

THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

The constructed space of a construction design team

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Abstract

Many industries today work with and around projects. One example is the construction industry where projects are typically constituted of multidisciplinary cross-organizational project members. Collaboration and knowledge sharing are crucial for the overall success of such a project, but are however also known to be difficult. This licentiate thesis focus on how a collocated multidisciplinary cross-organizational project team collaborates and shares knowledge. In connection with the concept of collocation, the influence of the physical space is often discussed, there however also exists other aspect such as power relations as well as how individual project team members experience a space – which influences how project team members collaborate and share knowledge. These elements all comprise a social construction of a project space and therefore, this licentiate more specifically addresses the concept of ‘space’ The notion on space is however barely discussed in connection with projects, but is discussed in connection with organizations.

This licentiate is based on three appended papers drawing on three qualitative case studies. The cases were studied through observations and interviews. Based on the findings it was seen that a project space is socially constructed based on how the project members use the space, behave within the space, and interact with the other project members. The way how the project space is constructed also influences the project team in terms of how they collaborate and share knowledge.

Key words: Construction design, Project, Collaboration, Organizational space, Project space and Knowledge sharing.

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June 2016, Janni Tjell

APPENDED PAPERS

Paper I:

“Visual Management in Mid-Sized Construction Design Projects”

Tjell, Janni; Bosch-Sijtsema, Petra M. In the proceedings of the 8th Nordic Conference on Construction Economics and Organization, 27-29 May, 2015, Tampera, Finland.

Paper II:

“Client’s presence during design. A study on roles, practice and visual management”

Tjell, Janni; Bosch-Sijtsema, Petra M. In the proceedings of the 31th ARCOM Annual Conference, 7-9 September, UK, 2015.

Paper III:

“The concept of project space and its impact on project teams”

Tjell, Janni; Bosch-Sijtserma, Petra M.
Submitted to an International Journal.

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1. Introduction

Project based organizations exist within a large range of industries (Hobday, 2000), and projects are deployed for many different reasons such as to solve tasks, test things in pilot projects, or investigate an incident. Some of the most important aspects characterizing projects are: (1) uniqueness, (2) with a predetermined date of delivery, (3) subject to one or several performance goals, e.g. resource usage and quality, and (4) they consist of a number of complex and/or interdependent activities (e.g. Packendorff, 1995). Furthermore, especially in the Architecture, Engineering and Construction industry, projects often consist of project team members from different organizations and disciplines.

One challenge regarding multidisciplinary cross organizational projects is to enable collaboration and knowledge sharing. Collaboration and knowledge sharing is known to be crucial for the success of a project, but becomes more complex when knowledge sharing crosses multiple boundaries like organizational boundaries, disciplinary boundaries (Carlile, 2002). Furthermore, knowledge within such projects is perceived as complex and difficult due to its contextualized and embedded nature (Newell et.al, 2009; Bosch-Sijtsema and Henriksson, 2014). Knowledge sharing and learning is often within project literature discussed in terms of how organizations learn from projects (Engwall, 2003; Scarbrough et al., 2004), how learning occurs between projects (Precipe and Tell, 2001), and how project team members learn from each other (Bosch and Henriksson, 2014).

Within multidisciplinary and cross organizational projects, the restricted timeframe makes it more difficult to develop trust and mutual understanding, elements which are important for establishing collaboration and knowledge sharing (Nilsson and Mattes, 2015). Therefore, the main concern in this licentiate is to explore how multidisciplinary cross organizational project teams collaborate and share knowledge. Knowledge sharing is defined here as “the provision of task information and know-how to help others and to collaborate with others to solve problems, develop new ideas, or implement policies and procedures” (Wang and Noe, 2010, p. 117).

In this context a number of studies indicate that communication, in particular face-to-face communication, can be an important factor in regards to developing trust and mutual understanding among projects team members (Rocco, 1998; Fiol et al., 2005; Nilsson and Mattes, 2015). There are, however, many studies discussing other forms of online or virtual collaboration methods, in which communication is performed through different forms of technology, e.g., internet, phone, email, video conferencing (e.g., Hatem et al., 2012). However, these types of virtual collaboration are beyond the scope of this licentiate, and this research only focuses on project teams that have the possibility to work collocated and communicate face-to-face.

In order to facilitate face-to-face communication, it is important that the project team members have the possibility to spend time together and this can be done for example through collocation. Several working methods focus on close collaboration in which people are able to collaborate on their tasks simultaneously instead of sequentially, often supported through collocation. Some of these approaches are the BIG Room concept (Liker; 2004), extreme collaboration (Garcia et al., 2004), and integrated concurrent design and engineering (Evbuomwan & Anumba, 1998; Love & Gunasekaran, 1998). In these methods, the project team works on tasks in parallel in a particular space – either face-to-face or virtually - with the help of specific technology and methods, such as visual means. The use of visual means can support sharing of knowledge, as well as enable new ways of collaborating (e.g. Boland et al., 2007; Ewenstein and Whyte, 2007; Henderson 1991; Nicolini 2007). Within the construction industry, examples of such visual representations can be sketches, drawings, 2D and 3D models (Henderson, 1991) In this licentiate the focus is on collocated spaces in which a project team can meet face-to-face and collaborate, and where the project team applies multiple visual means for their work. Collocation has shown to have a positive impact on the performance of a project team (Smith et al., 2010). Yet, there are challenges such as noise and lack of privacy (Pawar, et al., 1999; Chong, et al., 2012).

Many of the studies on collocation have focused on the psychical space in particular, and how this space should be formed and developed (REF). However, it is not only the physical space that influences how project team members collaborate. Other aspects are relevant such as social relations between the involved project members and how individual project team members experience the space in terms of their role, personal gains and work within the project and project space. These elements all comprise a social construction of a project space and therefore this licentiate is specifically interested in the concept of 'space'. It explores how a collocated multidisciplinary project team socially constructs such a project space, and how the project space influences the collaboration between the project members.

The concept of space is drawn on studies of organizational space (e.g. Dale & Burrell, 2008; Kornberger and Clegg, 2004; Taylor & Spicer, 2007). In this literature, studies discuss different aspects of space in terms of how it may impact the performance of an organization in terms of the physical work space (Allen and Gerstenberger, 1973; Kraut et al. 2001; Heerwagen, et al., 2004; Hau et al., 2010), how the architecture of a building may impact behaviors and interpretations of status and importance (Van Marrewijk, 2010), and how a space as social object may impact social relations and constellations such as power relations (Markus, 1993) positions and importance (Panayiotou and Kafiris, 2011). Taylor and Spicer (2007) review these spatial studies and define organizational space as consisting of three interrelated and inseparable conceptions: *“The first conception treats space as distance between two points. The second conception treats space as materialized power relations. The final conception treats space as the manifestation of our imagination”* (Taylor and Spicer, 2007: page 327). This conception of organizational space is primarily built on single and long-term studies of organizations aimed at gaining an understanding of the impact and influence of space. Few studies have, however, described the relation between social space

and temporary organizations i.e., projects in general and construction design projects in particular.

This licentiate thesis focuses primarily on construction design projects and is directed towards providing new insights into how project members in a construction design project collaborate and share knowledge. A construction design project consists of multidisciplinary cross-organizational members who are constituted for a relatively short period of time to solve a complex task (Chiu, 2002; Dainty *et al.*, 2007; Gray and Hughes, 2001; Moum, 2010). The particular focus of the thesis is a particular environment, i.e., *the project space* which is a combination of a physical space where the design team members meet one day per week, where they use a number of methods and tools such as visual means to carry out their various project tasks, as well as how the team behaves and uses the space. The focus is on gaining insights into: 1) how a project space is socially constructed by the design team members, and how such a project space influences how a design team collaborates and shares knowledge, 2) how visual means support their collaboration and knowledge sharing within the collocated space.

1.1 Aim and research questions

The aim of this research is to explore how project team members within a multidisciplinary, collocated, time limited project work together, and how their work is influenced by the project space, this leads to the formulation of the following two research questions (RQ):

RQ 1: *How is a project space constructed, and how does it influence a project team? (Paper III)*

Paper *III* addresses how a project space is produced and how a project space influences the design team using an organizational spatial perspective on the physicality of space, materialization in terms of social and power relations between the involved disciplines and their experiences of the space.

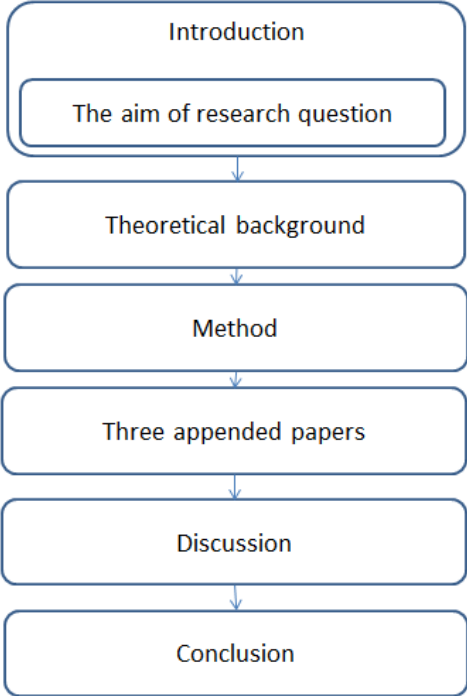
The second research question looks at how a project team uses a collocated space and the available artifacts including visual means to collaborate and share knowledge.

RQ 2: *How are collaboration and knowledge sharing supported in a collocated project space through visual artifacts and means? (Paper I, Paper II)*

To address this research question, paper *I* addresses how visual means support coordination of tasks and enable knowledge and information sharing within a multi-disciplinary design team. Paper *II* addresses how in particular the physical presence of the client and the use of visual means influence knowledge and collaboration practices in a collocated environment may facilitate the realization of the client's needs and wishes.

1.2 Structure of the thesis

In this chapter an overall introduction to the problem regarding how multidisciplinary and multi organisational project teams collaborate and work together has been provided, with a brief theoretical introduction. The introduction section has introduced the aim of the licentiate and the research questions. In the following chapter, the theoretical framing regarding social and organizational space is further developed as well as how the application of visual means influence project team collaboration. Chapter three documents the research method used for data collection and analysis. In the fourth chapter the summary and contribution of the three articles on which this licentiate is built are documented, and finally in chapter five and six the contribution of this research is discussed as well as of how it can support and lead to future research.



2 Theory

This section introduces the theoretical takeoff for this licentiate to investigate how a project space of a collocated multi-disciplinary project team is constructed as well as how it influences how the team collaborated and share knowledge. The primary focus is on social space from an organizational perspective (Dale and Burrell, 2008; Kornberger and Clegg 2004; Taylor and Spicer, 2007).

Secondly, this section introduces how collaboration and knowledge sharing can be supported by the use of visual means (Ewenstein and Whyte, 2007; Henderson, 1991, 2007; Nicolini, 2007).

2.1 Organizational space

The connection between organizations and space has been studied from various perspectives such as the relation between distances and space and the relation between power and space (Dale and Burrell, 2008; Kornberger and Clegg 2004; Taylor and Spicer, 2007). Based on a review article by Taylor and Spicer (2007) a more holistic view on organizational space is defined, which includes the following conceptions of: physicality of space, materialization of power relations and experience of space, which also align with Lefebvre's (1991) work on social space. Lefebvre's socially produced concept of space defines space as 'not' being determined by any physical boundaries; rather a joint purpose or goal provides demarcations of a space, i.e., an abstract space (Lefebvre, 1991). There are a number of elements that affect the formation of an abstract space, but the most significant element is according to Lefebvre the individual's interpretation of a space in terms of the value that they allocate to the purpose, the surroundings, the influence of power, the context, as well as whether other people are present in the space. Therefore, the understanding of space and how space affects us is subjective and socially produced (Lefebvre, 1991). Understanding of space according to Lefebvre depends on the following three aspects, which are dependent on each other and can therefore not be treated separately: i) interpretation of the physical space, ii) our prehistory, pre-knowledge, engagement, our value of the purpose and context, and mental status, and iii) our ability to connect in social interaction.

Taylor a Spicer (2007) spatial view on organizations has come forth based on a review of other studies that have lifted up the connection between organizations and space; these are the physical and social space as well as how a space is experienced.

Particularly the physical shape of office layout has and still is widely discussed in terms of how the physical shape impacts its occupant's possibilities for collaboration and knowledge sharing. Research on distance and physical space discusses the impact of physical space on communication and performance (Allan et al., 1977, Kraut et al., 2001; Olson, et al., 2002). If the physical distance between two coworkers within an office setting increases to more than

30 meters, their way of communication becomes similar to if they would have been geographically dispersed (Allen et al., 1977). Other researchers discuss the impact of the office layout, in terms of how the office layout can encourage informal interaction and communication between coworkers as well as provide space for independently concentrated work, in order to have a productive work space (Heerwagen, et al. 2004; Becker, 2004; Hau, et al., 2010).

When discussing the physical space and impact of distances, the concepts of proximity and physical collocation are often discussed, in particular how proximity to co-workers influence face-to-face communication, collaboration, trust-building and mutual understanding between team members (Fiol et al., 2005; Kraut et al., 2001; Nilsson et. al., 2015; Pawar, et al., 1999; Ricco, 1998). Proximity is particularly known to impact people's feeling of emotional and cognitive connection to a space and thereby influence people's behaviors positively (Kiesler and Cummings, 2002). Physical collocation and proximity also influence people to develop common expectations and experiences (Kiesler and Cummings, 2002; Olsson et al., 2002). However, not everything about collocation and proximity is positive. Aspects such as noise, lack of privacy, feelings of exposure, pressure from coworkers, stress, feelings of being overburdened by social interaction, lack of private space for doing concentrated work, and being forced to establish time-consuming social connection have been documented as negative effects of collocated work spaces (Chong, et al., 2012; Kiesler and Cummings, 2002; Pawar and Sharifi, 1997).

Next to proximity, distance and physicality of space, studies on space related to materialization of power relations have also constituted to Tayler and Spicer's (2007) view on organizational space. Materialization of social relations and positions can be formed in terms of power and importance in the organization through spatial elements such as corner offices, larger offices and more expensive furniture (Markus, 1993; Panayiotou and Kafiris, 2011). In a collocated environment, concurrent engineering studies have mentioned that people can feel exposed in an environment, can feel overburdened with a high degree of interactions and that for concurrent engineering there might be confusion over who is boss (Pawar et al., 1999). The physical space is also studied in combination with the social workplace, and how it influences the behavior of the workers. Cairns (2002) discusses how the impact of the physical space on the one hand can be controlling and on the other hand be empowering, therefore space can support a social landscape where social relations are mediated through spatial configurations (Halford, 2006).

When it comes to how space is experienced and in which space can be a manifest of our imagination, this is closely connected to individuals feelings, beliefs and earlier experiences (Cairns, 2002; Ford and Hardinger 2004; Taylor and Spicer, 2007). According to Halford (2006) spatial practices and meaning are constructed from a wide range of resources like experiences, memories and identities incorporating other spatial scales. Studies have lifted up symbolic and aesthetic aspects of organizations (e.g., Cairns, 2002), as well as narratives on organizational identity and culture (Taylor & Spicer, 2007; Ford and Harding, 2004; Yanow,

1995; 1998) which among more lift up how individuals can feel connected to an organization, according to personal values, beliefs and experiences.

2.2 Knowledge sharing through visual means

Collaboration and sharing of knowledge are as earlier described important for the overall success of a project (Bosch-Sijtsema and Henriksson, 2014). Projects in this case are temporary organizations, purposefully designed to provide benefits for a permanent organization or certain shareholders, through complex problem-solving processes (Söderlund, 2011). Literature acknowledges that project teams often consist of members from different organizations (e.g., Nesheim and Hunskaar, 2015), and can include permanent employees of the focal firm as well as workers that are employed by a third party or independent consultants. This is also common within the construction industry in which projects cross multiple organizational boundaries. Collaboration and sharing of knowledge is known to be complex, particularly in multidisciplinary cross-organizational projects (Bosch-Sijtsema and Henriksson, 2014).

Knowledge sharing may be related to the work within the project (Nesheim and Hunskaar, 2015), or the ability to learn from projects on an organizational level (Prencipe and Tell, 2001; Söderlund, 2011). Studies have looked into the project member's propensity to share knowledge, while others focus on knowledge sharing between different employment arrangements (Nesheim and Hunskaar, 2015). Project knowledge is however often contextualized and sticky (von Hippel, 1994) and is not always easily expressed in words, but can be presented through metaphors, drawings, sketches and actions (Koskinen et al., 2003). According to these authors project knowledge is not only about objective information but also implies subjective views, institutions and feelings of individual project members which are transferred to tacit project knowledge through face-to-face interactions. For sharing tacit and situational knowledge, Koskinen et al. (2003) suggest that corporeal proximity — a physically shared situationally place has a positive effect on tacit knowledge sharing in a project. Physical, corporeal proximity or collocation is recognized by several authors as an approach to address problems of knowledge sharing within multi-disciplinary cross-organizational projects. A shared physical space, i.e., collocation, can according to Nilsson (2015) support understanding and trust building, which are fundamental for collaboration and knowledge sharing.

Besides the development of trust, collocation also facilitates the ability for the project team members to work with a variety of visual methods and artefacts, which have also shown to have an effect on knowledge sharing. Studies have discussed the importance of visualization and visual means in the Architectural Engineering and Construction industry (AEC) (Ewenstein and Whyte, 2007; Nicolini, 2007; Whyte et al., 2008) to support and utilize the full potential of all the involved actors' know-how, embedded knowledge and expertise. Visualization has mainly focused on increasing understanding and sharing of knowledge through the visual representations that have the possibility to convey meaning (Whyte et al.,

2008). Visual artifacts that can be applied in collocated project spaces can be visual representations, such as 2D sketches and drawings as well as 3D models (Ewenstein and Whyte, 2007; Henderson, 2007; Luck, 2007; Nicolini, 2007). These can be applied to visualize and make challenges available more specifically and simultaneously to everybody involved in the project and initiate and stimulate discussion (Whyte et al. 2008).

3 Research design and methods

This licentiate thesis builds on a comparative study of three qualitative case studies of construction design projects documented during the schematic and detailed construction design phase. All three case studies were carried out at the same construction company, which is one of the largest construction companies in Scandinavia.

3.1 Research design

Initially, the focus of this research was on how visual means support and facilitate knowledge and information sharing within a collocated construction design team. The study was explorative and focused on observations of how the team collaborated and used visual artifacts and means. However, from the first empirical observation, it became clear that much of the collaboration that occurred in the collocated design space happened without any direct interaction with the visual means, but was more connected to people having the possibility to meet in person and work together within the same space. This therefore led to studying the concept of collocation more in-depth, in particular drawing on concepts such as “Big room” (Liker, 2004), “extreme collaboration” (Garcia *et al.*, 2004), and “integrated concurrent design” (Evbuomwan and Anumba 1998).

Based on further interviews and observations and by studying the effects of being collocated, it was furthermore discovered that not all design teams and/or even design team members used and experienced the collocated space in the same way. Not only the physical space was of relevance, but also how people experienced the space and how they interacted and collaborated in the space. Therefore, additional literature (Dale and Burrell, 2008; Kornberger and Clegg 2004; Taylor and Spicer, 2007) was studied, focusing on how a project space socially develops within a design team and how the project space influences the design team members and their collaboration. My research has followed an inductive explorative approach. Based on empirical findings and development of an understanding of the empirical material, the approach has adjusted along the way.

As mentioned above, a qualitative case study method was chosen, as the research is about understanding and depicting a contemporary situation involving ongoing connections and relations between human beings (Easterby-Smith *et al.*, 2014; Yin, 2009). One characteristic of the case-study approach is the number of different ways in which data can be collected, such as observation, interviews, informal communication, and collection of written documentation (e.g. Yin, 2009). A mix of these enable triangulation (Easterby-Smith *et al.*, 2014) of the collected data. For this research the data was collected from three different sources, i.e., interviews, observations and secondary data, in order to gain an insight in the social phenomena studied. The triangulation of multiple data collection approaches supports a validation of the data. This has especially been of relevance, because I have been, and still am employed by the company where the research was conducted. I was already employed by the case company for two years before I started the research project as part of an industrial PhD

project. During those first two years I was employed at the development department and was primarily involved in the development of a standardized collocation method that was targeted to facilitate the design process, particularly within the business area of domestic housing. During this period of employment, I became interested in studying these issues through an academic lens.

Throughout the entire research period, I have been fully employed by the company and connected to the same development department. As an employee of the company, I have had a well-established network within the company, which has given me the opportunity to follow decisions and reasoning's "backstage". Furthermore, I have had easy access to new and ongoing information and data throughout the entire research period. I have also reflected on my "insidership" and its possible consequences on the research in terms of me being biased or unconsciously being manipulated, in the following sections I will go into further detail about how and what I have done to mitigate these aspects.

3.2 Case descriptions

The study is based on a comparative case study approach which consists of three cases which have been selected due to case similarities which enable comparison. The main case study selection criteria that were considered, were the size of the project team, the type of construction, the budget of the design project, the use of similar work methods, physical settings and geographical collocation of the design team members (see also Tjell and Bosch-Sijtsema, 2015). The three selected cases were domestic housing projects developed internally within the company. This means that the client and the contractor belonged to the same company, but represented different departments within the company. The clients and the contractors therefore had well-established standard processes for developing these types of construction projects, and the contract between the organizations was based on the so-called "design-build" contract form.

All three selected projects were carried out in the area of Gothenburg (Sweden), and were studied throughout the schematic and detailed design period. All three projects were working collocated for one full day a week during both the schematic and detailed design phase, using the same physical facility for their collocation sessions. The same structured methods as well as a number of visual means to support the design team member's way of working were used in all cases. The three project teams included the following disciplines represented at every collocated session: client, architecture, structural engineering, heat, ventilation and air conditioning (HVAC), electricity and project management (PM). The PM was the same person in all three projects, except for the detailed design phase of project C where the PM was on maternity leave. Besides the mentioned disciplines, there were often additional people attending on and off such as managers, calculators, production specialists and specialists in fields like fire, moisture or landscaping. Sometimes some expert disciplines were represented by more than one person. The number of people therefore varied, not only from session to

session, but also during sessions. It is therefore difficult to exactly specify how many people were present during the collocation sessions, but typically the number was between six and thirteen (table 1). Generally, there were less people engaged during the schematic design phase than during the detailed design phase. The number of people present during collocated sessions, indicated in table 1 is therefore a rather rough estimation of how many team members were actively engaged to provide an indication of the size of the design team.

	Project A	Project B	Project C
Type of project	Domestic housing	Domestic housing	Domestic housing
Ways of meeting	Collocation one day pr. week.	Collocation one day pr. week.	Collocation one day pr. week
Area	Gothenburg	Gothenburg	Gothenburg
Size	110 apartments	61 apartments	113 apartments
Time for schematic design	Dec. 2012 – March 2013	Feb. 2013 – May 2013	Sep. 2014 – Dec 2014
Time for detailed design	Sep. 2013 – Dec 2013	Nov. 2013 – May 2014	May 2015 – Sep. 2015
Number of people involved during collocated sessions	6 -13 members	8-12 members	8-10 members
Total budget	200 MSEK	150 MSEK	160 MSEK

Table 1: Case description.

3.3 Data collection methods

During the study, a combination of several data collection methods was applied, i.e., observations, interviews, group discussion, informal communication and secondary data collection such as documents as depicted in table 2.

	Case study A	Case study B	Case study C
Number of full/half day observations	4 (16 hours)	3 (16 hours)	6 (28 hours)
Follow up meeting/group discussions	0	0	1
Number of interviews in total 26 – but several interviewees were engaged in two or all three projects	20	12	17
Informal conversations	>20 hours	>20 hours	>20 hours
Secondary data	Access to project database	Access to project database	Access to project database

Table 2: Overview of the collected qualitative data.

Observations: An important part of the data collection was carried out through observations (O’Toole, and Were, 2008). In the beginning of the research, unstructured observations were done through my employment in the investigated company. These observations were performed to gain insight into the project space and design team. Once the focus of the study began to take shape, the observations became more structured and followed a structured guideline with a focus on time stamps, activities, information technology (IT), spatial constellations, and artifacts used during the observed design meetings. The observations can give unique insights into the day-to-day working practices (McDonald, 2005). During the observations extensive field notes were taken with the help of a structured observation guideline, sketches were drawn of the lay-out, and photographs of activities and situations were taken. We applied a structured guideline as depicted in figure 1 (see also Fruchter et al., 2010).

Time	Activity	IT	Artifacts(like paper, whiteboard)	Interaction: Solo or collective (with whom)	Furniture/IT, People configuration

Figure 1: Structured observation guideline

In total, 60 hours of observations with help of the structured guidelines were carried out. Since I was actively engaged in the development of the concept of working collocated prior to the initiation of the research, the involved design team members knew me well. For this reason, my role in the research can be classified as a participant observer (Bryman and Bell, 2015) However, looking more closely at the role of a participant observer, scholars such as

Merriam (2009) suggest that there exist four levels of being a participant observer ranging from being a “complete participant” to being a “complete observer”, and in-between there exist “participant as observer” where the role of participation is primary to the role of being an observer. There is also “observer as participant” where the role of being an observer is primary to the role of being a participant (Merriam, 2009). I classify my role in this research project as being an ‘observer as participant’ as I did not actively take part in any of the cases, and tried to be as passive as possible during the collocated meetings, even though I was well-known to the teams and had been involved in the development and implementation of collocated work in the company. At one occasion in one of the initial workshops, I was actively involved and supported the project manager with an introduction to one of the visual tools available in the collocated space. However, I did not take an active role in any of the activities in any of the observed cases. During the observations, my role as a researcher and observer as well as the purpose of my observations were clearly articulated and well accepted and understood by everyone involved (Merriam, 2009).

Observations inherently include the risks of possibly being manipulated by the observed project team members or the researcher may become biased towards the investigated case. Aspects such as “over-seen incidences” can either mislead the observer or cause the observer to hide aspects which can corrupt the data and thus lead to erroneous conclusions (Merriam, 2009; Yin, 2009). In order to decrease bias and the influence of the data by the main observer, approximately half of the observations were done by two observers, where I was one of the observers and the other observer was not previously known to the project teams, however someone with great knowledge within the research area. This was done to mitigate the risks described above.

Follow-up meeting and group discussion: About a month after the last collocated session on the detailed design period of project C, the project group had a follow-up meeting focusing on “lessons learned”. This session was also observed. During this “lessons learned” session which took about 3 hours, all involved project members were invited and had the opportunity to talk about what worked well and what could be improved for the next project. The team members suggested how improvement could be done. At the meeting the following disciplines were represented: the project manager, client, moisture consultant, HVAC consultant x 3, ground consultant, architect, environmental impact consultant, construction consultant x 2 and a Virtual Design and Construction (VDC) coordinator who handled the building information models, adding up to 12 people. The feedback followed the concept of “going around the table” so that everybody had a chance to say something. At the end of the session, several suggestions proposed by the project manager regarding opportunities for future changes were discussed, and thoughts were written down on post-its and posted on a whiteboard.

Interviews: Besides the structured observations, the primary source of information was collected through interviews. A total of 26 in-depth interviews were carried out with key members of the three projects. Many of the design team members were engaged in a

minimum of two of the three projects. They represented the different disciplines as depicted in table 3.

Disciplines	Number of interviews
Project Manager (PM)	3
Senior Managers	5
Architects	4
Consultants (HVAC, Electricity)	6
Structural engineering	4
Client	3
Production	1
Total	26

Table 3: Overview of types of interviewees.

All interviews were conducted individually and in secluded spaces, which means that the interviewee was able to talk freely. The majority of interviews were even conducted at the interviewee’s office. For the interviews, I developed an interview guideline that has been applied to all interviews. It was considered important to develop semi-structured and to some extent open-ended questions, in order to encourage the interviewee to open up and talk freely about their view from their perspective (Kvale et al. 2009). All the interviews lasted from between a quarter of an hour and up to one and a half hours. All interviews were audio-recorded with the interviewee’s acceptance, on the condition that all interviewees were anonymized, and that no one besides the involved researcher and supervisors would be able to access to the recorded material. The interviews were transcribed.

Informal conversations: Due to my employment in the company and natural presence at the site and within the corridors, I had several spontaneous and ad hoc conversations during coffee breaks, travels, and during general social activities. In particular, four individuals within the company, i.e., three in management roles and one project manager provided valuable insight and understanding of the larger picture and the overall processes at hand.

Secondary data: I had access to all internal documents regarding company policies, company strategies and goals as well as internal documentation within the design teams. The secondary data on organizational level described both the company’s motivation and purpose of working with a particular design approach in which collocation and particular structured working methods were applied. Furthermore, I had access to documented experiences from similar projects within the company in the form of feedback sheets from previous projects in which members had to give feedback on the collocation and methods applied in short surveys. I also

had access to a common server, where documents related to the three cases were uploaded. All design projects had their own project location on the server which was accessible to all the design team members including me. On the server, members had access to all documentation, meeting minutes, decisions and requirements from the specific projects.

3.4 Data analysis

The data analysis started with a coding process of the interview material. Different coding schemes were used depending on the purpose, but all were based on a thematic coding approach related to a grounded theory analysis approach (Lincoln and Guba, 1985). The coding allowed me to get a new perspective on my data in terms of identifying important aspects not at first discovered.

The coding started off with a rather rough coding looking through the transcribed interviews. The initial coding was done with color coding in order to highlight major themes. After this, the coding became more detailed, and the labelling of themes was refined. The collected data for article III were coded in relation to Taylor and Spicer's (2007) review of organizational space in terms of physicality of space, materialization of power relations and experienced space. Articles I and II focused on the use of visual means and influences on working collocated.

After the coding, the data from the interviews were combined with my field notes, pictures and sketches from the observations, in support or contradicting interview statements. Furthermore, the observations provided examples of how the project team members collaborated and used the collocated space for example in terms of how they moved around and behaved in the physical space, which was an important part for understanding the social production of space.

3.5 Reliability and reflections

In order to ensure trustworthiness and credibility of the study, several methods for collecting data were applied, such as observations, interviews, informal communication and secondary data. According to Easterby-Smith *et al.*, (2014) data from a minimum of three different sources suffices for triangulation, and strengthens the reliability of the findings and conclusion.

In addition to triangulation, my analyses of the collected data were discussed and tested in regular meetings with a reference group consisting of members who themselves are actively engaged in the construction design phase, however not in the observed cases.

As mentioned above, even though I was employed by the contracting company in which the collocated sessions were held, I have tried as much as possible to be a ‘fly on the wall’ during the observations of the collocated sessions and to influence the team as little as possible. However, my role as representative of the contracting firm was transparent to all design team members. What, however, may be questioned is my role as a participant observer as I prior to this research project had been working for the company and had been involved in the development of collocated space that I studied. Nevertheless, it has been important to reflect on my role as a participant observer and how this role may have influenced the data collection and ability to handle the collected data objectively. Objectivity is almost impossible in qualitative research of this kind, which is also important to address and reflect upon. Objectivity becomes difficult because we all have a “backpack” of skills and knowledge which influence our ability to reflect, analyze and interpret. To mitigate risks of subjective bias, an external researcher has, as described in section 3.3, followed approximately half of the observations and participated in a number of interviews as well. Furthermore, this external researcher has read all the transcribed interviews, observational notes and sketches, and continuous in-depth discussions on all collected data were carried.

4 Summary of appended papers

Paper I:

Visual Management in Mid-Sized Construction Design Projects

Tjell, Janni; Bosch-Sijtsema, Petra M. In the proceedings of the 8th Nordic Conference on Construction Economics and Organization, 27-29 May, 2015, Tampere, Finland.

Purpose: The aim of this article is to explore how visual means support a construction design team in terms of coordination and how visual means can facilitate sharing of information and knowledge of a semi-located design team.

Data collection: We followed two projects throughout the entire design process, and carried out a total of 15 semi-structured interviews with key members of the two projects.

Findings: The findings are two-fold: (1) by using multiple visual means, i.e., visual management, the design teams become more self-going. (2) However, this self-going with the help of visual management was primarily related to the located setting and active engagement of all actors involved.

Reflections: This article was my first article, and is therefore also based on my first observations and interviews, where the focus of my research was on how visual means support knowledge and information sharing within a located environment. I was particularly studying how the design teams were applying the visual planning and coordination tools which were available on the walls in the located facility. Through my observations, I saw that the visual planning and coordination tools mainly facilitated a level of transparency, which in turn enabled the project team members to drive the design process forward and make joint decisions. This applied even during days when the project design manager was not able to attend. What I also noticed was that much of the team's communication in relation to the use of these visual planning and coordination tools was enabled by the project members being located. Most of the communication between the project members happened informally and because the project members spent time together. Therefore, how they were collaborating and sharing knowledge was actually more connected to them being located than the actual use of the visual means. This finding turned my attention towards studying the influence of being located even though the connection with the application of visual means remained.

Paper II:

Client's presence during design. A study on roles, practice and visual management

Tjell, Janni; Bosch-Sijtsema, Petra M. In the proceedings of the 31th ARCOM Annual Conference, 7-9 September, UK,2015

Purpose: The aim of this study was to explore how the physical presence of the client in an Integrated Design Team (IDT) setting could influence the relationship between the client and the design team in terms of knowledge and information sharing regarding the client's needs and wishes, how this may be supported by visual means, and how the use of visual means may influence knowledge sharing and collaboration practices in a collocated environment towards the realization of the client's needs and wishes.

Data collection: I followed three projects throughout the entire design process and more than 22 semi-structured interviews were carried out with key members of the three projects and interviews were recorded.

Findings: the following findings are discussed in the paper: (1) the physical presence of the client in an IDT environment influences (i) the relationship between the client and the IDT, and (ii) the client's role as an active member during the design development. (2) The client applies a traditional way of sharing information through a design brief to the IDT, which does not take account of opportunities of the visual setting of the IDT. (3) There exists potential for increasing the use of the available visual means and possibilities for visual management to enable sharing needs and wishes between client and IDT.

Reflection:

This is my second paper, where I had slightly shifted my focus towards the effect of being collocated and in particular the client's role in a collocated environment. Before the implementation? of collocating a design team, the client was hardly engaged during the detailed design period, and was therefore more of an abstract figure in the project team. By collocating the design team and client enabled them to work in parallel and simultaneously as a team. The physical presence of the client had an effect on the relationship between the client and project team: the project team members gained a much clearer picture of what it was that the client requested, as well as the client received a better understanding of how a design work, for example it became much clear to the client what "late change" initiated by him/her entailed in terms of challenges for the project team.

What I however also saw was that even though a design team including the client were collocated and through this have many new and different options of collaborating and sharing knowledge, the client in the studied cases still hold on to the more conventional ways of communication in terms of e.g. written documents. Therefore, I believe that there exist possibilities in thinking differently in terms of how to utilize the potential of working collocated in combination with the application of visual means. Based on the first two papers, I began to wonder why the observed cases were different in how they used the collocated

facilities and applied the visual means. All the three observed project teams were collocated in the same physical room although not at the same time, and they all had the same project manager and worked in similar types of projects. Therefore, it became interesting to study what influences the construction of a project space and again how such a project is influenced by the project space in terms of how the project members collaborate and share knowledge. Based on these thoughts, I started looking more into spatial literature, which is the basis of my third article.

Paper III:

The concept of project space and its impact on project teams

Tjell, Janni; Bosch-Sijtserma, Petra M.

Submitted to an International Journal.

Purpose: We study how a design space is socially constructed within a collocated environment

Data collection: We followed three projects throughout the entire design process and did a total of 26 semi-structured interviews with key members of the three projects. These interviews were recorded, transcribed and coded.

Findings: The lens of organizational space can be applied to give insight into how a collocated project space is constructed. Furthermore, it is important to keep a holistic view when examining a project space in terms of not looking separately at any of the three conceptions of space of physicality of people, changes in power relations and roles and how the space is experienced by the team members, as they are interrelated. Those three conceptions complement each other but can also disrupt each other. Furthermore, the socially constructed design space influences how project members collaborate and share knowledge.

Reflection: This is my third article and the final contribution to this licentiate. Within the process of collecting data and writing this article, I have had many eye-opening moments, in terms of gaining a vocabulary for expressing many of those thoughts that I have had for a long time but have not been able to articulate and communicate. For a long time, I have been aware that not only the physical space nor the social space determines how a project space developed but the social construction of space was depending on something more. It was about how to get involved people engaged and willing to collaborate and share knowledge. When introduced to the term experienced space, this gave me the possibility to articulate this particular observation. For me this was almost relieving to hear and find out that others have attempted to describe this aspect as well and that it was real. Many new questions obviously arose during this process in terms of how to measure this concept of how a space is experienced, how to document it etc. and I have only just begun this journey and consider it to be a vast unexplored area particularly within the construction industry. This opens up for a lot of new challenges which at present do not seem to be addressed at all, according to my current knowledge. I am happy to have looked at this topic and look forward to further exploration within this topic of getting a deeper insight into the experienced space and its relation to the physical as well as social space of a project more specifically in a construction design project.

5 Discussion and conclusion

Collaboration and knowledge sharing are crucial for the success of a construction project and in particular for a construction design project (Bosch-Sijtsema and Henriksson, 2014). The process of collaborating and sharing of knowledge is, however, complicated by the fact that a design team often consists of multidisciplinary cross-organizational team members and often has a limited time frame to deliver a joint design (Bosch-Sijtsema and Henriksson, 2014; Dainty et al., 2006). Furthermore, a large part of the knowledge which has to be shared within a design project is embedded, contextualized, and tacit (Bosch-Sijtsema and Henriksson, 2014; Koskinen et al., 2003), which makes it difficult to share with other disciplines that work in different contexts. Within the studied qualitative case studies, the projects actively tried to diminish the difficulties regarding collaboration and sharing of knowledge through the use of a collaboration approach that contains collocation, structured work methods and visual means. This approach can be related to the BIG room approach (Liker, 2004) concurrent design (Evbuomwan & Anumba, 1998; Love & Gunasekaran, 1998) or extreme collaboration approach (Garcia et al. 2004). Based on the three cases, I have explored how the whole approach impacts collaboration and knowledge sharing. From my study I have found the following aspects of applying such a design approach: 1) the design team members felt physically closer during the design sessions which enabled the design members to communicate face to face and work simultaneous on various tasks to support solving tasks faster, and integrate more view points during the discussion, 2) the design approach enabled team members to spend more time together and collaborate together in the collocated space which resulted in an increased understanding of the different disciplines and their way of working within the team. 3) The design approach supported that project members had the possibility to ask questions and go into detailed design discussions which they would not have done in more traditional projects due to different prioritizations (see paper II). 4) Through the use of visual means and artifacts, the work tasks, problems and design issues became more transparent for the whole team with help of visualization (see paper I and II). On the one hand the design approach with support of collocation and visual means was perceived as positive. On the other hand, others considered the concept of working collocated as being more chaotic and less structured as the full length of a collocated session did not follow a strict agenda determined by the project managers. Members had to be autonomous in administrating their own tasks and goals within the project, and outcome of the sessions was dependent on the preparation and engagement of the members. Furthermore, it was observed that not all members perceived the collaborative design approach as beneficial for their work, which affects how inclined individual design team members were in collaborating and sharing knowledge. These findings correlated with existing literature which raises the point that proximity and working collocated in general increases collaboration and knowledge sharing (Kiesler and Cummings, 2002; Nilsson and Mattes, 2015; Olsson et al, 2002) but also that working collocated can provoke certain side effects such as that some project members experience the project space as more chaotic and less structured as found in this research. In the literature on collocation and proximity this is more discussed in terms of an increase in noise level, lack of privacy and quiet space for knowledge work which impact collaboration

and knowledge sharing negatively (Chong, et al., 2012; Kiesler and Cummings, 2002; Pawar and Sharifi, 1997; 1999).

Much of this difference in regard to how the collocated space is perceived by the individual design team members was one of the reasons why I initially wanted to explore project space from a spatial perspective. More specifically, I wanted to gain a deeper insight in how a project space is constructed as well as how such a space may influence the project team, by looking at the impact of the physical and social space as well as how a space is experienced. There is a large amount of literature focusing on projects and knowledge sharing and collaboration in projects (Bosch-Sijtsema and Henriksson, 2014; Scarborough et al., 2004) as well as in construction projects (Koskinen et al., 2003; Nesheim and Hunskaar, 2015), many of these studies primarily look at the particular methods applied (Evbuomwan and Anumba, 1998), or how team members collaborate and which means they use for collaboration (cf. Hatem et al., 2012). However, there are hardly any studies that apply a spatial perspective on projects that connect the interrelationship of physical, social and experienced space with knowledge sharing. This is why I have addressed this problem from a social spatial organizational view, where several authors have addressed how an organization from a spatial perspective is constructed and influenced by the physical and social space as well as how a space is experienced by the members in an organization (Dale and Burrell, 2008; Kornberger and Clegg 2004; Taylor and Spicer, 2007). Based on three comparative qualitative case studies and three appended papers, I here discuss how the: (i) The lens of organizational space can be applied and provides an understanding of how a project space is constructed and how it may influence a project team in terms of collaboration and knowledge sharing. (ii) How visual means support collaboration and knowledge sharing within a construction project design team primarily in relation to a collocated setting and active engagement of all involved disciplines. These aspects are discussed in more detail in the following paragraphs to answer the individual research questions.

5.1 The construction of project space

The social construction of a project space and how such a social construction of space influences the project team becomes particularly interesting in the studied collocated design setting. The design approach, collocation and use of visual means can be studied from a spatial perspective in which the location, the behavior of team members and how they experience the space are relevant to study. In knowledge sharing literature the environment is often mentioned as important for sharing knowledge (Newel et al., 2009). The environment can consist of organizational support, communication infrastructure, but also the physical location and possibilities for collaboration in a space. Especially for sharing knowledge between organizations, between different disciplines and knowledge that is complex, embedded and often contextualized it becomes important that the project space is supported by interaction and face-to-face communication (Newell et al. 2009; Nilsson and Mattes, 2015) or visualization (Whyte et al., 2008).

The main focus in paper III is therefore to show that a spatial lens can be applied on projects and through such a holistic spatial view, which embraces the conceptions of the physical, social relation and experience of space, contribute with a more comprehensive view on how a project space is constructed and how it might influence collaboration and sharing of knowledge within the project team. Looking at projects from a spatial perspective as in paper III, I base the conceptions on space on the three elements as described by Lefebvre (1991), Dale and Burrell (2008), Kornberger and Clegg (2004) and Taylor and Spicer (2007). From the earlier studies and reviews mentioned above and my own findings, it is important to study these three conceptions of space concurrently as they are interrelated and dependent on each other.

Paper III discusses how the physical size and lay-out of a project space influences how project members can use the space in terms of moving around and use different parts of the physical space. Furthermore, the physical space is connected to accessibility in terms of accessing the working area, the team as well as physical locations outside the design project space. The physical space influences the project member's interest and willingness in engaging themselves in the collocated project space. The physical space therefore creates the physical setting for how the project members can use the space for their team work. The findings correlate with current literature on workspaces which also highlights how the physical workspace influences how people collaborate and share knowledge (Allen and Gerstenberger, 1973; Heerwagen, 2004; Hou et al. 2015). However how a space can facilitate collaboration and knowledge sharing is not solely determined by the physicality of space, here aspects such as social relations, power relations and individual experiences also influence the social construction of the project space.

Social relations and changes in power relations can influence collaboration and knowledge sharing e.g., in terms of different positions among the project team members. Construction project literature discusses that there are often clear positions and power relations in construction design and often architects, project managers and clients play important roles during design (Foley and Macmillan, 2005). For example, the project manager and the client both have a high impact on what decisions can be made. As a consequence, specific meetings between the project manager and client are important for sharing information between the client and the design team through the project manager (Boyd and Chinyio, 2008; Cherns and Bryant, 1984). Within the collocated project space, the more traditional social relations and power relations that are mentioned in literature (cf. Foley and Macmillan, 2005) are challenged in multiple ways. Firstly, the influence of the team members becomes more balanced and all disciplines have the possibility to interact and collaborate. Secondly, the power relations between the project manager, the client and the project team changed. In a collocated environment, the role of the project managers has become more of a facilitator and a guide supporting the interaction and collaboration between the different team members. The role of the client was previously an abstract, no present figure to the design team, where now the client is physically present and takes active part in the discussion and decision making regarding the design development. The active involvement of the client during collocated sessions has improved the understanding, collaboration and knowledge sharing between the

client and the project team (paper II). The changes in social and power relations were observed and mentioned during the interviews and had both positive and negative implications. On the one hand members perceived the new roles of the client and project managers as positive for their way of working and the self-going of the team. However, on the other hand, the changes in social relations and power relations also created confusion for other members, who felt unsure how to behave and collaborate. This confusion in terms of who is boss, is also lifted up by earlier studied in concurrent engineering (Pawar et al., 1999).

The physicality of the space as well as the changes in social and power relations impacted on how team members experienced the space. The way how the design team members experience the design space is showed to influence how collaboration and knowledge sharing takes place between the involved project members. As some consider the project space as an advantage in terms of enabling collaboration and knowledge sharing and others perceive the project space as hindering their work and time. Those project members who considered the design space to be an opportunity for personal growth were more inclined to engage themselves in the project space in terms of collaboration and sharing knowledge. Those project members who perceived the project space to be a disadvantage to their own way of working felt less inclined to engage within the project space. Some members of the project hardly entered the collocated space, which had a negative impact on the mutual understanding, collaboration and sharing of knowledge between team members. This contrast in perception and experiencing of space can be related to existing literature on experiencing space which argues that how people experience space is not solely determined by the physical and social space but also depends on personal experiences, such as what meaning they add to the space in terms of e.g. personal experience and conviction (Cains, 2002; Yonow, 1995, 1998; Ford and Harding, 2004).

Based on these findings I define a project space as socially constructed based on the involved project members use and experience of the project space and the interaction between the project members. While the project space is socially constructed on an individual level by every project member, in which individual experiences, the use of the space and how a project member experiences the space is relevant. On project level, the project space is also socially constructed based on the way the team uses the space, behaves within the space, and interacts with the other team members. The way how the project space is constructed also influences the project team in terms of how they continue to work within the space. The contrasting experiences and engagement of team members influenced subgrouping constellations during the project. Over time, members who were less inclined to work in the project space participated less or were replaced by other representatives of their firm later-on in the project or in future projects. This all together emphasizes the relevance of studying a project space from a spatial perspective in order to gain a deeper insight on how a project space is constructed and how it influences a project team in terms of its abilities for collaborating and knowledge sharing.

It is important to emphasize that the three conceptions of a project space can complement as well as disrupt each other. This means that for example the physicality of the space might

create the best physical conditions for the project team to collaborate and share knowledge, but when the project members are less inclined to collaborate and share knowledge due to personal reasons, different perspectives, experiences, or conflicting wishes for the project outcome, then the physicality of the space does not necessarily support the project team. On the other hand, the physicality of space can also create barriers for collaboration and knowledge sharing if the physical space is not providing the project members with the opportunity for creating a setting where it is possible to collaborate and share knowledge. Therefore, the three aspects of a project space in terms of the physicality of space, the social and power relations and the experience of space cannot be studied separately as they are interrelated. Therefore, applying an organizational space perspective (Dale and Burrell, 2008; Kornberger and Clegg, 2004 Taylor and Spicer, 2007) on a construction design project provides insight about how a project space is constructed and how the project space influences the project team.

The theoretical spatial lens lifts up how the physical and social space as well as the experience of space influences how project members collaborate and share knowledge. Looking at a project from a spatial perspective is, however, barely discussed in current project literature and therefore needs to be explored in much more detail for temporary (construction) projects in future research. Particularly, the aspect of how project members experience the space adds an important element for future research. Relevant would be to study how a project space is constructed as well as experienced by not only those project members who are full time engaged in the collocated setting, but also the members of a more extended project team who are contributing more sporadically, such as specialists in a construction setting like fire consultants, moisture consultants and none active design team members, such as senior managers and experts. This aspect is less explored in the current project literature and according to my findings has shown to have a high impact on how interested and willing individual project members are in collaboration and sharing knowledge as crucial aspects for the success of a project.

5.2 Visual means and collocation enable knowledge sharing

Working with design methods and collocation enables project team members to share knowledge and collaborate on their tasks parallel and simultaneously instead of sequentially as is often lifted up in literature on concurrent design (Evbuomwan and Anumba, 1998). In my cases the collocation of project team members enables face-to-face communication with the help of specific technology and methods, such as visual means. Visual means and artifacts are known to support sharing of knowledge, as well as enable new ways of collaborating (Boland et al., 2007; Ewenstein and Whyte, 2007; Henderson 1991; Nicolini 2007). Within the construction industry, visual means are applied in the form of visual representations, such as sketches, 2D and 3D models (Boland et al., 2007; Henderson, 1991), and visual representations of particular processes, like the time planning process that applies visual

means to jointly plan the design. Particularly, the possibility to visualize a collaborative developed time schedule through visual representations has shown to influence the coordination of tasks as well as support mutual understanding for the ways of working among the design team members (Paper I). With the application of visual means and artifacts, the involved design team members have experienced an increase in transparency in terms of gaining a better understanding of each other's work and the overall design process. This enabled them to take more responsibility for their own work tasks but also for the overall process and forth bringing of the project. The visualization through multiple means applied within the case studies makes knowledge of the design team members more visible (Whyte et al. 2008) and supported more transparent decision-making and problem solving. Through visual means team members were able to visualize and share a part of their contextual and embedded knowledge within their own discipline. According to Whyte et al. (2008) the visualization supports the tacit-codified dichotomy in the knowledge sharing literature. Objects as visual means have been discussed in research as relevant for knowledge development and learning and they can bridge boundaries (Carlile, 2002). Visual representations are objects that are made with the intention of conveying meaning (Whyte et al., 2008).

While literature lifts up the use of the multiple types of visual means that can be used both virtually or in collocated settings (Boland et al., 2007; Henderson, 1991; Whyte et al., 2008), my study has primarily studied visual means in a collocated project space. The physical collocation is shown to be tightly connected with an increased understanding for the overall process and the increased transparency between team members. Within the literature, various forms of collocation such as the BIG Room concept (Liker 2004), extreme collaboration (Garcia et al. 2004) and integrated concurrent engineering (Evbuomwan and Anumba 1998) are known to support and build mutual trust and understanding through aspects such as face-to-face communication and informal communication, which support knowledge and information sharing. In knowledge and learning literature, the physical proximity has been discussed as supporting knowledge sharing (Koskinen et al., 2003; Newell et al, 2009, Nilsson and Mattes, 2015; Scarborough et al., 2004). The visual means in combination with physical collocation has also been shown in my study to facilitate tacit, contextual and embedded knowledge representation and sharing within the design team.

The collocation in combination with the facilitation and application of visual means surely support collaboration and knowledge sharing, but as earlier stated not all project members have the same experience of a project space and therefore have varying contributions and engagement rates in the project space which also affects their use of the visual means. The increase in transparency caused by the application of visual means can only reach its full potential if information is shared and made available by the involved project members. Therefore, the impact from applying visual means in relation to collaboration and knowledge sharing is very dependent on the project members' engagement in the project space.

From the findings it is seen that the core design team members collaborated in the project space, but the more extended design team members consisting of specialists and more senior

managers who have a strong impact on a design project in terms of expertise or decision-making power are not present in the project space. The collocated project space had an impact on the core design team in terms of improving transparency, trust and mutual understanding. While a larger part of the collocated project team became more and more a collaborating team, the collocation and development of the project space also created more distance to people outside of the core design team (see paper III). The collocated project space might strengthen the tendency to establish local territories (Kiesler & Cummings, 2002) and therefore increase boundaries between the design team and external specialists and decision-makers of the mother organization. Particularly senior managers and specialists who have a strong impact on a design project, in terms of providing conditions and making decisions, monetary or related to particular design elements, are not part of the collocated sessions due to different reasons. This makes it difficult for these senior managers and specialist to have access to the same level of knowledge and information, as those who are actively engaged. It would therefore be interesting for future research to address the role and influence of these senior managers in relation to the design team members who are actively engaged during the collocated sessions. As those senior managers who are not actively taking part do have a large impact on the decision making as well as setting of the stage for the construction design teams.

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