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BIM as a communication and collaboration tool within a large-scale infrastructure construction project

Usage of BIM to support communication and collaboration in a complex infrastructure project

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

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Abstract

In large- and complex infrastructure construction projects, several actors are involved collaborating for easing projects' complexity and ensuring a successful delivery. This is a result of a shift in the construction industry from the traditional partnerships between project participants, where cost as a main focus, to an inter-organizational partnership where learning as an objective. Further, based on partnering principles, Early Contractor Involvement (ECI) as a relational contract form has emerged and is very popular in Sweden. Adopting Building Information Modeling (BIM) in complex construction projects combined with ECI enhances the overall communication and collaboration between the involved actors in the project. This paper aims to study how BIM is utilized as a communication and collaboration tool between involved actors within complex infrastructure construction projects. Data was collected by interviewing a team that only worked with BIM-related issues within the investigated infrastructure project, as well as a case study, secondary data and observation. The result showed that BIM is adept at facilitating work coordination of the many involved organizations in the project and promoting effective communications channels and a closer collaboration between project's participants and stakeholders. Also, collaboration is preferred to be the way through which complex and large infrastructure construction are delivered and that BIM is a very strong tie that connects, reaches and draws many disciplines with each other and to a common ground establishing common understandings and better project comprehensive picture.

Keywords: Complex- and large infrastructure construction projects, communication and collaboration, BIM, ECI, project network, VDC, ICE

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Preface

This master thesis is the final moment in the master's program Design and Construction project management and has been conducted at the Department of Technology Management and Economics at Chalmers University of Technology. This report has been completed as a result of five intensive months during a very sensitive global situation.

We would like to thank everyone that helped complete this master thesis. But first and foremost, we would like to thank our examiner and supervisor Petra Bosch-Sijtsema, professor at the Division of Service Management and Logistics at Chalmers. Your support and guidance were our main success factor, and that without you, this master thesis has not been possible. Thank you for everything, we have learned a lot and developed a huge competence in the studied field. We would also like to thank Anna af Hällström for all the inputs and ideas that helped form this master thesis. We appreciate your time and effort, and we hope that we could positively contribute to your research. Petra and Anna, thank you for initiating this master thesis and for accepting us for carrying this responsibility.

We would like to thank all interviewees and participants that have helped make this work possible; your words are knowledge and sharing this knowledge with us is appreciated.

A huge thank to our families who coped with us under this critical and intensive period. Thank you to all our colleagues at Chalmers who supported us during this journey.

This was an unforgettable period that shall be remembered for many years ahead and shall be talked about to next generations.

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Notations

2D - Two-dimension
3D - Three dimension
4D - four dimension
5D - five-dimension
AEC - Architecture, Engineering, and Construction
BIM - Building and Information Modelling
CAD - Computer-aided Design
HVAC - Heating, ventilation, and air conditioning
IFC - Industry Foundation Classes
MEP- Mechanical, Electrical, and Plumbing
BOQ- Bill of quantity
VDC- VIRTUAL DESIGN AND CONSTRUCTION
WDP - Work Disposition Plan
ECI – Early Contractor Involvement
ICE – Integrated Concurrent Engineering
STA - Swedish Transport Administration

1 INTRODUCTION

The construction industry is recognized as less effective and productive than other industries, such as the automotive industry (Elmqvist and Hjertquist, 2006). Although, to a large extent, both industries include different actors involved in complex projects in different departments, such as in the design- and production phases (Crowley, 1998), the construction industry is still lagging behind. Several researchers had explored the reasons behind that and proposed potential solutions. Part of these indicated that the implementation of new information technologies and applications could help to solve this problem (Bröchner, 1990; Al-Qazzaz, 2010; Egbu CO and Botterill C, 2002).

The comparably large size- and long execution time of construction projects and the complexity level of activities could be the main differences between the housing- and large infrastructure projects (Bradley et al., 2016). Due to projects' complexity, all the involved actors in large infrastructure construction projects are required to communicate effectively and collaborate closely using channels and tools that ensure the accomplishments of successful project outcomes. Communication and collaboration include working very close towards clients, suppliers, subcontractors, and other internal and external stakeholders (Chakkol et al.,2018; Kerzner, 2017), which is not an easy task to carry out due to the dynamic nature of activities in construction projects (Wikforss and Löfgren, 2007). Consequently, the construction industry has been employing Building Information Modeling (BIM) as a step towards solving the efficiency- and productivity issue, aiming to achieve high qualitative projects' outcomes through effective communication and closer collaboration between involved actors in complex construction projects (Aibinu and Papadonikolaki, 2016). BIM has been a trend in the research community for the last decade, and a vast body of articles have been discussing the benefits of its implementation in construction projects. BIM within the construction industry aims to facilitate processes, increase productivity, and efficiency in the related activities and processes within the projects (Smith, 2014). It can be applied regardless of project type and magnitude (Sacks et al., 2016).

However, there has been little research in BIM concerning infrastructure construction projects regarding communication and collaboration. Therefore, the master's thesis's primary focus is on how BIM is currently being utilized as a communication and collaboration tool in multidisciplinary complex infrastructure projects. The purpose is to highlight what has developed as a result of this implementation in one of the most significant infrastructure construction projects in a large Swedish city. Moreover, almost no research has been found linking the theory of Networks with BIM concerning the area of communication and collaboration between inter-organizational actors. Thus, this paper aims to outline BIM as a tie connecting different actors involved in large- and complex infrastructure construction projects through a Project Network perspective (i.e., The way projects are considered as being networks consisting of ties and nodes (Steen et al., 2018)).

1.1 Purpose

The master thesis is part of larger research carried out by a PhD student at Chalmers University of Technology which covers several areas of the investigated infrastructure construction project in a city, in Sweden. The delegated main purpose of the master thesis has been to highlight how BIM is being utilized as a communication and collaboration tool between actors in an investigated infrastructure construction project. More precisely, the main purpose is to observe and highlight how BIM can function as a tie between involved actors in infrastructure construction projects, such as between main- and subcontractor, client, and stakeholders.

1.2 Objectives

The objectives of the master thesis are to study a large infrastructure construction sub-project in one of the biggest cities in Sweden and observe how BIM is currently being applied as a communication and collaboration tool in this project. In regard to that, the goal is to observe how BIM is used for communication and collaboration between different organizations and actors within the investigated project. The focus of the master thesis is on the dynamics of the team that handles BIM throughout the project. The thesis addresses practical issues such as, who has the authority to upload, update and/or adjust the BIM models of the project, who owns the models, what digital BIM platforms are used and how do the client and main contractor approach these platforms. Through analyzing empirical data and by applying a theoretical framework, the objectives of the master thesis are approached.

1.3 Research questions

The authors have identified two main research questions based on the purpose and objectives of the master thesis. The research questions address the considered issue later in the discussion chapter. The research questions are the following:

- How is BIM being used as a communication and collaboration tool between different actors in the investigated infrastructure construction project?
- From a Project Network point of view, how does BIM function as a tie between all the involved actors in the investigated infrastructure construction project?

1.4 Delimitations

The thesis focuses on communication and collaboration between the involved actors in the investigated infrastructure project, such as the client, main contractor and subcontractor. No comparison between the investigated project and other projects of the same type and size is carried out, due to limited time and resources. The findings of the master thesis are based on collected empirical data of different types, see *Methodology*. Thus, neither the discussion nor conclusion shall be generalized. Other countries may not have utilized BIM in the same way Sweden has because of, among other things, technological reasons, but also cultural and social factors. Therefore, this master thesis may not be applicable or reproduce in other countries. Limitations concerning the study method are presented in the methodology chapter in more detail.

1.5 Thesis Structure

The master thesis report follows a typical report structure with main chapters presenting and discussing different topics. The report contains six chapters (see the figure below), as follows:

Chapter 1: The introduction which includes background, objectives, purpose and research questions, limitations of the study, and thesis structure. Chapter 2: The Theory & literature study which provides a deep understanding of the main research issue. Chapter 3: The Method, in which methodologies and approaches that have been adopted during this research, will be presented. Chapter 4: The empirical part, which provides empirical findings from different sources such as interviews and observations. Chapter 5: The discussion part, which provides an analysis and confrontation of the findings from the theoretical and empirical parts. Chapter 6: The conclusion part, which summarizes the master thesis in the form of results, findings, as well as providing answers to the research questions and future recommendations on future studies in the considered field.

Figure 1. The structure of the master thesis - The main chapters.

2 THEORETICAL FRAMEWORK

The theoretical framework begins by introducing Project as networks, moving on to highlight the nature of complex construction projects and how BIM is currently being used in the construction sector. The theoretical framework is an essential part of this study since it represents the lens through which the authors approach the studied issue.

Network theory is adept at explaining the coordination of work in temporary organizations (i.e. projects) and an increased number of papers adopting some form of network perspective have emerged (Steen et al., 2018). Borgatti and Halgin (2011) for more than a decade ago, affirmed the growing interest in network theory regardless of knowledge areas and that by the lens of a network, researchers and students investigated various relationships and affective factors on certain networks. In project management, networks are studied to observe, among other things, work performance within projects where multiple actors are involved from different organizations' technical areas. Adopting a network perspective has been argued to be the driving force behind successful markets (Biggart, 2002). Networks are recognized as the spot of innovation in some branches and that considering, for instance, projects as networks ease knowledge sharing and obtaining, which otherwise may be challenging to achieve.

2.1 Projects as networks

Construction projects are seldom carried out in isolation of external parties (Engwall, 2003). Construction projects can be perceived as temporary organizations (Bakker et al., 2016), where different actors from different disciplines and organizations are collaborating taking care of various projects' elements aiming to achieve the best overall result. Collaborations between the different actors inside construction projects are considered as key elements for successful project outcomes (Rahman et al., 2014), and that prior successful construction projects motivate new long-term collaborations between the parties and promote a positive sequence of successful construction projects in the industry (Ebers and Maurer, 2016).

Applying a network view on projects (i.e. projects network theory) is explaining project phenomena, processes, activities, etc. as if projects were networks (Steen et al., 2018). Looking at projects as networks is a means to understand the project's dynamic system (Steen et al., 2018). It is by examining the relations between involved actors, resources, and processes in the projects as well as studying the strength of their connections, which makes it possible to explore the significance of a specifically involved actor (Wasserman and Faust, 1994). However, there is no specific methodology to approach construction projects as networks (Steen et al., 2018). Carrying this out requires the adoption of a network perspective ''*terminology*'', which in this case is the well-known network perspective: Social Network Analysis (SNA). According to Otte and Rousseau (2002), SNA is the application of network theory and a broad strategy for investigating social structures and network shapes. The perspective prioritizes the relationships between actors in networks, and by studying the degree of connectivity of an actor in a network, it becomes possible to determine the importance of that actor and the position it occupies in the context (Steen et al., 2018). As mentioned, SNA is not being adopted for project networks, but its terminology of network theory is utilized.

2.1.1 What is a network

A network is a set of nodes connected through a set of ties (Borgatti and Foster, 2003, see figure 2. Networks represent a particular kind of relationship in a specific context. A relation may be physical or non-physical, tangible or intangible, and direct or indirect (Borgatti and Halgin, 2011). Nodes in networks represent the actors, and ties in networks represent the paths that link the actors together, allowing communication. Through ties, information flows from one actor to another (Borgatti and Halgin, 2011). Knowledge, emotions, rumors, reputations, ideas, etc., also flow through networks. This is depending on the context of the network in question.

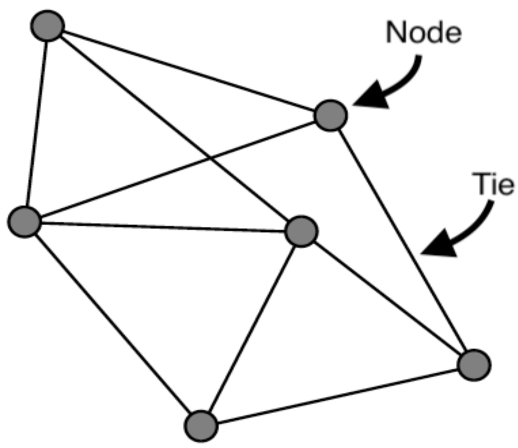

Figure 2. A network - consisting of nodes and ties, remodeled (Borgatti and Halgin, 2011, p.1169).

The actors inside a network are represented by nodes and may imply persons, teams, organizations, roles, and even concepts (Borgatti and Halgin, 2011). Whereas the ties, linking these nodes, imply the type of the medium through which nodes are connected. It is essential to notice though that a network is defined through what kind of ties and nodes it consists of (Borgatti and Halgin, 2011), and being a strong or weak network depends on the strength and weakness of ties linking the nodes.

Investigating a specific network, a consideration of the network context is essential; what is being connected, and through what means. According to Borgatti and Halgin (2011), networks have no natural boundaries per see. The researcher needs to establish a specific set of boundaries defining where networks begin and end. In certain cases, networks are not connected, see figure 3 (Borgatti and Halgin, 2011). Despite being altogether part of the same context, small networks in comprehensive ones are called Components (Otte and Rousseau, 2002).

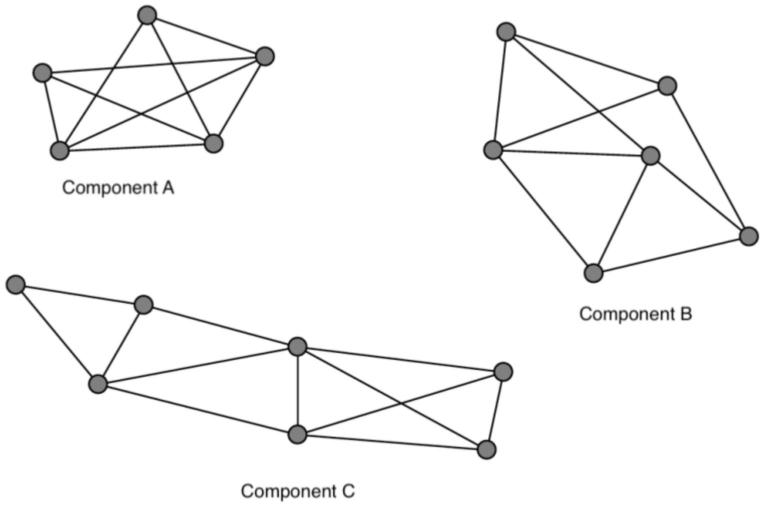

Figure 3. A network consisting of small fragments (components), remodeled, (Borgatti and Halgin, 2011, p.1169).

These components are fragments of a bigger network, that for some reason lost connection, and that nodes were not able to reach other nodes in the next components (Borgatti and Halgin, 2011). No substance can flow between these components, which makes it impossible to expect the arrival of any substance (Borgatti et al., 2013). Components in networks can reconnect with each other, and connectivity is then said to be improved.

Researchers separately study a particular actor in a network in isolation of others, aiming to understand the system and its dynamics (Otte and Rousseau, 2002), assuming that systems are built of inner components' properties summed up. However, networks (such as projects) include correlated components and no longer are defined by the properties of components (Knoke and Kuklinski, 1982). Systems' elements are interconnected (Knoke and Kuklinski, 1982), meaning that they communicate with each other, and collaborate. Thus, the location of elements (nodes) inside networks and the means (ties) through which these elements are connected (i.e. interconnectivity) is crucial.

2.1.2 Strength of ties and centrality of nodes

Borgatti and Halgin (2011) classify ties in two categories: "*the kinds of ties that network theorists tend to focus on can be categorized into two basic types: states and events*" (p.1170).
A ''*state*'' tie is a continuous type of tie between actors in a network. An example of a state tie, in the work context, implies the relationship between a manager and an employee. It does not indicate that it is a permanent tie, but at least it has some level of persistence, endurance, and continuity. An ''*event*'' tie, on the other hand, is more concrete, distinct, and temporary (Borgatti and Halgin, 2011). It emerges through event-based interactions between actors. Such interactions can imply sending emails to each other within organizations asking about work progress. Both of the types enable connectivity between the nodes.

The strength of a tie is estimated by studying at the frequency of the interactions between the actors in networks (Steen et al., 2018), but also through measuring the duration of the connection as well as the significance of it. For instance, Granovetter (2005) examined the role of ties in societies and how social networks, among other things, affect communities. He studied, among other things, how shapes of social networks and societies have an impact on information flows. One conclusion of Granovetter's study was that ties played a significant role in social networks (Granovetter, 1983). It is depending on how well people knew each other, communication- and informational flows were influenced. Information is often vague and needs a proper communication channel in order to communicate correctly, he stated. Depending on the strength of ties, the roles of actors in a certain network might differ. Strong ties may function less critical compared to weak ties, which may be essential in a particular context but not in another. The strength of ties is defined as how well one actor in the social network knows the other, how much time is spent between them, and how emotionally reciprocal the relation is. Weak ties between actors are those that may emerge based on events, such as greeting each other during a workday. Granovetter means that weak ties function as bridges connecting clusters (components) in networks. Granovetter believes that weak ties are better capable of spreading information than strong ties. However, in order to establish a strong tie in a certain network, a node with a strategic position is needed. Thus, centrality of nodes in every network is critical and significant in every study of networks.

Centrality of a node is a measure of how important a node is (Casciaro, 1998). The centrality of a node tells how influential that node is (See figure 4). Otte and Rousseau (2002) state that centrality is about how many ties a specific node has.

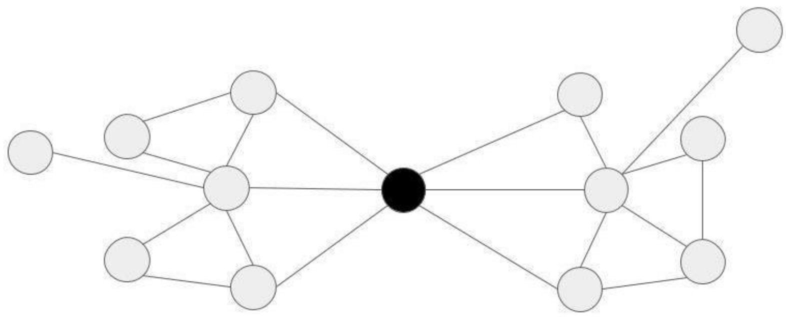

Figure 4. A node functions as a ‘‘bridge’’ coupling components, authors’ own figure.

Bavelas (1948) has investigated how centrality regarding communication was applied. He concluded that there was a very explicit and direct relationship between centrality and influences in processes carried out by groups. Baveles and Barrett (1951), via Leavitt (1951), came to the point that centrality was directly connected to the efficiency of groups when it comes to problem-solving. In addition to that, Cohn and Marriott (1958) focused on how centers in communities help organize societies. Pitts (1965) studied how centrality in urban planning was a significant aspect of the transportation network of countries.

The significance of a node means different things depending on contexts. Although the degree of connectivity expresses the importance of nodes, it does not tell where nodes are localized in networks. Thus, to measure centrality (significance) of nodes, closeness-, betweenness- and prestige centrality are essential factors to be considered. Closeness centrality is about how close a node to other nodes in networks, and how well a node reaches other nodes (Otte and Rousseau, 2002). It is also about how easily a node can reach other nodes (See figure 5).

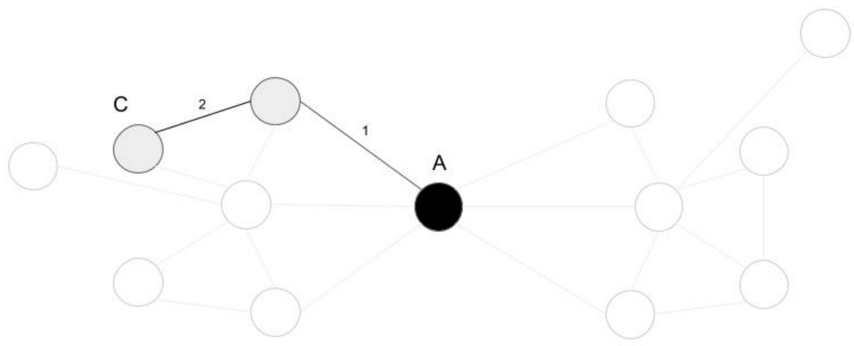

Figure 5. Node A reaches all other nodes through only two steps, authors' own figure.

Borgatti et al. (2013) define closeness centrality as "*Sum of geodesic distances from node to all others*". Closeness centrality of individuals in a network (studying an ego-network) can be combined to aggregate a global closeness centrality measure/degree of the whole network (Otte and Rousseau, 2002). Closeness centrality also means that the shorter the distance from a particular node to the other connected nodes is, the more centrality it has. Thus, it becomes, for instance, easier for this node to spread information and to communicate with other nodes in the network. By that, if the question is about communication, this metric may be beneficial and handy to determine where the weight lies in a specific global network. Closeness centrality for a node can easily influence the other connected ones as it is easier for it to reach them and grant inputs. Other nodes that are far away in the distance and having the same number of ties connected to it may not be as effective and capable as the considered node with a high degree of closeness centrality.

According to Otte and Rousseau (2002, p.443), betweenness centrality of nodes is defined as "*the number of shortest paths that pass through a given node*." Betweenness centrality is a measure that tells if a node functions as a "*bridge*" that couples together nodes in the network. Borgatti et al. (2013) state that through betweenness centrality, it is possible to determine the frequency of exposure of substances in networks. It is considered as a "gatekeeper" that filters what flows in and through networks. A node of this kind reconnects separated components (i.eg small unconnected networks).

Prestige centrality describes how significant a particular node is, based on the importance of the connected nodes. Networks include a variety of essential nodes with different statuses, and the centrality of a node can be affected by which nodes it is connected to. Thus, one may not consider a node as central when this nod is linked to less essential and less critical nodes in the context. Borgatti et al. (2013) refer to this measure as the following" *node is well-connected if connected to many well-connected* *nodes.*" A node is more valuable and has a high prestige centrality when the connected nodes have a large sum of prestige centrality degree. This means, the more important and significant the connected actors with an actor, the more important and central this actor itself becomes.

2.2 Communication and collaboration in complex infrastructure construction projects

In this section an overview of complex infrastructure construction projects' nature is provided. Later, an overview of current communication and collaboration in complex construction projects will be provided. Communication and collaboration, according to the literature, are key elements for the success of any construction project of any type and, hence, need to be considered profoundly. For both of the concepts it is pertinent to provide an overview.

2.2.1 Complex infrastructure construction projects

A typical construction project lifecycle often consists of several phases. These project phases require a range of different work methods and services. In their book *Construction Project Management*, Sears et al. (2015, p.3) briefly and very concrete state that:

‘‘*In progressing from initial planning to project completion, the typical job passes through successive and distinct stages that demand input from such disparate areas as financial organizations, governmental agencies, engineers, architects, lawyers, insurance and surety companies, contractors, material and equipment manufacturers and supplies, and construction craft workers.*’’

This long journey that construction projects pass is due, among other things, to the fact that construction projects are made to stand stable for many years. The result of these different activities, combined resources, and competences in construction projects is a qualitative- valuable outcome that may take different shapes (Sears et al., 2015).

Infrastructure systems play a vital and leading role in societies, and are significant for the economic cycle, growth and the citizen's life (Bradley et al., 2016). Large and complex construction projects often entail long periods of time frames and command inter-organizational synchronization between interdependent project participants (Chakkol et al., 2018). Infrastructure construction projects are large in size, very visible to the public, often initiated by public sectors, and need to stand for at least more than one year (Foti, 2001). Infrastructure construction projects are, among others, tunnels, bridges, pipeline networks, sewage systems, and water treatment facilities (Eriksson et al., 2017, Hyari and Kandil, 2009). These projects utilize a considerable amount of material and equipment. Thus, the expected benefits of infrastructure construction projects need to be equal to or exceed the expenses of the projects. Large infrastructure construction projects often require hundreds of workers, dozens of stakeholders and the complexity of them arise when contractors often need to set up their own construction site (i.e., a temporary factory), and to a great extent, project segments must be constructed in customization, fitting the purpose of the project (Sears et al., 2015). Construction projects are meant to suit the environment in question, provide a unique function they are built for, and, in its design, reflect a specific taste. Infrastructure construction projects are affected by unpredictable factors such as disturbed weather, material supply problems, transportation delays, lack of services and tools, and harsh labor conditions. These factors add more complexity to these projects. However, such large- and complex infrastructure construction projects can suffer from information and communication problems (Winch, 2009, Dainty et al., 2007), which are essential key aspects to a successful collaboration and an overall project outcome (Kerzner, 2017). A majority of construction projects still have major problems communicating in the design phase, which leads to various forms of project issues, such as delays. Eriksson et al. (2017) state that infrastructure construction projects often are affected by delays that cause fewer benefit returns and bigger expenditures. Changes in the projects are unavoidable (Sun and Meng, 2009), and that the more a project becomes complex the more changes emerge that require adaptation in order to carry the work out (Bröchner and Badenfelt, 2011). Since project delays not only cause project overruns but also decrees societal benefits; because the use of infrastructure projects services by the public are suspended, Eriksson et al. (2017) suggest large construction projects need more flexibility in collaboration between the involved actors when carrying out these undertakings, in order to manage unpredicted changes.

The complexity of large construction projects derives from, among other things, the uncertainties in the project at different levels (Geraldi et al., 2011), even when reasonable and sufficient information about the project is available at hand. Vidal and Marle (2008) found that organizational complexity within large construction projects is considered as a dominant complexity category and comprises 70% of all complexity factors. The organizational complexity consists of, among other things, the complexity of contexts that imply interactions of the involved actors in the projects with consideration given to the diversity and complexity of undertakings and activities taking place through and by the involved actors. However, using data management methods and tools benefits the whole project and speeds up the whole program (Sears et al., 2015). In these data management programs and tools, several large components of the project that need to be designed can be summoned in one massive database to produce an integrated 3D design model. To the 3D design model, information regarding time and production can also be added, which gives birth to the Building Information Modeling (BIM) concept. For a construction project, BIM is meant to contain every necessary piece of information regarding the project.

2.2.2 Collaboration in complex infrastructure construction projects

Collaboration is preferred to be the way through which complex and large infrastructure construction are delivered, where several parties are involved, such as suppliers and clients (Chakkol et al., 2018). In any project, regardless of type and magnitude and in almost every industry, collaboration is vital (Oraee et al., 2019), and crucial in several areas of project management including project communication, integration, resource, and stakeholder management. There is a huge connection between project collaboration and work performance and thereby a huge potential of taking care of project uncertainties (Walker et al., 2017). Collaboration is a process through which entities (such as organizations and teams) share information, resources, and responsibilities to commonly plan, implement, and evaluate a set of activities and processes, in order to accomplish common goals . Camarinha-Matos and Afsarmanesh (2008) represent four different key components that collaboration consists of cooperation, networking, communication, and coordination.

- Networking is a process of communication and part of the collaboration, occurring between entities and aiming to achieve common benefits (Camarinha-Matos and Afsarmanesh, 2008). It occurs, for instance, when people and organizations in a certain industry share information between each other about diverse things. No goals are specifically established when networking in this ecosystem, but actors may benefit from the available information.
- Cooperation is characterized as being a process of a lower level (i.e. individual level) than collaboration and occurs where humans are jointly working towards a common goal in which social relations are engaged cooperatively to maximize common benefits (Schalk and Curşeu, 2010). To a huge extent, one may not distinguish cooperation from collaboration. But the latter contains the former (Camarinha-Matos and Afsarmanesh, 2008).
- However, sharing information between organizations in a more collaborative way is a process of coordination. Coordination is an essential component of collaboration and occurs when there is an act of harmoniously and organized operations between and across people and organizations. By corporation, the organization aims to achieve goals and objectives.
- Communication is the medium through which collaboration occurs, see section 2.2.3, and implies the act through which one person can provide information regarding his or her desire, need, and perception of anything to anyone, and that it can be carried out intentionally, verbally, conventionally, and vice versa (Velentzas and Broni, 2014).

Collaboration is a key success element in the construction industry and within projects (Mosey, 2009). Walker et al. (2017) affirm that collaboration in construction projects has the ability to draw the project participants closer into a common ground and work framework. This framework embraces information- and knowledge sharing basis within the project. What characterizes collaboration in complex construction projects is the capability of easing work complexity and promoting mutual respect and interest. Through collaboration, construction projects uncertainties and ambiguity can, to a great extent, be limited. Uncertainties in construction projects emerge when, among other things, not having accurate information before making a decision or not having the required information for decision-making at all. This uncertainty, among other things, is what characterizes the construction projects and what leads to big failures in many of them. Thus, new project delivery collaborative relationships have emerged in the construction industry across the globe (Tadayon et al., 2018). Such collaborative- and relational contracts as Partnering and Early Contract Involvement (ECI) have been very popular. Although to a large extent mutual trust is a key factor in complex projects, contracts help define who is in charge to do what and what are teams entitled to do, which, by its turn, promotes transparency in the projects as well as fewer conflicts and misunderstandings (Chakkol et al., 2018). A contractual basis for collaborative work is essential in order to ensure high work performance and commitments within construction projects (Mosey, 2009) since governance of collaboration in multifaceted large construction undertakings is problematic and commands effective tools of different kinds (Chakkol et al., 2018). By contractual power of inter-organizational collaboration, agreements set precise roles, privileges, and obligations of each participant and hinder opportunism.

Researchers have examined collaboration between different actors inside the construction industry from a strategic point of view and concluded that alliances and partnerships are becoming key elements in successful projects (Rahman et al., 2014). There is a shift from the traditional partnerships between project participants in the industry, where cost is the main focus, to an inter-organizational partnership where learning as an objective (Douma et al., 2000). This transition in the industry is practiced through the adaptation of collaborative project delivery methods based on relational contracts. In Sweden, partnering has been very popular as a collaborative project delivery method. Partnering is a commitment of the long-term type between several organizations (usually between client and main contractor) aiming at accomplishing collaboration enhancements, business goals for every involved organization (Tadayon et al., 2018). Partnering, as a collaborative relationship, aims to carry out construction projects, especially of infrastructure type, commonly and across the organizational boundaries. The basis of partnering is mutual trust, full engagement, and goal-focused, respect and understanding of participants' benefits and expectations. Partnering does not hinder innovative approaches, as well as aiming to deliver qualitative projects and services. The literature has found that Partnering can reduce oppositional culture and reduce conflicts between involved actors in construction projects (Eriksson, 2010). These conflicts are what make the construction project less effective and create a great need for better collaboration (Walker et al., 2017). Thus, partnering is a major contributor to a more effective and profitable construction industry (Ling et al., 2006). Adapting a collaborative working approach in large infrastructure projects ensures more effectiveness and efficiency, not just within projects, but also in the whole industry (Lloyd-Walker and Walker, 2015). Based on the partnering principle, Early Contractor Involvement (ECI) has emerged and is very popular in Sweden (Laryea and Watermeyer, 2016). ECI is a collaborative form where the contractor is more formally involved early in the design phase to make full use of expertise. The first phase of the contractor's involvement in construction projects is when together with the consultants, design, and set a target price for the project as whole (Walker and Lloyd-Walker, 2012). The second phase is when the contractor has been approved and awarded the contract construction of the project. ECI is highly collaborative where project teams and networks establish collaborative cultures within projects. In order to ensure project success, it is preferred that the same contractor carry out both phase 1 and phase 2, see the figure above. In a collaborative approach, leaving the opportunistic and devious sight, the literature provides a very promising future for the construction industry using ECI. One benefit of ECI is involving the many parties in the project, sharing knowledge and eliminating misunderstandings. This results in creating better relationships and mutual trust between clients, contractors, and consultants.

2.2.3 Communication in complex infrastructure construction projects

According to Kelvin-Iloafu (2017, p.93), communication is defined as ‘‘ … *the art of passing information from one person to another so that they can be received in the manner they were meant*’’. In the same manner, Velentzas and Broni (2014) define communication as the act through which one person can provide information regarding his or her desire, need, and perception to anyone, and that it can be carried out intentionally, verbally, conventional, and vice versa. No communication process is said to be complete, until a common understanding is achieved by the receiver (Kelvin-Iloafu, 2017), thus, communication is a two-way process, meaning that the transmitter often receives feedback ensuring the receiver has successfully received information (Dainty et al., 2007). Communication occurs not only between people, but also between teams, groups, organizations, and other types of entities. The construction industry in its nature is team activity-oriented, containing various specialists concurrently working to successfully deliver construction projects. Communication in the construction industry, according to Project Management Institute (2017b, p.361) is, "*the process of ensuring timely and appropriate collection, creation, distribution, storage, retrieval, management, monitoring, and the ultimate disposition of project information*.". Communication is a necessity and considered as a development tool and a key successful element (Kerzner, 2017), and that in order to manage construction tasks and activities in construction projects, especially in complex ones, clear communication channels need to be established. Communication channels imply speech and body language, but also electronic mediums such as digital and online emails and phone calls, or a combination of all of these (Dainty et al., 2007).

The process of communication in construction projects is continuous, passing through each stage of the project (Kerzner, 2017, Dainty et al., 2007). This occurs in all types of construction projects of different magnitudes since the project teams and networks often are temporary and follow the dynamics of projects' development. In order to overcome the challenging- unpredictable work environment's complexity, teams in construction projects consider communication as a fundamental element. According to Illia et al., (2006), communication does not only take place within- and across the different disciplines at the project (i.e. lateral- and diagonal communication), but also between the different involved organizations (Velentzas and Broni, 2014); *inter-organizational*.

2.2.4 Effective communication easing complex construction projects

Dainty et al. (2007) affirms the importance of the interpersonal- and intergroup communication occurring in the construction projects. Interpersonal communication is between people, where individuals play transmitter-and receiver roles considering information. Regardless of what investments have been made in the field of Information- and communication technology (ICT), the success of any construction project has its roots in, among other things, the interactions within project teams. However, for large and complex construction projects, and more generic in the

construction industry, ICT is essential to adapt to ease the complexity emerging due to the geographical distances between project organizations and construction sites (Manley and Chen, 2015).
Transmitting information from one person to another requires a format that is understandable by the other person, the receiver. Thus, usually, communication orally in a face-to-face format encodes information into ‘’words’’ which the receiver will need to interpret in order to make sense of these words and act accordingly. Dainty et al. (2007) affirm the importance of effective communication in the construction industry. Velentzas and Broni (2014, p.) state that effective communication occurs when ‘’... *a desired effect is the result of intentional or unintentional information sharing, which is interpreted between multiple entities and acted on in a desired way*’’. In order to ensure a process of effective communication within construction projects, the sender of information and the receiver need to accomplish the goal of the communication, maintain it, and increase the effect if desired. This simply implies elicit change, generates understanding, and/or creates action in accordance. As a project participant, effective communication does not only mean sending and receiving information and acting based on it but also being a good listener and a very careful observer of the all-around work environment. Effective communication in construction projects implies considering any context in which communication is occurring (i.eg background, age, and sex, as well as how intellectual the receiver is). Communication is the lifeblood of any type of organization, including construction projects of various magnitude (Kelvin-Iloafu, 2017). It can, to a huge extent, ease the complexity of large infrastructure construction projects, enhance work performance and increase employee engagement (Dainty et al., 2007). Change in large and complex construction projects is inevitable and coping with it is a challenge, thereby, effective communication has the ability to bring involved actors from different disciplines and organizations together, easing the processes and breaking down barriers. It enhances collaboration and promotes the integration of work.

2.3 The concept of Building Information Modelling

Authors approach Building Information Modelling (BIM) and examine the conceptualization of it and its definitions in different means. Some of them approach BIM and explain it theoretically, whereas others refer to it more technically. In this section of the paper, BIM and its principles will be presented based on relevant literature. BIM is crucial to understand in this study, and to carry out a literature study for. Thus, this section handles BIM in a deeper manner to provide a wider knowledge area.

2.3.1 Building Information Modeling (BIM)

BIM as an idea and terminology started to take place in the market in the 2000s (Volk et al., 2014). BIM is not a specific software or program; it is a methodology, concept, and working environment platform (Eastman et al., 2011). Moreover, BIM is presented as a group of solutions and technologies that facilitate the work process and enhance the communication between all the involved actors and disciplines within a specific project (Aibinu and Papadonikolaki, 2016). In their research, *The advantages of information management through building information modeling,* Demian and Walters (2014., p. 4) describe BIM as the following:

" *BIM is defined as a comprehensive accumulation of information (including documents) about the design, construction, and operation of a building*."

The involved design engineers create the BIM model or part of it for the entire project by using computer software. The BIM model consists of objects or components that each includes relevant and necessary data, such as settings, dimensions, material and cost (Azhar et al., 2012). These data and information are used for analyzing and simulating purposes during all the phases within the project, from the design phase until the construction phase (Eastman et al., 2011). For instance, if one of the design engineers wants to change something in the project's BIM model, the BIM software will apply the changes directly and precisely to the entire model and update all its related drawings and documents (Eastman et al., 2011). Thus, if the architects want to add a window to the plan, the software will automatically and precisely add this window to the whole BIM model, elevation, sections, and so on. Moreover, the included data are used for simulating, analyzing, and predicting purposes within the whole project (Bradley et al., 2016), as well as for estimating needed time for the planning activities, cost estimation, run simulations, and perform clash detections (Azhar et al., 2012). Consequently, that leads to time and money-saving via a decrease in the necessary time for clash detection meetings and to check the mistakes and errors in the project.

2.3.2 BIM in large- infrastructure construction projects

Many organizations and administrations, both in public and private sectors, primarily within infrastructure projects, set new contractual rules requiring construction companies to use and apply BIM in the whole project, starting from the design phase and ending in the maintenance phase (Sacks et al., 2016). The involved actors within an infrastructure construction project often face the challenge to hand-over a high-quality project without mistakes, despite the limited resources such as time, budget, and workforce (Bradley et al., 2016).
The BIM implementation within infrastructure projects and its relevant processes are often similar to the building projects (Bradley et al., 2016). The design engineers within infrastructure projects can use the BIM model to create 3D visualizations, perform clash detection, and coordinate with other actors in the project (Demian and Walters, 2014). However, the infrastructure projects are characterized by the relatively long construction time and large size (Chakkol et al., 2018). That generates a considerable amount of information and data. One of the essential benefits of the BIM is its capability to manage the project's data and information (Bradley et al., 2016).

The BIM model and its related process can play a vital role in saving, coordinating, connecting, and simulating the project's non-graphical data. Such as material specifications and cost information. Additionally, BIM can provide the tools to evaluate and exchange data between different involved actors in complex projects (Bradley et al., 2016). Consequently, it increases the collaboration- and communication level, facilitates the work processes, and saves time and money. In their research, *BIM for Infrastructure: An Overall Review*, Bradley et al. (2016., p. 13) present the main advantages of using BIM in infrastructure construction projects, for example in highways, and state that:

"*The advantage in highways comes from the coordination and visual integration of non-graphical data into the model and will be used most efficiently during the pre-construction and construction phase, linking field-gathered information into a site (field) BIM modeling approach, generating accurate and data-rich Project Information models operating agents in a form that can be automatically integrated into their network dataset.*"

The BIM implementation within large infrastructure projects offer the involved actors several benefits such as the followings:

1. The BIM model can provide a clear visualization, comprehensive overview for the whole project and its details early in the design phase even before the construction activities start on the site (Eastman et al., 2011). When the involved design engineers can see the entire project and every small detail in the BIM model, that will help them to build their mental picture and imagination (Azhar et al., 2012). Consequently, it leads to reducing the level of misunderstanding, conflicts, and the needed time in coordination meetings. This advantage is one of the communicative benefits of the BIM model.

2. The BIM implementation is offering an efficient and successful way to manage the changes within the project. If any change in the design occurs, the BIM software will automatically update the BIM model, quickly and precisely. The changes also will affect related documents and drawings (Eastman et al., 2011). Therefore, it leads to a reduction in time-wasting when performing changes manually and presenting them in coordination meetings.

3. The design engineers can use the BIM model to operate the clash controls process to discover potential errors early in the design phase before starting with the production phase (Eastman et al., 2011). Instead of finding the overlaps and mistakes later in the execution phase and solving them on-site, which can be costly. Therefore, using BIM in complex construction projects leads to saving time, money, efforts and reduces the risk of costly conflicts in the production phase (Aibinu and Papadonikolaki, 2016).

4. Using BIM also offers the opportunity to forecast and expect the behavior of certain elements of the project during a specific condition, such as earthquakes, by making supplementary analysis and simulating processes (Bennett and Ls, 2012). The BIM model and its related data are used to help the involved actors, especially the contractors, to construct the infrastructure project in an efficient and effective way (Bradley et al., 2016).

Many construction companies that build large infrastructure projects in many countries, such as the United Kingdom, Finland, Norway, United States of America, and Sweden, have begun to implement BIM in their projects. However, a survey concluded that countries in western Europe have a BIM adoption rate (36%) while the USA has (49%). Those numbers show a lack of BIM adoption within the construction infrastructure industry (Bradley et al., 2016). Despite the many benefits of BIM implementation within the infrastructure projects, there are several barriers, obstacles, and challenges to implementing BIM in large infrastructure projects. One of these is the lack of understanding for the importance of BIM complex infrastructure projects (Bradley et al., 2016). Moreover, the decision-makers at the high level of administration in construction companies show a social resistance to change (Yan and Demian, 2008), and may not believe in the benefits of BIM when implementing in their projects. Also, they think that there is no need to develop new working methods while the current ones still generate profits as they are (Yan and Demian, 2008). Additionally, the leaders think that BIM implementation is considered expensive and there is no need to invest much money to upgrade the work process and training the staff, because of the relatively high cost of obtaining the software and training the staff (Yan and Demian, 2008). Therefore, this way of approaching BIM in the construction industry leads to the lack of high-skilled and competent people concerning BIM in the market. Finally, the legal issues when training to implement BIM could also be mentioned and considered as a challenge and a problem to solve in order to fully implement BIM. Such problems can emerge for instance concerning the model's ownership, responsibility, authority, and accountability for modifying and sharing it (Azhar, 2011).

Several new roles and job opportunities emerged and will emerge through BIM implementation within the construction sector (Davies et al., 2017). Within a BIM-based project, BIM-responsible people communicate and collaborate to deliver an integrated BIM model presenting the project in question. They work as one chain with a close collaboration and effective communication trying to achieve the final goals of the project (Davies et al., 2017). The following roles have well known in BIM-based construction projects:

BIM Manager
The BIM manager has an essential role in infrastructure projects; leading and supervising BIM Coordinators and BIM modelers, as well as setting plans and strategies to implement BIM during all phases in the projects.

BIM Coordinator
The BIM coordinator plays a vital role in the infrastructure project; leading BIM technicians and coordinating the work between the involved different disciplines concerning the BIM model for the infrastructure project during the meetings.

BIM Technician
BIM technician or BIM modeler has a vital role in creating and updating the BIM model for construction projects. He or she should be very skilled using BIM software and have excellent communication- and collaboration skills (Davies et al., 2017).

2.3.3 Communication and collaboration using BIM in large infrastructure construction projects

Infrastructure construction projects have many key players and actors involved in the working process, such as client, design engineers, main contractor, and sub-contractors (Bradley et al., 2016). Often, the result of one stakeholder's work depends on other's works and achievements (Eastman et al., 2011). For instance, if the project is about building a bridge, HVAC (Heating, Ventilation, Air conditioning, electricity) engineers may not be able to start their tasks before structural engineers complete their work. From here comes the importance of communication and collaboration in different phases of the infrastructure project (Du et al., 2014). To accomplish the final project's goals, all the involved actors must create an active communication channel to eliminate unnecessary spending time on inefficient communications to focus on the quality of the project (Eastman et al., 2011). In that regard, traditional communication channels still are being used in infrastructure projects such as emails, phone calls, and video conferences (Eastman et al., 2011). However, implementing BIM within complex infrastructure projects offers the actors an effective way to communicate and exchange information (Doughty, 2013). The BIM model plays a vital role in information sharing and management throughout the project (Bradley et al., 2016). The involved actors upload the BIM model into the BIM platform, which allows all of them to explore the BIM model and its related data and information, quickly, efficiently, without installing any specific programs, regardless of their geographical locations (Du et al., 2014). Consequently, the BIM model in the digital BIM platform becomes the core and the center for all the integrated information of the project (Nguyen et al., 2018).

The BIM platform is used during all phases of the project (Nguyen et al., 2018). The utilization of the BIM platform reduces the needed time for communication, and facilitates the information flow, furthermore, reduces the amount of administrative paperwork (Du et al., 2014). Consequently, accomplish better collaboration level and improve project quality (Nguyen et al., 2018). In their research, *The BIM Utopia:*

Centralizing Collaboration and Communication through Technologies, Azouz et al. (2014., p. 6) state that:

" BIM platform is mainly used in the construction sector, such as the organization of collaborators around a centralized digital platform. the platform becomes the central node of communication and information database through which information is stored, structured, shared, and updated."

However, using BIM may require certain working methods that support the collaboration and communication between the involved actors in infrastructure construction projects using BIM (Chachere et al., 2009). These methods aim to increase the level of information flow between the involved actors, solve future problems, and avoid future conflicts to accomplish the final goals of the project (Garcia et al., 2004).

2.3.4 Virtual Design and Construction (VDC) & Integrated Concurrent Engineering (ICE)

Virtual Design and Construction (VDC) is a methodology that aims to achieve a clear understanding of the project's difficulties and evaluates them virtually before starting the activities in the production phase. This is by using the digital BIM models which therefore save efforts, time, and many (Kunz and Fischer, 2012). In their article, *A Guide to Applying the Principles of Virtual Design & Construction (VDC) to the Lean Project Delivery Process*, Khanzode et al. (2006., p. 8) describe VDC as following:

" the use of multi-disciplinary performance models of design-construction projects, including the Product (i.e., facilities), Work Processes and Organization of the design - construction - operation team in order to support business objectives."

VDC is the utilization of the integrated multi-disciplinary digital BIM models for the whole project in the design- and production phases. The involved actors create the multi-disciplinary digital BIM model for the whole project, and these models are *the project model*, *process model*, and the *organizational model* (Kunz and Fischer, 2012). The three models perform parallel and complete each other under VDC methodology and framework.

> The model of the project (3D model) is used to coordinate the multi-disciplines' activities and provide the involved actors a comprehensive understanding of the whole project and its details.
>
> The model of the processes (4D model) is produced by connecting the 3D model with a timeline. The 4D model is used to help the involved actors in the project to know and see how the projects will be constructed in reality.
>
> The organizational model is utilized and used to evaluate the project's risks and approximate the administrative effort necessary to execute the project (Khanzode et al., 2006).

VCD and its related models provide the opportunity to design, construct, and manage the construction projects using the comprehensive virtual overview of the whole project in all the phases. Furthermore, the visualizations within the construction projects enhance the communication and collaboration, facilitating information sharing and management between all involved actors in the project (Tjell and Bosch-Sijtsema, 2015).

The involved stakeholders that implement VDC in their projects need to meet in order to exchange information regarding the project and avoid the re-work (Garcia et al., 2004). They use the ‘‘Big Room’’, which is the physical place where the involved stakeholders make their meetings around BIM. This room includes some technical devices like computers, touch screens, and projectors as well as communication devices and internet connections which allow the involved actors to communicate and collaborate regardless of the geographical location of them (Kunz and Fischer, 2012).

Integrated Concurrent Engineering (ICE), at the other hand, is a methodology that aims to establish collaboration between different teams within the construction projects. NASA has developed ICE as a collaboration method for their projects (Chachere et al., 2009). Moreover, ICE is used for a parallel and logical process in a project between the involved design teams applying analysis tools and using models for visualizations and social processes. All the activities occur in the Big Room by removing the physical and organizational borders to communicate and collaborate successfully and efficiently to finish the design phase in weeks instead of months or years (Chachere et al., 2009).

The implementation of ICE has many benefits, such as reaching a high-quality model without errors and saving the design time. Consequently, it leads to an efficient and effective collaboration process between the involved actors in construction projects (Chachere et al., 2004). However, there are some challenges that ICE has that need to be solved in order to be implemented and fully utilized, likewise other collaboration methods, such as what is the structure of the participant's design teams. For instance, each design team from the involved disciplines should have a BIM modeler, BIM coordinator, and a decision-maker person to make the correct decisions at the right time (Tjell and Bosch-Sijtsema, 2015).

VDC and ICE work together and integrate with each other and both of them use the Big Room as well. VDC needs all the involved actors to meet in one Big Room to exchange, control, evaluate and simulate the information; therefore, VDC performs in an integrated concurrent engineering atmosphere. Consequently, it leads to reduce the risk of costly problems in the construction phase, avoid delays in the timeline, reduce the misunderstanding and future conflicts (Kunz and Fischer, 2012).

3. METHODOLOGY

The methodology through which this master thesis has been carried out will be presented and explained in more depth in this chapter. This is to argue for the quality of the master thesis, but also to clarify the process so that interested readers can reproduce the master thesis using the methodology. The chapter begins by exploring the two main research methods, quantitative and qualitative, moving further to describe research design approaches: Deductive, and Abductive.

3.1 Research design and approaches

Generally, for such studies like this master thesis, two popular research methods are used to carry it out: a quantitative- and qualitative research method. In this section, an overview of the research methods will be provided as well as explanation and argumentation for the chosen research- method and design approach in the master thesis.

3.1.1 Qualitative research method with an abductive approach

The **quantitative** research method is defined as the approach to explain and further explore a specific issue through the collected data (Apuke, 2017). The aim of this study type is to test hypotheses (e.g. ideas), consider causes and effects and create predictions based on analyzed information. It focuses on particular variables, quantifying and analyzing them to come to a result. The result of this research type can be generalized, depending on the context and final reports of this research method are often statistical comparing means and importance of findings.

Table 1. Briefly explaining the difference between a Qualitative and Quantitative research method.

	Qualitative research method	**Quantitative research method**
Purpose	Describe, understand and interpret	Make predictions
Methods	Interviews, observations and field notes	Structural observations, content analysis, social surveys etc.
Result	Particular, specialized and not generalized	Can be generalized to population
Final report	Narrative and contextual described report	Statistical and mathematical comparing means and findings.

Table 1 presents the differences between the two research methods. The **qualitative** research method is often used to explore, understand and interpret social relationships and interactions (Apuke, 2017). The studied issues normally are small, limited and well identified. The data in qualitative research can imply objects and words and sources are such as interviews and observations. The analysis of this data often aims to identify patterns and themes in the studied issue. The reached result communicated in the final report from this type of study is specialized and not of a generalized type.

The qualitative research method is chosen to be followed in this master thesis, due to the flexibility it provides and the opportunity of exploring and interpreting the collected data (Bell et al., 2018). This research method opens for more change throughout the working process and that the study adapts to emerging circumstances and conditions. The qualitative research method suits this master thesis since the authors found not much research focusing on how BIM is utilized as a communication and collaboration tool within large-scale infrastructure projects. Whereas a large buddy of scientific articles was found describing the concept of Building Information Modelling (BIM) and the benefits of its applications in the construction sector in general. Thus, new discoveries and theory can be generated after conducting the study that is in regard to the chosen issue. Nevertheless, authors aimed to begin the research by constructing a theoretical framework through which collected empirical data later is analyzed.

When it comes to research approaches in the chosen research method, among the inductive, deductive, and abductive - an abductive research approach was chosen. The most used research approaches for this kind of studies (e.g. master theses), are inductive, deductive, and abductive. The significant distinctions between these approaches are that the deductive approach begins by building a theoretical framework then it moves to data collection and validation, to test it if the theoretical framework confirms, rejects, or extends the gathered data. The inductive research approach starts from the collected data and moves further to create the theory and may depend on the researchers' experience and knowledge (Snieder and Larner, 2009). while the abductive could be described as a combination between inductive- and deductive research approach.

The authors started carrying out this study by preparing a brief planning report. In the planning report, an explanation and formulation of the investigated issue was provided and further discussed. The planning report contains the motivation behind why this topic is relevant in the master program and essential to be investigated, as well as study what delimitation, objectives, possible research questions and the potential theory there are. A schedule/time planning for activities of the process and key dates were identified and quantified in a Ghant-chart.

The authors started two parallel processes at the same time. The first process is reading, exploring, and searching for relevant theoretical literature and scientific papers as well as building a theoretical framework. The theoretical framework acts as lenses through which the authors approach the investigated issues. But also, to achieve a deep understanding of how BIM is used as a communication and collaboration tool within infrastructure projects.

The second process is seeking empirical data (e.g reaching out to interviewees, formulating and developing an interview guideline, conducting a case study, having supervision meetings, attending inquiry- method lectures, etc). By diving deeply in details, through the theoretical framework and the case study, an interview guideline was prepared and formulated. Supervision was provided by the examiner and supervisor at the university and through discussions and instructions, the next step was decided to be data collection via interviews, case study, observations and follow-questions (questionnaires).

3.2 Data collection methods

This section describes the empirical data collection methods. Authors collected empirical data through interviews, observations, secondary data collection and a case-study.

3.2.1 Interviews

A brief presentation in this section will be about the collection of data through interviews. According to Kvale et al. (2009), there are seven different stages to conducting successful interviews (see the figure below), which the authors of the master thesis followed and implemented for the master thesis.

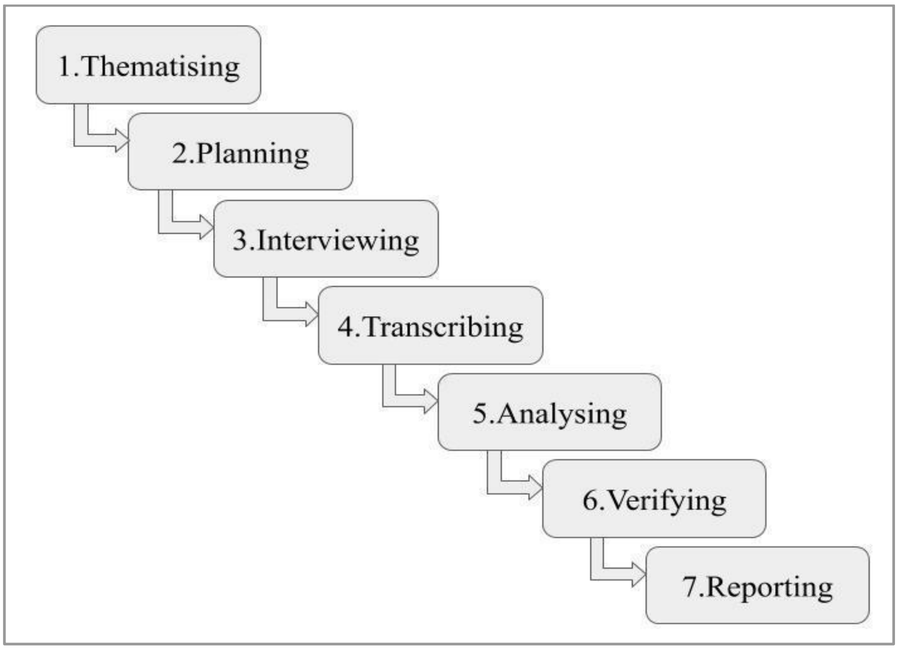

Figure 9. The seven stages to conduct a successful interview, remodeled (Kvale et al., 2009).

In the *Thematizing* stage, using the research questions of the master thesis as point of departure, the purpose of the movement was established, and the interview gained a clear and specific theme. Together with the supervisor and examiner at the university, the objectives of the interviews were identified.

Interviews in the master thesis were conducted using a semi-structured design. The semi-structured interview guaranteed the use of the already prepared questions, plus the ability to be more flexible and ask follow-up questions (Bryman and Bell, 2011). This structure of the interview allows for a control and reasonable management of the whole interview. Through interviews, the authors aimed to collect relevant data and saw that flexibility was needed. Flexibility in this case means the divergent from the script and the diving into interesting fields that emerges throughout the interviewing process. This means, authors are less strict by the prepared script (e.g. interview guideline).

During the *Planning* stage, the authors developed an interview guideline and planned the interview process. Interviews were conducted in Swedish, thus, authors exercised in advance so that questions were logical and rationally spoken, and that interview time was measured. In this stage, the authors started contacting the selected participants gradually. The selected interviewees are working at the sub-project together as a team that handles BIM (e.g BIM-Team). They responded after a long duration/delay. The participants were selected based on, among other things, their role in the investigated sub-project in the city. However, unfortunately, only three out of five participated in the interview.

The interview guideline was created in close collaboration with the examiner and supervisor at the university. Interview participants received a copy of the interview guideline in advance in order to study the questions and prepare relevant answers, for the sake of effectiveness. The ''*Interview Guideline of Harvard''* and ''*Bryman bell (2017)''* were the main sources for the construction of the interview guideline. The interview guideline was categorized in specific knowledge areas:

- The background, where the main research questions were presented so that interviewees observe the course/direction of the thesis.
- General information concerning the workflow with BIM,
- Work organization around BIM (authors intention is to observe the project network),
- Communication and collaboration with BIM,
- Legal responsibility and decision-making in regard to BIM,
- Last area was the interviewees' own opinions concerning, among other things, the future of BIM in the Swedish construction industry.

The interview questions were formulated objectively and as open questions which allows researchers to ask follow-up questions and should not hinder the optional viewpoints and opinions. This is according to Bryman and Bell (2011), that interview questions should not be prime questions, and should be comprehensible for the interviewees.

In the *Interviewing* stage, online-based interviews were conducted because of the Corona epidemic that struck the whole world. Organizations and companies in meantime, were very careful and reacted in a manner that may decrease the virus spreading. Thus, no physical interviews were allowed to occur, nor any field visit at the construction site.

The interviewees were reached out to initially by emailing, and secondly by calling. Interview request contained all necessary information and the purpose behind the interviews. Since the interviewees worked as a team (e.g. BIM-team) on the investigated project, they preferred to be interviewed jointly. They stated that they could help answer the questions jointly providing a picture of a collaborative work. Thus, the interviews were carried out in one single interview that approximately lasted for one hour and ten minutes, where all interviewees sat together in one side, and authors in another. The interviewees were selected carefully based on relevant experience and knowledge in BIM and infrastructure projects. The authors were provided their contact information from the supervisor at the university. The intention was to interview different actors within the investigated infrastructure project. The interviewees are presented as following:

- **Interviewee 1**: BIM-coordinator

  Interviewee 1 is a structural engineer and has been working as a Design manager for many years. Interviewee 1 has been working at several big international consultant companies, among others, in Sweden and started working at the main contractor construction company in 2012. Interviewee 1 has many years of experience in this field. Now, Interviewee 1 is a BIM-coordinator working in design in this infrastructure construction project.

- **Interviewee 2**: BIM-coordinator who mostly works towards the production/construction.

  Interviewee 2 is a BIM-coordinator at the main contractor construction company and works towards production, disposition, planning, and coordination. He works with digital solutions for the project (BIM solutions). Interviewee 2 originally is a structural engineer and started working with the main contractor in 2009. Interviewee 2 has many years of experience in this field and in 2017, Interviewee 2 began working at the major infrastructure construction project in the city.

- **Interviewee 3**: Data- and BIM coordinator working at the client-side (STA).

  Interviewee 3 works as a consultant from a consulting company located in Sweden. Interviewee 3 has a background as a web developer and has no engineering background but considerable experience in this field. Interviewee 3 has been working on the design side with data coordination from the beginning. Moreover, for ten years, Interviewee 3 has worked as a consultant for the public client. In the project, interviewee 3 acts as a client regarding BIM.

In the *Transcribing* stage, the recorded audio of the interviews was converted/transformed to written text and prepared to be analyzed.

During the *Analysis* stage, the data was converted to information and put into categories that are relevant to specific topics. The analysis of the collected information implied extracting what was relevant, sorting the information, interpreting certain parts to enhance clarity and adding miner details to support the intended ideas.

The *Verifying* stages were confirmed beginning from data and information validity and ending up with reliability. The interviews were found confirming the initial purpose of them (valid), as well as the trustworthiness of the empirical findings were found to be highly reliable.

The *Reporting* stage was carried out by the authors communicating the empirical findings from the interviews in form of written text. All findings, from all sources, are to be found in the Result chapter in this report. The academic style of writing was highly considered, and the manner intended to be scientific.

3.2.2 Observations

During the interviews, interviewees intended to share their computer-screen with the authors to introduce the model of the project as it is seen by all project participants, regardless of BIM-knowledge. The authors made notes and, based on what was shown, asked follow-up questions. These observation findings will shortly be presented in the result chapter. Later, in the discussion chapter, shall these observations be discussed.

3.2.3 Secondary data collection

As a secondary data for the master thesis, the authors got the permission to analyze a conducted interview with the client (e.g. STA). The examiner of the master thesis at the university has interviewed a BIM coordinator who currently works at the investigated major infrastructure construction project in the city. The BIM coordinator is heavily involved in the project and has considerable experience working at the client-side, and at the moment, is engaged in all sub-projects. In this paper, the BIM coordinator is referred to as interviewee 4 and the collected data is found in a separate section within the empirical chapter.

3.2.4 The case study

The case study was conducted to gain wider perception of the investigated infrastructure construction project and the Swedish context of infrastructure construction projects. The main purpose is to support the empirical data with relevant and reliable information in order to carry out a reliable discussion. The benefits of selecting a case study as an approach is to explore state of the art information and compromise for study limitations described in the next chapter. The case study is found under a separate chapter in the report.

3.4 Limitations of the study method

The master thesis did not fully follow the preplanned study method through which it was intended to conduct. This is due to a major issue that occurred during the process. During the writing process of the master thesis, an epidemic issue has struck the whole world. COVID-19, a virus that has led to the death of thousands of people all around the globe and caused huge economic problems. The Swedish construction companies were very careful when it came to allowing outsiders inside project offices. Thus, no visit has been carried out to the investigated infrastructure construction project and the authors did not have the chance to meet the involved actors in the project. As a result, no observations were made at the construction site nor at the construction office, neither any field study.

Because of the epidemic issue, the interviews were conducted digitally over the internet. The interviewees had no issue participating in an online interview and believed that it suited them best since it ensured a sufficient social distance between the authors and them. The interviews followed the interview guideline and almost each question was answered. The authors believe that digital interviews were very effective and less critical. More time and relief as a result were gained and more precise and relevant follow-up questions emerged. However, a face-to-face interview should have provided more clarification and enforced understandings of some issues. A face-to-face interview would feel more social and promote a comfort zone that may generate interesting discussions and lift up critical questions, since the interviews took the course of a semi-structured design and had some flexibility. However, since the authors had no experience in conducting interviews, face-to-face interviews may have felt very stressful and generated biased understanding.

3.5 Data analysis

As mentioned before, authors collected empirical data from different resources: interviews, case study, observations and secondary data such documents and interviews conducted by other than the authors. The collected data from interviews were analyzed by color coding. The authors discussed what data was relevant to which topic and provided a specific color for that. In the interview text, the authors step-by-step marked the corresponding areas by the relevant color. This allows the authors to gradually turn the interview text into manageable data that can become critical information. Different keywords were also looked for when analyzing the interview data, such as collaboration, communication, BIM etc. The observations were managed digitally and collected data was converted to written text, before analyzing them. The analysis of the case study and the observation took the course as the interviews. This means that critically and according to relevance of the topics, data was approached. The analysis of the secondary data, to a large extent, took the same approach.

3.6 Reliability and validity

Both validity and reliability are important factors in research reports and academic papers. Using these factors, the value of the research reports and academic papers could be determined. According to Kvale & Brinkmann (2009), validity points out whether what is investigated matches the purpose of a study. While reliability points to in which extent the outputs of the research study can be trusted. The outputs of the research study should be achieved when the research is being reproduced. The following producers were followed in order to achieve a high level of validity and reliability:
The interviewees were selected with relevant experience and knowledge concerning BIM and infrastructure projects from different actors within the investigated construction project. Interview questions were formulated objectively and targeted the subject of the thesis. Moreover, collected data from interviews and observations was immediately analyzed afterwards. The case study and the secondary data collection was relevant and up to the date.

3.7 Ethical Considerations

During the working progress of the master thesis, an ethical consideration was taken into consideration. During the preparation for the interview, the authors sent requests via e-mails asking for permissions for conducting the interviews. The emails contained a brief description of the master thesis, the concerned topic and an introduction of the authors themselves. The permission was taken before voice-recording the interviews and a complete anonymity of interviewees was promised and granted. The interviewees were free to answer or not and could express opinions in any way desired. The answers from the interviews were written honestly and precisely. A copy of the analyzed data was sent to the interviewees afterwards to give them the opportunity to confirm what authors have come up with from the answers of interviews. Anonymity of other stakeholders within the construction project was an essential element and that no sensitive information of the project was attributed.

4 THE CASE STUDY

This chapter of the paper aims to explain the investigated case that lies in the center of the master thesis. Through the case study more understanding of the current condition of the infrastructure construction industry in Sweden was an objective.

4.1 Major transport infrastructure project

The studied project is a major transport infrastructure construction project in Sweden. The project is initiated by STA and aims to enhance the transportation and facilitate traveling for passengers (Trafikverket 2019b). The Swedish Transport Administration (STA) is responsible for all long-term planning of the transport system in the country (Trafikverket 2019). This major infrastructure project is part of STA's plane that aims to integrate the whole transportation system in a holistic- strategic and cross-borders way (Österberg, 2016). However, no construction-, nor maintenance work in regard to roads and railways is carried out by STA (Trafikverket 2019a). The main role of STA is to act as a client and sets the requirements and red threads for the construction companies carrying out projects and ensures that requirements are met (Österberg, 2016). The project aims to increase the railway capacity in one of the largest cities in Sweden by a factor of two. It is about building a double-track railway in a tunnel under the city. The project is approximately 8 kilometers long and consists of several large, significant phases (segments) (Trafikverket 2019b). The regional- and suburban trains will be passing through tunnels, making room for other types of trains.

4.1.1 The sub-project in focus

The major infrastructure construction project is divided into several construction sub-projects which different construction contractors have been awarded contracts for. The sub-project duration is estimated to sex years, and thus, to be concluded during 2023/2024 (Brunbäck, 2014). The sub-project that is 1.8 kilometers long (TFIP, 2019) is the main focus of this paper. The master thesis investigated how the main contractor for this specific sub-project, with other actors involved, carried out the communication and collaboration using BIM as a tool.

The main contractor for the sub-project in question is one of the largest construction entrepreneurs in the Swedish construction industry. The contractor has been involved from the initiation stage helping to establish a target price for the project on a collaborative basis with STA. Later on, the contractor was awarded the contract for construction of the sub-project in focus. Through an Early Contractor Involvement (ECI) contract form, the contractor works in close collaboration and partnership with STA carrying out the planning and optimization of the sub-project. STA states that ECI is chosen as a contract form so that the contractor's knowledge and expertise can be taken advantage of in one of the most complex projects in the county, and that the contract form, according to STA, can generate new collaboration- and production work methods (Brunbäck, 2014). The project is divided in two stages where the first stage is about the detail design, target-cost development, schedule of production as well as risk management. Whereas the second phase stands for the actual construction work at the sites. The main contractor of the sub-project describes the initial phase as a very intensive period where work method choices and production/constructuction solutions are being the focus. Complex technical challenges are almost everywhere in the project, and concerns such as work environment, organization, sustainability and economy. However, the main contractor states that by a co-located project organization, a more efficient collaboration is advocated. With a target price developed in collaboration with the public client (STA), both parties can safely take the step further into the project's construction- and production phase. Even in the construction/production phase, the project is still a big challenge to solve, the main contractor states. While the underground work is being taken care of, all logistics above the ground must be handled flatly. In addition to that, all traffic in the city above the area of the underground tunnel must run normally and as usual. This applies to all vehicle traffic, trams, but also such infrastructure elements that need not to be disturbed as power lines, water pipes and district heating, and internet cables. The contractor refers to that as being a big puzzle to solve, where several actors and stakeholders are actively involved throughout the whole project.

To ease the complexity of the sub-project, the main contractor is adapting an advanced BIM-related work-method called Virtual Design and Construction (VDC). The main contractor refers to VDC as a new way of thinking and approaching innovations in a project, in terms of information management, collaborative work activities, and working methods. The point of departure for VDC is Building Information Models (BIMs). The BIM models are essential sources of information that encourages all planned collaboration between all involved actors in the project.

4.1.2 The Swedish context of infrastructure construction projects

According to the Swedish Transport Administrations (STA), BIM enables visualization of projects during the planning phase and that there is a specific database that accumulates all the relevant information of the construction project (Trafikverket, 2017). STA declares that BIM makes the work in the Swedish AEC industry more effective, ensures higher quality and reduces cost in a long-term aspect. All 3D models that conclude all relevant information about the construction project are accessible through a certain BIM it-platform. By that, STA states that communication and coordination within construction projects are enhanced. Also, that less traditional documents exist when BIM is in-use which makes it easier and more effective to follow work structure/arrangement in projects. STA states that a better communication between actors in a construction/building process is a result of easily accessible information, which in its turn occurs using BIM.

In infrastructure projects in the Swedish AEC industry, every single discipline in the design phase; for instance, the structural engineer and HVAC engineer, creates its part of the BIM model (Bosch-Sijtsema et al., 2020). Then all the BIM models are gathered in one coordination model which exists in one of the BIM platforms. The existing model on the BIM platform offers the opportunity for all involved disciplines to follow the updates which could occur to the BIM model and manage the information flow. Via using the model in the center of the collaboration process in the integrated working method, many benefits could be earned, such as a clear picture and a deep understanding of the whole project, which could be considered as the successful key for increasing the level of in-between communication and collaboration. When all the stakeholders have the same and correct understanding of the whole project and its details, it facilitates the decision-making process and solves the future problem. The way in which STA uses BIM model in infrastructure projects differ depending on the level of project`s complexity, but in general, the following can be stated:

STA uses BIM models for facilitating the design and construction process and for increasing the collaboration and coordination level; creating visualizations, estimating the calculations, checking up quality control, and analyzing the model and discovering the potential errors via using clash detection, as well as creating important information such as drawings and tables (Bosch-Sijtsema et al., 2020). All different actors and participants collaborate and work together in an integrated working method. Many benefits could be earned by using this method, such as reducing the risks, problems, and uncertainties within the infrastructure project and increasing the effective collaboration and the in-between trusting level. To enhance the information flow and the in-between collaboration and communication level, the involved disciplines are required to upload the BIM model on one of BIM platforms and also upload the updates and related information continuously. Bosch-Sijtsema et al., (2020) point out the importance of determining legal and organizational issues for the BIM platform. Furthermore, they add that it will also be essential to decide on the requirements for BIM model exchanging formats such as IFC format, which use ISO 19650 to standardize and unifies the BIM exchanging model. Regarding the relevant process for the integrated working method, a unique process is required on different levels. For example, collaboration level and contractual level. In order to fully gain the potential of BIM for collaboration, BIM model needs to be at the center. Moreover, it is significant to focus on the essential activities in the center, which means that all the involved actors, disciplines, and parties should participate in collaborative meetings around BIM (Bosch-Sijtsema et al., 2020). This is to discuss the comprehensive overview for the entire project, and its related details in the design phase to avoid the mistakes and errors early before the construction phase started. These meetings offer the chance to discover potential errors and decrease the risks and conflicts in the projects and facilitate the decision-making process. To achieve that, many companies in Sweden start to use ICE (Integrated Concurrent Engineering) as an integrated working method and VDC (Virtual Design and Construction).

Regarding the contractual collaboration level, STA decided to follow a new business strategy by using new procurement and contract forms that arrange and organize the collaboration between different parties to achieve a high level of cooperation, especially in the infrastructure projects with a high level of complexity and uncertainty (Bosch-Sijtsema et al., 2020). Collaboration in the contractual level is vital and necessary between different involved disciplines within the project to maximize BIM benefits. Therefore, most of the recommendations require the information exchange and collaboration between the involved disciplines in both design and construction phases. When it comes to the contractual collaboration regarding BIM, STA requires that the drawings and documents can be generated from BIM, which means the BIM model is more important than drawings and documents.

5 EMPIRICAL PART

As it is already stated, the empirical part is mainly constructed of the conducted interviews as primary data, the available information on the studied infrastructure project as well as authors' observations. In this section, gathered data from interviews will be introduced in detail for the sake of comparing it with the structured theoretical framework, spotting differences and observing applicability.

5.1 Primary data

The result of the collected data from interviews and observations is presented in this chapter.

5.1.1 The BIM Team

The BIM-Team is an official team within the project that covers almost every other discipline within the project such as design, time planning, construction/production, quality, environment, and work environment. This team consists of project design managers from different organizations (client, contractor, and design engineers) from different disciplines and BIM-coordinators from different phases of the project (design- and production/construction phase). This team works in a very close collaboration, and regardless of communication channels and collaboration methods, they (The BIM-team) communicate and "talk" with almost everyone involved in the project. The BIM team is responsible for what is then to be delivered to the public client; The coordinated BIM model.

In regard to the current work with BIM, the main contractor of the project works on a digital platform for BIM which the various technical areas of different organizations involved in the project can access to upload their BIM models.

In the beginning of the investigated project (i.e., design phase), which information the BIM model that will be delivered to the public client shall include is decided, the interviewees affirmed. It implies, for instance, which structure, status of the model, which parameters, and other information that will be needed later in the project. The BIM model should include which construction segments the work will be about, what status this segment will be in a specific time during the work, and so on.

In the project, every subcontractor and discipline need to upload their BIM models concerning their work area to the main contractor' digital BIM platform so that the BIM team can have them, as well as keep updating them. Each company and discipline have a BIM- responsible that needs to deliver the model and make sure it follows all the requirements of the main contractor and STA (i.e., the public client). Project design managers in these companies have the final responsibility for the delivery of the BIM models of their discipline into the contractor's digital BIM platform (to the BIM team). The BIM team can see who in which discipline and company had shared what models and other materials. The BIM-team uses this digital BIM platform (i.e., the contractors') for coordination and collaboration. In addition to that, this digital platform allows other project planners to view others' BIM models of the project from other disciplines after they are shared.

Furthermore, to be able to view all the models (coordinated) in a single spot (program), the BIM team locally uses another program/software for this purpose. In this program, the models are brought/put together, and a new ''coordinated model'' is created, with each model from different disciplines of different organizations/companies inside. This model is a comprehensive one and should later be handed to the client; STA.

The public client (STA) uses another digital platform of its own, where the main contractor delivers/uploads the final BIM coordinated model. The main contractor has the opportunity to access the client's digital BIM platform to upload the BIM model and access the same materials as STA does.
The main contractor can invite the public client, however, to access the main contractor's digital BIM platform used in the project as well. The public client can see what the main contractor is working on regarding BIM, and what has been done and by who.

Inside the disciplines of the different organizations that work under the main contractor (such as architect firms and engineering consultancy firms, etc.), different modeling programs/software are used in order to create the BIM models. However, there is a way to see all these models combined through the main contractor's BIM digital platform, and to observe future overlapping and critical elements.

The digital BIM platform, according to all of the interviewees, is the main place of information sharing and collaborative work. Software in the background is needed in order to view the models in detail and extract files from it, such as drawings and specifications of a particular segment.

5.1.2 Implications of collaborating using BIM

The BIM-team stated that BIM enables viewing the project visually so that communication and collaboration are enhanced and even for someone not so much involved in the project. According to them, BIM contains a 4D model of the project which is a combination of the 3D comprehensive model with a time frame. This BIM model enables seeing the progress of the work in regard to time, so that anyone who has access can observe the progress of the work. It is a very communicative way, the BIM team stated, in a project that lasts for five years or more, with thousands of activities taking place within.

When asked a follow-up question during the interview: using these online tools, which are part of the BIM concept, do you think it is an effective way to communicate and collaborate, the answer was very positive. The BIM-team asserted that using BIM makes things very obvious, and one can get a very clear picture of how things are in the project. Everyone is at the same point of departure, which is very important since many stakeholders are involved and have their own kind of specialists looking at different areas in the project.

The BIM team affirmed that when having meetings and discussing different topics, showing the BIM model on the screen like this (They refer to the model on the screen during the interview. It is the ‘‘coordinated model’’ that is available online via a link for the sake of visualization. They entered it through the internet browser, without a need for software in the background) to make everyone know what is being discussed, which part of the project in question, and what concerns it.

‘’It is super good, and people do not have to think " what are we talking about ", but can point directly and say " here we are ", and that saves time I would say ‘’ - Interviewee 1

At the project office, there is a very large BIM-table. The BIM-table is a large touch screen that visualizes the BIM model of the project. It is connected to the software where the model is stored, and the BIM team uses the BIM table for the purpose of creating a common understanding for the project. However, each project member, regardless of knowledge level in BIM, can handle the BIM-table. This is to discuss the project-related topics while rotating and viewing the model. In the future, projects shall be able to have meetings around this table more often, the BIM team stated.

Out of the 3D models, 2D drawings were exported for detailed information to be used for different purposes, since the models are very comprehensive.

Within the main contractor’s organization, there is a forum for communicating, cooperating and discussing BIM related questions and the models. Currently, within the project and between the main contractor and subcontractors, all the BIM models from different disciplines such as plumbing, heating, water, and sanitation are brought up/viewed for discussion. These forum meetings are mainly for BIM related questions as mentioned.

The main contractor and the client also have a common forum where they discuss BIM relevant issues and collaborate for the project. In these meetings, BIM coordinators, among others, are the primary participants. However, other main contractors responsible for other subprojects are also participating to discuss BIM questions, since BIM is adopted for the whole large infrastructure project in the city.

Regarding the smoothness of the information flow and efficient collaboration using the Cloud-based model, the following follow-up question was asked: If you want to access detailed information for a specific element in the project, is there detailed information in the model that is easily accessible via the cloud? The answer from interviewee 2 was negative and stated that the cloud-based model is available for the sake of visualization. He continued that this is possible, referring to the follow-up questions, to do in the other model, since this model is in the Cloud, and no software is running it in the background. He stated that there are weekly meetings discussing the construction/production part with BIM. In these meetings a full version of the model is used, and detailed information can easily be exported. Everyone involved in the project and production/construction can come along and keep up with what the next steps will come then and create their own perspective. Although there may be 20-25 persons in these weekly meetings discussing WDP (Work Disposition Plan), it becomes obvious, and each participant needs only to consider the things to work on and mark them. Then a copy is sent out determining what everyone needs to do. Hence, no one can later say that they have not been aware of what is to be done. This makes the workflow more effective and less disturbed.

However, in the future, interviewee 2 stated that more implementation of BIM is needed in the production/construction phase and that it needs to be good enough to replace the current 2D drawings. There is also a need to automate the process of searching and finding specific information, and that too needs to be easily managed.

In addition to that, when asked if new roles will emerge in the future regarding BIM, interviewees 1 and 2 explicitly answered positively. They shared the same opinion stating that the construction industry has definitely a bit left to go regarding BIM. They pointed out that, no matter where in the organization, BIM will be used more and more in the future.

''It will be at all stages and affect the whole work, I think.'' - Interviewee 1

Having BIM and working on a digital platform is very powerful when it comes to planning where different materials should be at the site. The ability to access the models in construction/production without a need for installing programs in backgrounds is easily reachable, and a crucial factor. One can see all the updates in the project since an orthophoto is taken once a month. In addition to that, one can occasionally add extra information in the model about different things in the project such as new containers, roads and places for craines. What is already existing at the construction site can be added to the models as updates, such as construction roads and containers.

In production/construction, communication and collaboration are preferably in a digital form, since there are several divisions in construction/production, such as Concrete workgroup, Ground/Soil workgroup etc., the communication flow is more digital. It helps to find solutions (digitally) for field issues as well as ordering diverse materials in advance. This is to ease the workflow and make explicit digital-based solutions.

For the planning of the construction site, interviewee 2 stated that they use BIM for the WDP. This is to comprehend where different materials, for instance, should be located at the site. Having BIM in this part of the work is very powerful, interviewee 2 affirmed.

Interviewee 2 declared that in the construction/production, no changes are made to the models and that the models are mainly being viewed, which works great. For the inspection at the field, no 3D models are used. The models are the basis behind the used 2D-pdf files/drawings. He continued, it is the job of the design managers/project planners to design, and the production/construction is the performer that receives all the finished documents.

5.1.3 Communication and collaboration with and without BIM as a tool.

Briefly, sharing project's BIM models and other materials between the involved actors does not occur using emails, but in a digital and easily accessible BIM platform. Typical communication and collaboration (e.g. emails, phone calls, meetings) in the project is carried out through usual communication channels and collaboration methods.

Meetings at the project office are preferred to be physical in order to minimize misunderstandings at projects. At the moment, all meetings and reconciliations are managed online due to the current pandemic issue. Usually, typical communication channels are used within the project, and for specific questions for particular individuals, emails and phone calls are used as well as other available collaboration tools available at the companies. The communication channels are not always optimal, and the challenge is to find an adequate level of communication. The biggest challenge concerning communication and collaboration in the project is that the project organization is enormous, and there are many people involved. Collaborating with five persons in the project, for instance, who will later spread the information to their organization and disciplines, may end up causing unnecessary work for certain people. The information reaches employees that are not related to the issue, but still take part of the spread information and try to understand it and act accordingly.

‘‘*One is being crowded with emails and information about things that you do not work with but still are put in it, then it will be time that really goes into unnecessary work.’’* - Interviewee 1

The biggest challenge with BIM is not that it is not obvious and not easy enough to understand the models and the different elements, but rather the ability to share these models with each other. The challenge rests in the coordination between different workgroups. There are many people in different divisions, such as ‘‘*Concrete-west and Concrete-east, Ground/Soil, Wiring, Water and Electricity*’’. Coordinating all of that is a challenge, interviewee 2 stated. Therefore, there are for instance weekly meetings discussing WDP, where the full BIM models of the project are used. These meetings are about 45 minutes, in which the project is examined deeply from the west side to the bridge (interviewee refers to the bridge that is also included in the contract as a sub-project which the main contractor is responsible for too). Apart from that, during the interview, the interviewee intended to share their computer screen with the authors for the sake of showing around the model of the project. The interviewees did use an online based BIM platform that only contained the model of the project for the sake of visualization. This digital BIM platform is not the comprehensive one (the coordinated model) in which all the models of each discipline are combined, but rather a simpler version. This digital platform was available through the internet browser with no additional software running in the background. The authors could see/observe in the shown model where the project geographically began and ended and how the environment looked like around the marked area (i.e., construction site). Different project phases/sections were colored-coded so that every section/segment easily was visualized. Every section was labeled with text. The authors saw how the documents regarding the project were easily reachable on the platform. Documents were summoned in a clear search-patch and no additional steps were needed to access these documents. Although the online model cannot be modified, there is a possibility to make measurements. The authors observed the available tools and functionalities in the online digital platform and the potential to measure, capture pictures, rotate and orientate within the model. However, no detailed information could be shown in this version. But the environment, roads, resident buildings were shown as well as railways and other borders.

When asked if all actors involved in the project have good knowledge about BIM, highlighting if this may be considered as a challenge, the answer was ‘’no’’. According to interviewees 1 and 3, there is a variety concerning knowledge on BIM by all involved actors in the project and that they may ask the BIM-team when something is unclear. However, the digital platforms for BIM are very BIM-friendly and that without other software in the background and no considerable knowledge for BIM, one can orientate in the 3D models and understand the content of them. In addition to that, BIM manuals have been created by, among others, the BIM-team as well as video tutorials about how certain moments should be handled. In other words, everyone involved in the project has a different level of knowledge concerning BIM and that BIM manuals can help increase knowledge about BIM.

5.1.4 The project network - The BIM team

All participants have emphasized the need of working together in cooperation within the project as a team. Although the participants did not mention any "*project network*", they pointed out the importance of working from the same point of departure and the need to stick together with the same plan and work methods. In fact, the BIM team refused to be interviewed separately and asserted to be interviewed as a ‘‘Team’’.

The BIM team comprises different actors, technical areas and disciplines from different organizations. They work as a team in an interorganizational way, where BIM draws them together to a common ground. Interviewee 1 stated that despite BIM being in focus in the project, it does also touch a lot of key elements in the project and that almost everyone is affected by it somehow. Through BIM, for instance, interviewee 1 works with planner-leaders, engineering consultants, clients, and even with the construction department. Interviewee 3 works with other planner-leaders and consultants and believes that BIM draws people together and enforces the networks when it is in-use. Interview 2 works mostly with foremen from different construction divisions and the ‘‘*block-managers*’’ in the construction leadership. However, in the BIM team they all work together and share what they have learnt through these interactions with the mentioned areas and disciplines.

All the meetings and forums concerning BIM are currently online based, partly due to the epidemic situation. However, all of them clearly expressed that they are willing to occasionally physically meet around BIM to investigate the models together, and that not all meetings need to be online using software. This is to minimize the misunderstandings and enhance collaboration and the project network they are inside.

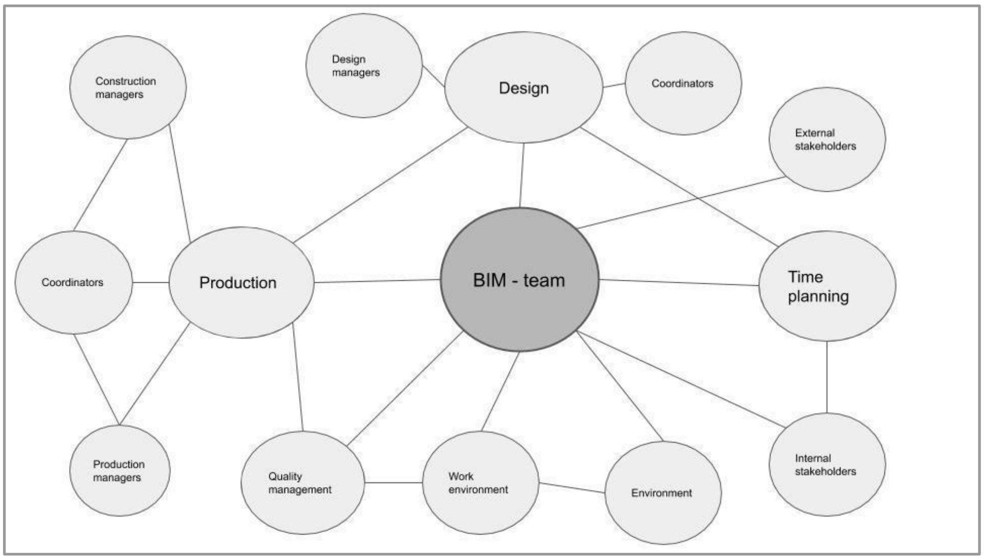

Figure 10. A project network consisting of different actors, disciplines and divisions within the project - It shows how the BIM-Team occupies a central position, authors' own figure.

In a follow-up question that was sent to the interviewees asking about who they mostly work with as actors and other project participants in the project, they stated ''almost everyone''. The figure above illustrates ''partly'' the disciplines, divisions, roles etc., that the BIM-team work with.

In a complex- and large construction project as this, there are external and internal stakeholders that need to be shown careful and extra considerations. The external stakeholders imply those who work in the whole infrastructure project in the city (i.e. other main contractors for other sub-projects). Also, those that work on other projects above the ground and may imply railways companies, shopping malls and collective traffic companies. The internal stakeholders are those who work inside the same sub-project which the main contractor is responsible for. BIM is helping coordinate diverse work moments between different actors inside the project, they stated. BIM also helps answer stakeholders' questions and meet their requirements and bring closer opinions and perspective.

5.2 Secondary data

In this section, secondary collected data is presented based on an interview conducted by the examiner of the master thesis at the university.

5.2.1 The external interview

From the client side (STA), a considerable amount of work concerning BIM in the major infrastructure project is ensuring that the requirements are met by the main contractor. This implies all deliverables, such as the delivery of 3D models, and other critical information. It is about ensuring that information delivered by the main contractor is consistent, reliable, and appropriate. However, discussions regarding that manner occur at the project office/department where the BIM coordinator is engaged as well as the BIM team. Such discussions are BIM related and can be about how and when to deliver some designed elements during the construction phase. It is an advantage to be present at the project office, the BIM coordinator stated, since other BIM coordinators from diverse disciplines are attending. The project's main contractor can access the digital BIM platform of the public client and see what is delivered since they have the responsibility for the delivery.

Currently, many contractors in the construction industry are using advanced- cloud-based digital platforms for BIM and continually looking at how to deliver projects' BIM models and materials in a friendly and integrated approach. However, STA does not consider adapting these cloud-based BIM digital platforms at the moment since the platform is owned by the contractor. The public client cannot select one single platform over another, since it is a governmental agency and needs to be neutral. However, according to the interview, the BIM coordinator believes that not everything should be in the cloud; hence, STA is careful regarding what is to be shared (i.e., uploaded to the cloud).

For the construction work, objects/segments, at the moment, are being divided into smaller packages when being designed and must be delivered to STA digital BIM platform. However, STA seeks to minimize the occasional deliverables from the contractors, especially these smaller packages of more prominent construction elements/segments. Nevertheless, STA needs to be able to inspect and review the deliverables to ensure that requirements are met probably. In this infrastructure project, and other, there are strict rules to investigate/control deliverables and it is extra crucial.

However, the BIM coordinator considers BIM only as a working tool; that BIM moves barriers, help to find implementations (e.g., digital solutions). It can pack information more smartly and communicate the information with responsible people at construction sites (e.g., construction leaders) in a more intelligent way facilitating making common understandings. This can mean visualizing critical aspects in the project using a 3D model, such as to show where trees are located in the construction area so that responsible people at the contractor's side take care of them. Another implementation of BIM in the investigated project at the moment is the coordination between disciplines including, among other things, clash controls. The project organization has increased lately, and new employees have entered the project both in STA and in the project as a whole (e.g in other involved organizations). Many employees are new in their roles and have not yet been used to the document system STA has, and need support. Thus, discussions with contractors in the project concerning BIM working methods and how they work in their systems, contra how STA does, take place occasionally.

6. ANALYSIS AND DISCUSSION

In this chapter, empirical findings are analyzed and discussed using the theoretical framework. The discussion chapter aims to provide answers to the main research questions of the master thesis.

6.1 What can generally be stated?

The literature showed that a contractual basis for collaborative work is essential in order to ensure high work performance and commitments within construction projects (Mosey, 2009), but also since governance of collaboration in multifaceted large construction undertakings is problematic and commands effective tools of different kinds (Chakkol et al., 2018). What can be generally stated about communication and collaboration in the investigated infrastructure construction project using BIM between the involved actors, is that it is possible because of a contractual cover/basis. The ECI (Early contractor involvement) contract form allows the main contractor to be involved early in the project (in the design phase) determining what the BIM models of the project should be including Lloyd-Walker and Walker, 2015). Through this collaborative contract, a team within the investigated construction project that only works with BIM-related issues has been created; *the BIM-team*. The BIM-Team is an official team within the project that is in touch with almost every area within the project such as design, time planning, construction/production, quality, environment, and work environment. This team consists of project design managers, BIM- and data coordinators from different organizations (client, contractor, and design engineering firms), disciplines and phases (design- and production/construction phase). In the BIM-team, the public client is present by having a data-coordinator acting as a client collaborating with the rest of the team. BIM-team works together in a very close collaboration, and regardless of communication channels and collaboration methods, they communicate and "talk" with almost everyone involved in the investigated project. The BIM team is responsible for what is then to be delivered as BIM models to the public client BIM platform; The coordinated BIM model. This does indeed confirm what is found in the literature regarding BIM as a tool in BIM- based construction projects (Bradley et al., 2016), but not what comes to BIM teams. In the literature, BIM is not so much discussed in the form of teams. It is approached rather as separate individual roles performing specific tasks concerning BIM models (Sacks et al., 2016). Thus, approaching BIM as a tool in complex construction projects while focusing on teams is considered as a new insight that is not so well-known in the research community.

However, what is empirically found regarding the functionality of BIM as a tool for communication and collaboration inside the investigated project is confirmed by the literature of BIM.

6.2 How is BIM used as a communication and collaboration tool between different actors in the project?

The literature regarding BIM describes how the different disciplines create the BIM models using the relevant processes to eventually enhance the in-between communication and collaboration. According to Eastman et al. (2011), the BIM model is created by disciplines in the projects that contain relevant information such as settings, dimensions, material, and cost. This information is used for analyzing- and simulating purposes in the project (Eastman et al., 2011). Later, the created BIM models are uploaded to a digital BIM platform (Azouz et al., 2014), to create an active communication channel between the disciplines. This decreases unnecessary time spent on inefficient communications and instead focuses on the quality of the project (Nguyen et al., 2018). Empirically found is that the different disciplines' teams build their BIM models for the project. Every single discipline in the design phase creates their part of the BIM model and inserts the related data and information into the BIM elements. Then all the models are gathered in one big coordinated model, which is located on a digital BIM platform. The BIM model being in the BIM platform, offers the opportunity for all involved actors to follow the updates that occur and manage the information flow. This confirms what the literature stated about creating an active communication channel enhancing the collaboration between the disciplines.

Empirically found is that the main contractor of the investigated project, through a very close collaboration with the public client (STA), better understands what is expected to be delivered as a BIM model for the project, in order to be controlled and inspected according to requirements, specifications and standards. The public client can easily access the digital BIM platform of the main contractor and examine what is being carried out. This close collaboration promotes a certain level of flexibility, transparency and a more obvious picture of working methods. That confirms what is found in the literature regarding the flexibility that these types of complex projects (Winch, 2009, Dainty et al., 2007) needs to embrace between the involved main actors in order to adapt to future changes and unpredicted circumstances (Eriksson et al., 2017) and deliver a successful project. This close collaboration, to a large extent, diminishes misunderstandings and prevents future errors that may cost a considerable amount of time and money, but also a project- overall delay. In the literature, Walker et al. (2017) affirms that there is indeed a huge connection between close collaboration and better work performance; taking care of projects' uncertainties and delivering valuable projects, which is confirmed by the empirical findings.

The literature showed that the BIM model and its communicative features help achieve projects' goals. According to Eastman et al. (2011), some of the BIM model`s main communicative functions are to provide the involved actors in the project a clear visualization, a deep understanding and comprehensive overview of the entire project; early in the design phase. It leads to reduced misunderstanding, conflicts, and fewer coordination- and collaboration meetings (Azhar et al., 2012). The literature also showed that the BIM model can be used to make clash controls and other analyses. These analyses help discover errors early in the design phase (Aibinu and

Papadonikolaki, 2016). For instance, the BIM model can be used in taking off the calculations. As a result, it leads to saving time, money, efforts, and also decreases the risk of costly conflicts in the production phase (Eastman et al., 2011). This is confirmed since the empirical data showed that using BIM provided a deeper understanding and a clearer picture of the whole project, which is considered as a key element for an increased level of communication and collaboration, but also for better employee engagement and solving future problems.

According to Azhar et al. (2012), the actors could use the BIM model to create a 4D model by connecting the 3D model with a timeline for the activities. The BIM model also helps to prepare the WDP plan, which allows contractors to organize the construction site. Another feature is that it is offering an effective way to manage the changes within the BIM model. As mentioned in theory, if any change in the design occurs, the BIM software will update the BIM model and its relevant documents automatically, quickly, and precisely (Eastman et al., 2011). Furthermore, empirical data affirmed what is mentioned above concerning the 4D models and indicated that the 4D model is usually created by connecting the 3D model to the timeline of the activities. This feature of BIM in the project enables the actors to see the progress of the work concerning time, and therefore 4D is considered a very communicative approach. Besides, the findings from the empirical data describes that the BIM is used in the coordination process in both design- and construction phases; for visualization, for calculations, for quality control, and clash detection, as well as creating vital information to create related drawings. As a result, it is observed that it reduces the risks, problems, and uncertainties within the infrastructure project and increases the communication, collaboration and the in-between trusting level. Furthermore, the empirical findings showed that the actors use the BIM model for the Work Disposition Plan (WDP), in other words, to organize the construction site, such as add new containers, roads, and places for cranes; which confirmed what is found in the literature as presented above.

According to the literature, all the stakeholders within the infrastructure project usually participate in physical meetings like ICE to increase the level of collaboration and communication, to solve future problems, and to accomplish the final project goals (Chachere et al., 2009). The involved actors in the project use VDC to enhance the understanding of the entire project, as it provides a comprehensive virtual overview for the whole project within all phases (Khanzode et al., 2006). The findings from the empirical part confirms and points out that many companies in Sweden use ICE as an integrated working method, as well as VDC. Using ICE contributes to making the BIM work in the construction industry more efficient by gathering all involved actors in one place to solve the problems early in the design phase. While VDC is a working methodology to manage the multi-disciplines model to achieve the success criteria and project goals. The literature showed that VDC is usually used with a specific method like Big room / I Room, and that ICE supports the work on the BIM model (Garcia et al., 2004). To implement VDC correctly in construction projects, literature showed that project managers should allocate a permanent working area or office for the VDC devices and activities. VDC and ICE are usually working together and completing each other. VDC needs all members of the design team to meet early in the design phase to create the BIM model for the whole project (Kunz and Fischer, 2012). The literature also showed that traditional communication channels are still working even in BIM-based projects (Eastman et al., 2011). These communication channels include emails, phone calls, video conferences. However, the physical meetings are still a more effective and efficient communication channel within the BIM-based projects.

Regarding the practical findings of the mentioned relevant processes of BIM within the investigated infrastructure project, the empirical findings point out and confirm that traditional communication channels like emails and phone calls are still used in the investigated infrastructure project. Moreover, it is essential and vital to all the design teams from different disciplines to participate in physical meetings and discuss the whole project and its details. These meetings offer the chance to discover errors in the design phase and avoid moving them to the execution phase. As a result, physical meetings decrease the risks and conflicts in the projects and facilitate the decision-making process.

What is found in the literature is that communication and collaboration between different actors in large and complex construction projects are a success factor (Mosey, 2009) and a necessary element and that there is a major connection between project collaboration and communication and work performance (Oraee et al., 2019). Thereby, there is an important potential of taking care of uncertainties in complex projects through effective communication and collaboration (Walker et al., 2017) and that collaboration is preferred to be the way through which complex and large infrastructure construction projects are delivered (Chakkol et al., 2018). This is confirmed by the empirical data, since it is found that the communication channels are not always optimal, and the challenge in the investigated project is to find an adequate level of communication in order to enhance the collaboration between the different project participants. The biggest challenge found concerning communication and collaboration in the investigated project is that the project organization is enormous. The challenge rests in the coordination between different workgroups. There are many people involved from different divisions at different organizations and coordinating all of that in as large as the investigated project is a challenge. The literature affirmed that large infrastructure construction projects embrace hundreds of workers and dozens of stakeholders (Sears et al., 2015), which requires effective communication and interorganizational closer collaboration and coordination. The literature affirms that the complexity of large construction projects derives from, among other things, the ambiguities and uncertainties in the project at different levels (Geraldi et al., 2011), even when reasonable and sufficient information about the project is available at hands. This is also seen empirically and affirmed by the interviewees as being a major challenge in the investigated project. Vidal and Marle (2008) found that organizational complexity within large construction projects is considered as a dominant complexity category and comprises 70% of all complexity factors. The literature and the case study showed that organizational complexity consists of, among other things, complexity of contexts which imply interactions between involved actors in the projects with consideration given to the diversity and complexity of undertakings and activities taking place through and by the involved actors. The empirical data confirmed and indicated that in order to diminish organizational complexity as described above, meeting in one spot such as at the project office is an advantage. It is because at the project office, other project participants and actors are attending, such as BIM coordinators, where cooperation and discussion can take place.

6.3 From a Project Network point of view, how does BIM function as a tie between the involved actors in the project?

The literature showed that there is no specific methodology to approach construction projects as networks (Steen et al., 2018). Applying a network view on projects is explaining projects' dynamic systems as if projects were networks (Steen et al., 2018), and for that a terminology is needed. The terminology of a network perspective named Social Network Analysis (SNA) is utilized due to being adept to study and explain a project's dynamic system (Steen et al., 2018). It is by examining the relations between involved actors, resources, and processes in the projects as well as studying the strength of their connections, projects are said to be considered as networks (e.g. projects network theory). Otte and Rousseau (2002) affirmed that SNA is the application of network theory and a strategy for investigating, among other things, network shapes. The literature affirmed that construction projects are seldom carried out in isolation of external parties (Engwall, 2003) and that different actors from different disciplines and organizations are involved in collaborating taking care of various projects' elements aiming to achieve the best overall result (Bakker et al., 2016). When applying the network lens then the involved actors in the investigated project can be presented as nodes and BIM as the tie. In the investigated project, there is a vast range of different construction firms and organizations collaborating taking care of the project. The main contractor is working hand-in-hand with the public client, subcontractors and consultancies. The BIM-team comprises all competences needed to accomplish the goals of the project and to deliver a successful product. There are almost no isolations in terms of nodes within the project and concerning BIM. According to the interviewees, the BIM team works and ''talks'' with almost everyone in the project helping and guiding as much as needed. The very obvious ''tie'' between the BIM-team and all other departments and involvers in the project is *BIM*. Thus, BIM is considered as a very strong tie that links all the involved actors in the project and enhances the communication and collaboration within the project to a large extent.

6.3.1 The strength of BIM as a tie and the centrality of BIM-team as a node

According to the theory, through ties in networks information can flow from one actor to another, but also knowledge and ideas (Borgatti and Halgin, 2011). BIM as a tie within the project is the medium through which the involved actors in the project are being linked together, since the BIM-team affirmed that communication and collaboration concerning BIM models mainly occur through the digital BIM platforms. No BIM models are being shared or worked on by the traditional communication channels or collaboration methods. Even though individual communication still occurs using emails and phone calls, work concerning BIM is mainly carried out through the digital platforms. That makes BIM a very strong and robust tie within the projects' various teams and organizations.

Theoretically Borgatti and Halgin (2011) classify ties of networks in two categories: States- and events ties, where the former is continuous and persistent occurring between different hierarchical levels in projects, and the latter emerges through temporary communications and collaborations such as sending emails to a coworker. In the investigated project, the authors believe that BIM combines and merges the two types of ties and helps represent a new one, *a collaborative tie*. Thus, we conclude that BIM can be called a collaborative tie, since it embraces the long- and consistent relationship between people (i.e. state tie (Borgatti and Halgin, 2011)) and the short- and very precise tie (i.e. event tie (Borgatti and Halgin, 2011)) in the same time and context. There is no communication concerning the BIM models that occurs through traditional communication channels, nor any work carried out by traditional way: A superior ordering an inferior. The current collaboration through BIM is inter-organizational. Thus, BIM does indeed develop relational atmosphere in the project and enable connectivity between all involved actors.

In the investigated project, the position that BIM occupies is very central and touches almost every part in the project. Regardless of the complexity of the investigated project, BIM draws everyone to a common ground and helps reach even the furthest in the project both physically and organizationally, such as disciplines and departments far away located in the organizational hierarchy. The theory affirms that networks can contain smaller unconnected components (i.e. small unconnected networks within the comprehensive network) (Borgatti and Halgin, 2011), and that no substance can flow between these components until they are reconnected (Borgatti et al., 2013). The meaning of the substance that can flow, in this context, may imply effective communication between all the involved actors and their different technical disciplines. In the investigated project, the interviewees affirmed that one major challenge is to coordinate work between all involved technical areas from different disciplines and organizations and that BIM powerfully resolves this issue through being a tool of communication and collaboration as discussed earlier in the former section. Even when it comes to all the BIM forums that the main contractor in the project arrange with other actors, such as clients and subcontractors, BIM is literally the tie that connects all these actors in one area. BIM enables viewing the project visually so that communication and collaboration between all actors are enhanced, and even for an outsider who is not involved in the project.

However, drawing together all these unconnected teams and technical areas within the project and letting them corporate, is possible through the BIM-team as being central in the project. According to the theory, centrality of a node (In this contexts; the BIM-team) in a specific network (the project) is about how many ties this node has (Otte and Rousseau, 2002), how important the node is in the network (Bavelas, 1948), and how influential that node is (Casciaro, 1998). Centrality derives its definition from where the node is positioned in a network, which nodes it is connected with and whether it functions as a bridge between network components or not. All of that implies to the BIM-team in the project, hence, the authors believe that the BIM-team is a node with a high degree of centrality in the project network. Most of all, betweenness centrality is what can characterize the BIM-team in the project, since the BIM-team reaches almost every discipline and is close and easily reachable by all involved in the project. This is affirmed by the interviewees stating that regardless of BIM knowledge, everyone who can access the project office can get a clear picture of the project progress and grow an understanding of what has been done and by who. This implies even for workers on the ground level that have almost no knowledge in BIM through a huge BIM-table that is friendly handled by anyone helping increase project communication level and work performance.

Nevertheless, in order to have a high degree of centrality, the theory states that prestige centrality is needed, and it describes how significant a particular node is, based on the importance of the connected nodes (Borgatti et al., 2013). Empirically, the BIM-team in the investigated project is found having a high degree of prestige centrality, based on what they stated. The BIM-team works help answering the needs of the various stakeholders in the project, which count as very important nodes in the project networks, the authors believe. In order for the work to maintain a stable workflow, stakeholders and others who are involved in the project need to show a huge consideration. That implies even the environment where the construction site is located and, thus, all traffic that is ongoing on the surface are very important nodes and having a high prestige centrality.

Coping with changes and ensuring meeting the requirements of actors (the involved stakeholders, client, subcontractors, etc.) is what the BIM-team has been doing, they stated. And that per see, makes the BIM-team a very central axel which the investigated project is rotating around, we conclude. On the other hand, the robustness/strength of BIM as a tie in the project can be noticed when observing how much it helps create common understandings, solving technical problems, facing unpredicted changes, caving costs, clearly dividing work and showing responsibilities and enhancing the overall efficiency of the work in the project.

However, it is important to keep in mind that BIM is not fully utilized in the investigated project, the BIM-team stated. And that future features and BIM elements are yet to be implemented, which may enhance work performance even more and hinder misunderstandings alongside the whole project. This is due to the capability of BIM as being a very communicative and collaborative tool in large and complex infrastructure construction projects.

7 CONCLUSION

The authors conclude that BIM is adept when being utilized as a communication and collaboration tool with large- and complex construction projects. BIM enables effective communication in the projects and hinder misunderstandings that often cause future issues, such as project delivery delays. The ability of coordinating the work of the many involved actors in the investigated project is found to be one central element, and according to the literature, the traditional way of carrying this out is less effective. It is concluded that BIM is being more and more utilized in large-infrastructure projects**.** These projects are characterized by a relatively high number of involved stakeholders and actors, such as the main contractor, sub-contractor, client, etc. These actors work closely to create and manage effective communication channels and collaboration methods. They aim to eliminate misunderstandings and misinterpretations of shared information and data and facilitate the complexity of activities and increase the in-between collaboration level. This is to accomplish the final goal of the project, which is delivering a valuable- qualitative project.

BIM implementation plays an essential role in enhancing the collaboration and communication level within infrastructure projects. It is by creating a high-detailed BIM model of the project in question, with necessary objects' information, and uploading it to the cloud-based BIM platform. The cloud-based BIM platform is found to be the main sport for communication and collaboration between the involved actors in the investigated project. This makes BIM a very strong tie coupling many workgroups together in the project and reaching to the furthest.

Relational collaborative contracts could also be used to enhance the level of in-between collaboration and communication levels. Adopting ECI as a contractual basis when carrying out complex infrastructure projects allows the main contractor to be involved in the project as early as in the design phase. This is to interact with all the other actors and make use of the huge experience of the main contractor when preparing and determining the scope of the project. Using BIM and adopting relational contracts in complex construction projects is seen as a successful collaborative working approach, generating a team that only works with BIM-related issues throughout the whole project; A BIM team that consists of persons from different organizations and disciplines working very close regardless of organizational borders. This team is considered as an essential success element coupling vast amounts of work groups in the project together by BIM.

Additionally, to maximize the benefits of using BIM models and its relevant communicative features, the involved actors in the projects should apply additional processes that are used to enhance the collaboration and communication level within the BIM-based projects. The actors should use ICE and VDC together to maximize the benefits of them. ICE is a collaboration methodology, and VDC is a working methodology that aims to manage the multi-disciplines BIM model.

7.1 Recommendations for future research and a reflection on the master thesis

The authors of the master thesis also conclude that BIM has not been classified as tie before and that approaching it by applying the Network perspective can provide new insights on how to study BIM. Thus, a future study in that regard is recommended. Furthermore, in the literature concerning BIM, almost no teams were presented regarding BIM such as in this report. The literature has been exploring less how the work with BIM can be addressed by teams, and mostly focused on separate and individual roles. Thus, a recommendation for a future study can be a combination of studying BIM as a tie, coupling several and different work groups/disciplines from different organizations in projects, with more focus on BIM teams. A study on the BIM teams in the future determining what exactly the teams are doing and entitled to do, what does it contribute to projects and what benefits of having it, may be very interesting in the construction industry.

Communication and collaboration in the investigated infrastructure project were seen to have enhanced as a result of adopting an ECI contract form. Thus, a future recommendation is also to study the effect of relational contracts on complex infrastructure construction projects in Sweden, as presented in this paper. This is because these types of contractual basis are becoming very popular and being known for facilitating the complexities of such complex projects. In other words, a combination of relational contacts in construction projects and BIM is seen to be a successful strategy in the construction industry, the authors believe, and thus needs further considerations.

Reflecting on the process of carrying out this master thesis, the authors believe that more observations and a field study were needed in order to explore the infrastructure industry through the investigated project even further and accumulate deeper empirical data. This is also to observe things that the project participants may have not been seeing, such as digital solutions concerning BIM and better use of the current digital BIM platform. There is a need for seeing the BIM models of the investigated project and the construction site, in order to examine to what extent BIM-related theory matches reality. More precisely is to observe the communication- and collaboration processes between the involved actors in a daily routine and basis. Interviews with the majority of these teams are interesting, since the participants are working in different organizations and disciplines, yet they work as a team in the project concerning BIM

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