & Anumba, C. J., 2019. Analysis of Knowledge-Transfer Mechanisms in construction Project Cooperation Networks. *Journal of Management in Engineering,* 35(2).

Swan, J., Scarbrough, H. & Newell, S., 2010. Why don't (or do) organizations learn from projects?. *Management Learning,* 41(3), pp. 325-344.

von Krogh, G., Ishijo, K. & Nonaka, I., 2000. *Enabling knowledge creation: How to unlock the mystery of tacit knowledge and release the power of innovation.* New York, NY: Oxford University Press.

Wiig, K., 1997. Knowledge management: An introduction and perspective. *he Journal of Knowledge Management. Vol. 1. No. 1,* pp. pp. 6-14..

Yang, B., 2003. Towards a Holistic Theory of Knowledge and Adult Learning. *Human Resource Development,* 2(2), pp. 106-129.

Yang, B., Zheng, W. & Viere, C., 2009. Holistic Views of Knowledge Management Models. *Advances in Developing Human Resources Vol. 11, No. 3,* 11(3), pp. 273-289.

Yépez, V. & López, S., 2021. Knowledge management in the construction industry: current state of knowledge and future research. *Journal of Civil Engineering and Management,* 27(8), p. 671–680.

Zhou, Q. o.a., 2020. Integrated Framework of Horizontal and VerticalCross-Project Knowledge Transfer Mechanism within Project-Based Organizations. *Journal of Management Engineering,* 36(5)(ASCE).

10 Appendix – Interview Questionnaire

Formalities

- Ask to record
- Inform about anonymization
- Discuss preference of language: English – Swedish

Framing and context for interview

- Master's thesis at Chalmers, DCPM, focus on knowledge on organizations and management.
- *RQ: Why is knowledge lost when a project transitions from the early to the detailed design phase, as the project is handed over from the client to the detailed design coordinator and consultant?*
- Research is based on a case study.
- Focus is interaction between client and the detailed design coordinator, as well as consultant
- If you have any questions, let us know.
- What do we mean with knowledge?
- We are interested in what knowledge about the project one needs to perform the work satisfactorily and pass it on to the next phase with the same understanding.

Knowledge about the expectations and requirements of the previous phase and knowledge about the technical solutions and scope.

Interviewee role and project organization

"We will start with some questions about your role and how you were related to the project. We are trying to get an overview on how the work was organized between the different companies, departments and disciplines"

- What is your position at your company?
- What was your role in the project? What were your responsibilities? What did this mean in practice, how involved were you?
- Can you give us a quick overview on how the project was organized and where in the project organization did you fit in?
- Did you collaborate in any teams or groups? Which ones? What were their goals?
- Who did you report to? On what issues? Why was it needed to report your work? What role did the person have?

In your view, did the work in practice function as the project was organized on paper? In no, what was different and why?

Need and receiving of knowledge

"We will move on to questions about *the work that you do in the project. We are interested in what knowledge about the project you need going into the project to fulfil*

your role satisfyingly, to know what is expected of you and how you receive this knowledge."

- What knowledge did you need to do your job?
- How is knowledge transferred between the early design phase and the detailed design phase?
- In what form do you receive this knowledge (mechanisms, practices, routines, etc.)?
- How much of it is project specific, as opposed to routine?
- Do you know what is expected of you in your work on the project (as opposed to your position in the company)?
- Did you feel that you had enough knowledge to perform your work satisfyingly? Same throughout all the project or did it change? Any stages that were more/less clear?
- When the client hands over the project to you, what knowledge about the project do you think they should include to give you the best chances of a successful detailed design phase?
- What do you see as the main barriers?
- (If mentions knowledge is lost). In your opinion, why do you think is the reason why knowledge is lost through the early design and detail design phase?
- Returning to your role and connection to the project organization.
- Is it clear where the knowledge comes from and why it matters?
- Is it clear who you are working with and what knowledge they need from you?
- Please expand on the communication channels in the project (the knowledge infrastructure).
- What are they? What is the purpose of each system and how does it function?
- How well do they work with regards to getting you knowledge about the project?
- Which ones are more/less useful?
- What are their limits? Are there things that the channels do not or cannot communicate what they are meant to?
- Are there any additional channels you missed that you think would make your work easier/better?
- How do you think that the organization of the project hand-over affected yours and your team's understanding of project?

DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING
DIVISION OF CONSTRUCTION MANAGEMENT
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2022
www.chalmers.se

CHALMERS
UNIVERSITY OF TECHNOLOGY