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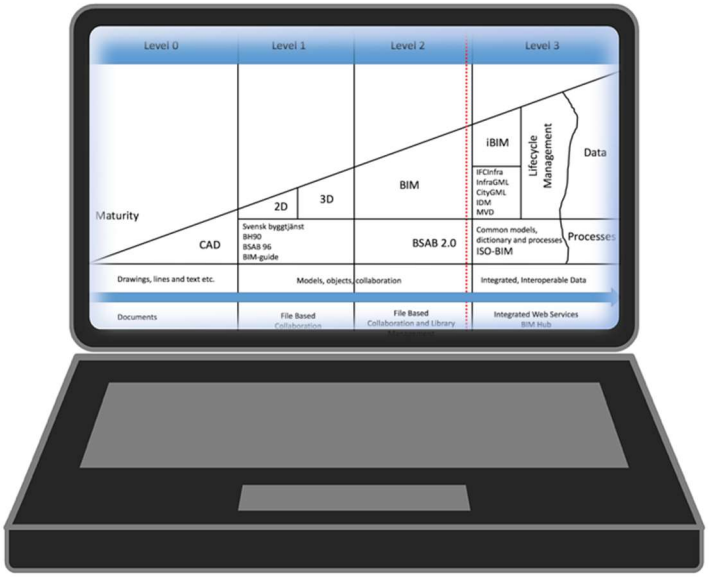

ECI & BIM: A Multiple Case Study in the Swedish Context

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

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Department of Architecture and Civil Engineering
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ABSTRACT

The AEC industry has traditionally been connected to a lack of collaboration and adversarial relationships leading to problems regarding both cost and quality in projects. Early contractor involvement (ECI) is a newly implemented concept in the Swedish AEC industry, aimed to manage these problems. Further, Building information modelling (BIM) is becoming more adopted throughout the industry as a step to increase efficiency through the use of digital practises. With the goal of increasing efficiency and innovation in the industry, the Swedish Transport Administration (STA) decided to use both ECI and BIM in a major infrastructure project, carried out in the city of Gothenburg.

This master's thesis investigated how ECI is used together with BIM in a major Swedish infrastructure project. Furthermore, it clarifies the managerial aspects in need of consideration for achieving successful ECI projects where BIM is used. The research questions were answered through a qualitative and abductive methodology consisting of a literature review and a multiple case study. The literature review explores the concept of ECI and other collaboration forms together with BIM, and the relation between them. The empirical findings revealed inexperience of ECI causing unclear roles, expectations and perceptions. Further, that lack of maintenance aspects and cultural issues were hindering BIM adoption.

It was concluded that BIM and ECI can both hinder and facilitate one another. There is a need of managing the collaboration to bridge the different perception of ECI and unclear roles in the case study projects, since these are hindering both the BIM and ECI process. This master's thesis contributes towards covering the knowledge gap currently existing regarding BIM usage and adoption in ECI projects.

Key words: Early contractor involvement, Building information modelling, collaboration, collaboration management.

ECI& BIM: En flerfallstudie i den svenska kontexten

Examensarbete inom masterprogrammet Design and Construction Project Management

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SAMMANFATTNING

Byggindustrin har traditionellt varit förknippad med bristande samarbete och fientliga relationer som leder till problem gällande både kostnad och kvalitet i projekt. Early contractor involvement (ECI) är en ny samverkans metod i den svenska byggindustrin som syftar till att hantera dessa problem. Vidare har branschen sett en ökad implementation av Building Information Modelling (BIM) som ett steg för att öka effektiviteten genom användandet av digitala verktyg. Med målet att öka effektiviteten och innovationer inom industrin beslutade Trafikverket att använda både ECI och BIM i ett omfattande infrastrukturprojekt som genomförs i Göteborg.

I detta examensarbete undersöktes hur ECI används tillsammans med BIM i ett omfattande svenskt infrastrukturprojekt. Dessutom förtydligas de ledningsaspekterna som bör beaktas för att uppnå framgångsrika ECI-projekt där BIM används. Forskningsfrågorna besvarades genom en kvalitativ och abduktiv metod som bestod av en litteraturöversikt och en flerfallstudie. Litteraturgenomgången undersöker konceptet ECI och andra samarbetsformer tillsammans med BIM och förhållandet mellan dem. Resultaten påvisade en bristande erfarenhet gällande ECI som frambringar oklara roller, delade förväntningar och olika uppfattningar. Vidare hindrade bristen på underhållsperspektivet samt kulturella problem BIM-adoptionen.

Slutsats, BIM och ECI kan både hindra och främja varandra. Det finns ett behov av att leda samarbetet för att ena de olika uppfattningarna om ECI samt förtydliga de otydliga rollerna i fallstudieprojekten, eftersom dessa hindrar både BIM- och ECI-processen. Detta examensarbete bidrar till att täcka den kunskapsklyfta som för närvarande finns gällande BIM-användning och -adoption i ECI-projekt.

Nyckelord: Early contractor involvement, Building information modelling, samverkan, samverkansledning.

Contents

Preface

This master's thesis has been conducted at the Department of Architecture and Civil Engineering at Chalmers University of Technology, Sweden, from February to June 2017. The multiple case study has been carried out with the help from several companies and persons that should be acknowledged.

Firstly, we would like to thank Petra Bosch, Professor and Head of Division at the Division of Construction Management at Chalmers for guiding us through this master's thesis. Your ideas and inputs have been of great value for the outcome of this master's thesis and thereby we would like to thank you for both your time and interest. We would also like to thank Rasmus Rempling, researcher at the Division of Structural Engineering and Structural Engineer at NCC for helping us setting up this master's thesis.

Further, we would extend our thanks to the case companies and the interviewees taking part in the interview study and providing us with interesting thoughts and findings to our master thesis. Your willingness to allocate time and knowledge have enabled us to conduct this master's thesis.

This master's thesis has been carried out as the final part of our education at Chalmers University of Technology. Throughout the study, a lot has been learned about ECI in the Swedish context together with BIM and how extended collaboration has the possibility to change the AEC industry. Lastly, thank you to all involved in this master's thesis.

Göteborg, June 2017

Max Hallgren
Filip Häggblad

Notations

AEC – Architecture, Engineering, and Construction

BIM – Building Information Modelling

CE – Concurrent Engineering

ECI – Early Contractor Involvement

ICE – Integrated Concurrent Engineering

IPD – Integrated Project Delivery

STA – Swedish Transport Administration

VDC – Virtual Design and Construction

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1 Introduction

This chapter aims to give a background to the master's thesis subject and the problem discussion regarding collaboration forms in the AEC industry. Further, the master's thesis purpose and research questions, delimitations and a method outline is presented.

1.1 Background

In 2009 the Swedish Building Commission published a report called "Sega Gubbar" in which it is concluded that the Swedish AEC industry struggles to increase its efficiency (Statskontoret, 2009). It is stated that a major reason to this is an indistinct request in the industry and low incentives to change traditional workways and processes . Further, Eriksson (2008) expresses that these traditional workways and procurement methods tend to not encourage collaboration which have led to problems regarding both cost and quality in projects.

A decade prior the Swedish report, The Latham Report (1994) and the Egan Report (1998) had already used words as low efficiency, a fragmented process, and adversarial relations to describe the AEC industry in the UK (Egan, 1998, Latham, 1994). Both these reports presented Partnering to be a way of re-thinking construction through teamwork, collaboration and integrated supply chains. However, this had also been recognised in 1964, where Banwell pointed out the benefits of collaboration between design and construction through an early appointed contractor (Mosey, 2009). Even though the concept has been around for half a century, the attempt to implement partnering as a new industry standard has not been as successful as expected (Gottlieb and Haugbølle, 2013). Mosey (2009) argues that, even though partnering has proven to work through many successful projects, the slow implementation is due to the confusion of its definition. Claiming that by stating the features of the partnering relationship, appointment of an early contractor, together with agreed team-based processes and programs, can help to achieve successful partnering.

IPD (Integrated Project Delivery) is a more recent method, developed 2003 in USA, used to gain the same benefits, which Partnering sought to deliver. Both IPD and partnering share the same essentials, although IPD is based on the integration of design and construction processes by involving the contractor and other important stakeholders in an early stage of the project. (Lahdenperä, 2012). Another approach similar to IPD is Early Contractor Involvement (ECI) which focuses on increasing the buildability by involving the contractor already in the design phase (Rahmani et al., 2013).

ECI is a two-stage collaboration process (Love et al., 2014). In the first stage, the contractor is paid by the hour and acts like a consultant (Rahmani et al., 2013). The aim of this stage is to develop a target price, production plan, and to allocate risk. When this is carried out and if the client is satisfied with the contractor the same contractor will be awarded the contract in the second stage. In this stage, the process carries on like a design build contract, and the contractor is paid by a self-cost principle with pain/gain incentives based on the target cost set in the first stage.

So far ECI has not been a common form of collaboration in the Swedish AEC industry, only a few projects have been carried out in this form. Although recently, ECI has gotten more attention in Sweden as the Swedish Transportation Administration (STA) have chosen an ECI-contract for two projects included in a major infrastructure project (Trafikverket, 2014b). This is in line with the STA collaboration strategy, where extended collaboration is required in larger projects. Further requirements, from the STA, are that BIM must be used in all new projects, including the two presented in the multiple case study.

BIM has brought major possibilities for the design stage to become more effective through the use of software. Although, BIM should not only be considered as a software, it is also a process, which promotes collaboration and integration between involved parties (Azhar, 2011). The barriers with this work process considers the investment resources which are needed in the learning process when it comes to time and human resource that organisations need to use to adapt the BIM-model (Yan and Damian, 2008). In this master's thesis, BIM is considered as a process extending beyond the model, covering the same aspects as Virtual Design and Construction (VDC). Therefore, BIM will be the terminology used throughout this master's thesis when considering digital practises and the processes connected to it.

Potential synergies achieved by combining BIM and ECI can be related to what has been said about synergies between BIM and IPD, for both collaboration types, it has not been verified in many quantitative studies (Kelly and Ilozor, 2012). The effects of implementing BIM in an IPD project is perceived to have positive effects. Likewise, IPD is believed to have positive effects on the use of BIM.

Even though the combination of IPD and BIM has been discussed and studied in research, the combination of using BIM for ECI has been less prominent. Therefore, the knowledge gap between BIM and ECI motivates carrying out this master's thesis. Further, the ECI concept has not been adopted much on the Swedish market which leads to that this thesis contributes towards exploring and improving what aspects are relevant in achieving a successful ECI collaboration where BIM is used.

1.2 Purpose and research questions

The purpose of this master's thesis is to investigate potential synergies between BIM and ECI in a large Swedish infrastructure project.

- What are hindrances and possibilities using ECI in Sweden?
- What are hindrances and possibilities for using BIM in ECI?
- How can the future use of BIM in ECI projects be improved?

1.3 Method outline

This master's thesis is based on a multiple case study considering two part-projects included in a major infrastructure project. The two cases, together with the thesis scope, were identified and developed together with supervisors at Chalmers University of Technology.

In order to develop knowledge about the investigated cases and ECI together with BIM, it was suitable to collect scientific data through a literature study. Semi structured interviews were the primary source for empirical data collection. A series of interviews were conducted with key personnel in the cases. This included interviews with project members from different organisations with different competences. The interviewee selection was based on trying to find the equivalent part in each case to get comparable results. The research questions were answered through combining and comparing the findings in the empirical data with the theoretical data developed in the literature study. In Chapter 3, Methodology, a more detailed description of the chosen method will be presented.

1.4 Delimitations

The master's thesis will only consider BIM and ECI on a project level and not on an organisational perspective from the involved parties. The scope is also limited to only focus on two Swedish projects with the same client, Case A and Case B. Further, BIM and ECI will only be evaluated in the first stage of the ECI process.

2 Theoretical Framework

This chapter aims to give the reader an explanation of concepts and theory that is used in this master's thesis. Theory regarding ECI, together with success factors and obstacles will be presented and explained. Further, theory regarding BIM will be presented and finally, move towards how BIM and collaboration forms work together. There are several different collaboration forms mentioned in this chapter, Partnering, IPD, ICE, and ECI. To stay true to what was written by the authors, there is no common name for the different collaboration forms. However, regardless the name, all reviewed collaboration forms are based on similar principles and aim. Therefore, the arguments and views regarding the different collaboration forms can to a certain extent be generalised for all collaboration forms.

2.1 Early Contractor Involvement

Civil engineering projects such as road and rail work, which are often quite straightforward to build, often use traditional or design and build contracts. The problem with these contract is the lack of collaboration between different parties and that it tends to encourage a culture where the contractor bid low and claim later (Eadie and Graham, 2014). This in turn leads to an adversarial relationship with lack of trust. Already in 1962 construction projects with separated design and construction phase have been identified as a problem in the UK and that contractor expertise was needed in the early stages (Eadie and Graham, 2014). However, there are collaboration forms with the focus of resolving this issue. Walker and Lloyd-Walker (2012) claim that it exists several different procurement approaches between the client and the contractor where the parties work in close collaboration, with one of these being Early Contractor Involvement (ECI).

The ECI project delivery approach refers to the use of the contractor's knowledge and expertise in the early design phase of the project to increase the buildability (Rahman and Alhassan, 2012). The UK Highways Agency was first to introduced the ECI approach in 2001. ECI has the aim of creating better relationships, increase understanding among parties and decrease the potential of adversarial relationships through frequent interaction and communication (Eadie and Graham, 2014, Wondimu et al., 2016). This is also supported by Rahman and Alhassan (2012) who explain that ECI aims to develop long-term relationship between the involved parties to achieve best value. Moreover, another study by Song et al. (2009) which focused on scheduling and ECI, express that contractor involvement in the design phase leads to reduced project duration due to better planning thanks to the contractor's knowledge inputs. To achieve project success with the ECI approach, openness and honest communication between all the parties is required. This also includes sharing sensitive information about the different companies involved (Rahman and Alhassan, 2012).

2.1.1 The two stages of early contractor involvement

In order to understand the project life cycle of an ECI project Walker and Lloyd-Walker (2012) map the ECI process on the project life cycle explanation by the Project Management Institute and their body of knowledge. The result shows that ECI fits into 3 out of 4 phases in the project life cycle, see Figure 1.

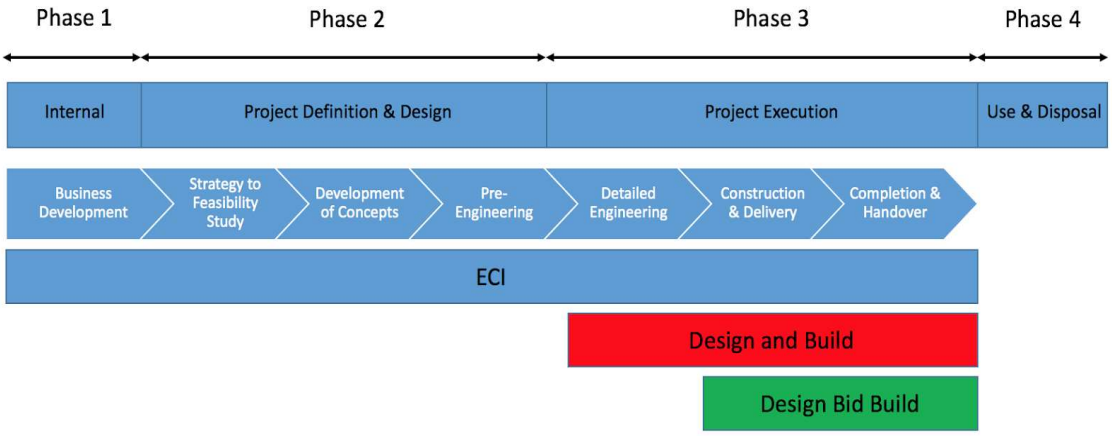

Figure 1 The project cycle from PMI mapped on the ECI process remodelled from Walker and Lloyd Walker (2012).

Further, the different phases of the ECI project life cycle is explained (Walker and Lloyd-Walker, 2012).

Phase 1: This phase represents the development of the project idea and the recognition that the project can deliver value, thus be worth realising. If the project idea meets the requirements it can pass through to phase 2.

Phase 2: The second phase includes the definition and design, which in turn are structured into three stages.

Phase 3: Includes the project execution and construction phase. This phase consists of three stages which includes, detailed engineering, construction and handover.

Phase 4: The operation phase and finally disposal. The contractor tends to not be included in this last phase of the project life cycle.

According to Walker and Lloyd-Walker (2012) the ECI project life cycle can vary between projects depending on when the contractor enters. In some projects the contractor are involved already in phase 1, thus the client need advice about specific project matter when developing the project idea. In others, the client just need the contractor's input regarding the pre-engineering stage in phase 2. The experience and knowledge possessed by the client but also the complexity of the project, will impact when the contractor enters the project. A more experienced client, or a non-complex project will need less contributions from the contractor in the early stages.

It can be seen in Figure 1 how ECI differs from procurement methods like Design and Build and Design Bid Build (Walker and Lloyd-Walker, 2012). In comparison to these two contracts, ECI is a two-stage process with two separate contracts, one for the design stage and one for the construction stage (Love et al., 2014). The main contractor is selected on terms of profit margin, overheads, pre-construction fee, approach to risk pricing and other cost components. Furthermore, the contractor is also evaluated in terms of non-price based criteria such as proposed construction method, risk solving strategy, experience with similar projects and familiarity with local subcontractors and suppliers (Love et al., 2014). The idea of stage 1 is that the contractor together with client develop the project design and jointly agree with a target price including a pain/gain share formula for the construction phase (Rahman and Alhassan, 2012, Rahmani et al., 2013), see Figure 2. In this stage, the contractor

is paid by the hour like a consultancy agreement. If the client is satisfied with the contractor and all the requirements set by the client have been fulfilled the same contractor will be awarded the contract for stage 2, the construction phase. According to Walker and Lloyd-Walker (2012) the client can include a go/no go moment between stage 1 and 2, which implicates that the client can choose another contractor to procure for stage 2. The collaboration can also be ended if the two parties cannot reach an agreement regarding the target price. To achieve the best result from an ECI collaboration it is expressed by Rahman and Alhassan (2012) that it is preferable to procure the same contractor for both ECI stages to be able to use and continue developing the already established collaboration process.

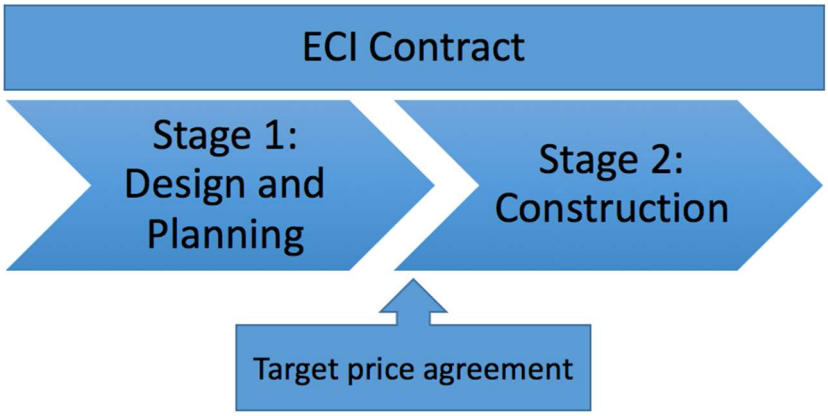

Figure 2 The stages of ECI

2.1.2 ECI success factors

Rahman and Alhassan (2012) conducted a survey to gain knowledge how a large contractor in the UK perceive the ECI approach. The result showed that the main benefits with the ECI approach concerned opportunity to create better relationships, that the contractor's knowledge are more effectively involved in the design phase, better risk allocation and overall a better project delivery. However, Wondimu et al. (2016) claims that there is an ambiguity about the definition of ECI. The meaning of ECI can differ and is adapted differently depending on the specific needs and situations of different countries. Some use an approach going through the whole project life cycle, while others focus on the planning phase and uses a more traditional contract, together with an incentive based payment form, when construction starts. Regardless the definition, Wondimu et al. (2016) presents six success factors of ECI, which are based on the findings of a case study covering eleven Norwegian bridge projects.

1. *Involve contractors early enough* - If contractors are involved too early their influence on major decision making is high, it might also increase bureaucracy and transaction cost due to the procurement process. However, if involved too late it might be difficult to accept their contributions to the project due to the approval process of projects as well as client resistance. Further, the more complex a project is, the earlier the contractor should be involved.

2. *Manageable risk transfer to the contractor* – In the early phases, where risk is high due to lack of information, it is of importance that the risk level is appropriate for the contractor. Otherwise, if the risk is too high, it is difficult to find a contractor who is capable to carry it. Further, if a contractor accepts elevated risk, it will be more expensive for the client, as of the higher risk premia. This is also supported by Mosey (2009) who argues for proper risk management before and after the tendering of a contractor. Conditions which might be critical for the project should be presented to the contractor who then is allowed to make an own perception of said risk.

3. *Client competence* – From the case studies it was also found that client competence, including technical competence, procurement competence, and previous experience of ECI, is a success factor (Wondimu et al., 2016). Even if the contractor is not very involved in the design, the project should have a properly defined scope. Although, Mosey (2009) argues that clear requirements and expectation as well as client involvement, will influence the efficiency of the design process.

4. *Proper compensation for contractor contribution* – Contractors main objective is to gain the maximal profit out of projects (Wondimu et al., 2016). The client should therefore compensate the contractor properly for the contractor to share their knowledge. It was argued that contractor interest varies depending on what compensation form that was used. Therefore, it is important to develop a compensation form that enables a win-win situation for both the client and contractor. It is also stated by Kadefors and Badenfelt (2009) that the use of a target price emphasises and encourages healthy relationships which is needed in ECI projects. It communicates trust, risk sharing and efficiency.

5. *Competence of contractor* – For contractors to be able to contribute in the early phases, certain capability is required, the contractor must have experience of similar projects. This highlights the importance of not only using lowest price as a selection criteria when procuring a contractor. However, as the first stages of the ECI process contains a fee based payment method, there is still a probability that the contractor is tendered for the lowest fixed fee. Lahdenperä (2013) argues for a balanced fee and capability competition, to find the most economically advantageous decision.

6. *Trust between client and contractor* – Higher trust between client and contractor will lead to more openness and communication, which in turn will lead to more and better contribution from the contractor. Further, high trust will make the client more willing to give responsibility to the contractor and can be decisive in how early the contractor is involved. This is also supported by Kadefors (2004) who expresses that a higher level of trust between client and contractor should enhance project result. Further, it has been concluded that early involvement of project participant with project-wide communication and team building processes facilities trust in the project.

2.1.3 Obstacles of ECI

To answer the question why ECI is not used in all projects and if all projects can benefit from it, Mosey (2009) discusses possible obstacles of ECI. In small or simple projects, it might not be justifiable to put effort in the preparatory processes, as the design-team might be able to complete the design before tendering contractors. Further, getting input from the contractor will most likely cost more than the value it creates. Another type of projects where ECI might not be suitable is when the client does not wish to participate in the project, only state their performance requirements, tender it to a fixed price, and leaving the design and construction up to the contractor to solve. The client will often have little information regarding the progress or problems of the projects. Eadie and Graham (2014) presents something similar based on an online survey and a case study, where ECI is compared with other procurement methods. It is concluded that ECI projects increase the value of a project and produce cost savings. Although, these effects are most common in larger projects with high risk and less benefits were found using ECI on smaller and low risk projects (Eadie and Graham, 2014).

Regulatory constraints can be an obstacle as well (Mosey, 2009). For example, clients might be bound to select contractor according to lowest price and not highest value, this will hinder the possibility to choose an early contractor to be a part of the early design phase. Although, to public clients regulated by the Public Procurement Act there is often a way of selecting the contractor by the most economically advantageous tender, which can be argued to be an ECI collaboration.

The transaction costs of setting up an ECI collaboration can also hinder the use of ECI, it must be a common belief that it is an investment, which is going to pay off in the end (Mosey, 2009). Further, having a standard agreement can be a way of minimising the transaction costs. To reach mutual agreements required in an ECI collaboration can be difficult as there are several parties that should be considered. Reaching an agreement in a team is said to be tricky even when preparing a single-stage tendering, and in ECI there is also the addition of the contractor, yet another party.

An additional barrier for ECI is personal obstacles, which are attitudes that in some cases might be changed through education or persuasion. It is mentioned that the AEC industry has a deeply rooted short term thinking and adverse behaviour. Mosey (2009) argues that using ECI and working jointly in the pre-design phase could be a way of breaking down the barriers between clients and consultants on one side and contractors on the other. Further, openness and flexibility from the project members is also required. Attitudes among the project members towards each other must also be open for ECI to be successful. Therefore, personal chemistry is a key factor when choosing professionals for a project team. This is also supported by Rahman and Alhassan (2012) who found in their paper that the drawbacks with ECI concerned that the commitment and engagement from the different parties could vary. Further, Rahman and Alhassan (2012) conclude that is also exist a lack of win-win attitude between the parties. The openness that the ECI approach need to have when it comes to company secrets was seen less as important problem.

2.2 BIM

The AEC industry is becoming more and more complex, requiring more inter-organisational connections, which in turn requires trust among the involved parties to achieve a successful result (Bryde et al., 2013). An efficient information sharing system is needed to get a satisfied result. Information and Communication Technology (ICT) have emerged to handle these new challenges. Building Information Modelling (BIM) have during the last decade been one of these new ICT approaches which navigates the new way of approaching the design, construction and maintenance of construction projects (Bryde et al., 2013). BIM allows information to be shared in a much more efficient way, from 2D modelling to 3D modelling (Yan and Damian, 2008). Further, BIM serves as a repository of information as it represents both the physical and the functional characteristics of a building (Johansson et al., 2015). Through this, BIM works like a supporting function alongside the design and construction processes, by enabling cost-estimation and production planning. The 3D aspects of BIM bring also other opportunities when it comes to visualisation. When all the data is available in 3D, real-time visualisations can be used as a communication tool in order to discuss ideas and sharing information among the project stakeholders (Johansson et al., 2015). If BIM is executed in the right way, it has the potential to improve collaboration between project stakeholders and reduce the time concerning reading and process documentation of the project (Bryde et al., 2013).

Based on literature, Barlish and Sullivan (2012) develop a methodology to quantify the impact of BIM in construction projects. This model was implemented in projects within a company where some use BIM and some use traditional methods. It was concluded that savings could be made with the use of BIM. Although, it was also mentioned that the success of BIM is relative to the project and the organisation. Project size, BIM experience, communication between project members, and other external factors can be decisive regarding successful BIM projects. Moreover, Yan and Damian (2008) argue that BIM in the design phase enables better decisions, reduce time and cost. In the operation phase BIM have the possibilities to facilities cost control, digital trail, accelerates the adaptation of standard building prototypes. Meaning that BIM increases the efficiency throughout the whole project lifecycle.

Succar (2009) defines BIM as "a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life cycle". This definition lifts that BIM is something more than just a computer software which is also supported by Azhar (2011) who argues that BIM is a process, which should encourage integration between different project stakeholders. Parties that earlier saw each other as competitors will now need to work together. The same argument is expressed in a paper by He et al. (2016) who explain that BIM in the construction sector is not merely a software. In order to achieve the potential benefits of BIM. He et al. (2016) lift up that it is more about management changes than technology issues that hinder the implementation.

According to Bryde et al. (2013) BIM can meet challenges as the roles of the different stakeholders need to change to achieve the full potential of BIM. Further, Bryde et al. (2013) state that it is not evaluated yet if BIM will facilitate the knowledge transfer

between projects which can increase the effectiveness of an organisation as new projects do not need to start from scratch every time.

The implementation cost be an obstacle with BIM as organisation needs to invest in BIM education and training staff. BIM will only be successful if the people using it adapt and use the working practices that suits the process (Bryde et al., 2013). This is also supported by Yan and Damian (2008), who argue that one of the drawbacks with BIM is the time-consuming learning process requiring a lot of human resources.

2.2.1 BIM success factors

In a paper by Sebastian (2011), successful factors regarding collaboration using BIM is discussed. The study tries to find a general view of practical implication of BIM by investigating a hospital building project. Sebastian (2011) argues that in order to achieve full potential of information sharing between different actors in the AEC industry, open data standards should be used. This is also expressed by Porwal and Hewage (2013) who argue that common BIM standards needs to be developed to facilitate BIM adoption and communication. To be able to collaborate through BIM. Sebastian (2011) express the need of a model manager who possess knowledge of the construction process and the BIM process. The model manager should manage the information flow, maintain technical solutions required for BIM and improve the ICT skills of the involved actors. However, the model manager should not be responsible for the quality and content of the shared material through BIM, that responsibility lies on each actor involved.

Constraints regarding the use of BIM can be related to adversarial relationships and views connected to the traditional contracts and roles of the construction process. Sebastian (2011) argues that the different organisations must become more integrated and collaborative, and that there is need of incentives and common goals to achieve this. This is supported by Gu and London (2010) who state that for a successful BIM adoption the organisation needs to change the work practices as a new integrated model requires better collaboration and communication between disciplines. Further, there is a need of coordination of work processes through the whole construction process. However, Sebastian (2011) points out that neither BIM or collaborative work methods are possible to standardise as projects can differ greatly. Therefore, work methods and processes should be tailored to the specific context at hand. However, to bridge the gap between technological inventions and building practice Sebastian (2011) explains the need of real project experience. Further arguing that it is a crucial factor, to breach the mental barrier in the industry when it comes to collaboration. To achieve this a closer cooperation between universities, research institutes and the building sector is required.

2.3 Collaboration forms

In order to explain synergies between BIM and ECI it is important to be aware of the more common collaboration forms, and how they can be linked to BIM.

2.3.1 Partnering

Construction partnering have been an emerging collaboration form during the last decades and is argued to bring advantages such as better quality, cost reduction, sustainability and safety performance (Bresnen and Marshall, 2000, Eriksson, 2010). Although, Eriksson (2010) discusses that one problem with the partnering concept have been the lack of a universal definition leading to misunderstandings, thus hampering the implementation process. This is also supported by Bygballe et al. (2010) who lift that a better understanding of partnering relationship would increase the collaboration in the AEC industry. In a paper, Eriksson (2010) tries to solve this issue by contributing with a partnering concept definition. Partnering is described as a cooperative governance form that is based on core procedures and cooperative procurement procedures, where these procedures should facilitate a cooperation-based coopetition. The core procedures include for instance, bid evaluation based on soft parameters, usage of collaborative tools, joint objectives and follow-up workshops. Optional producers, on the other hand, focus on early involvement of contractor in concurrent engineering, joint IT tools and incentives based on group performance etc. Moreover, it is expressed that partnering is mostly useful for complex projects, with long duration time and high uncertainty (Eriksson, 2010). This is also stressed by Bygballe et al. (2010) who address that partnering is a long-term relationship between actors in the AEC industry.

2.3.2 Integrated project delivery (IPD)

Integrated Project delivery (IPD) was a new form of project delivery approach that was developed 2003 in USA (Lahdenperä, 2012). The basis of the IPD approach builds on an early collaboration between the client, the contractor and important suppliers but also on management methods such as lean, which can be defined in the contract. Further, El Asmar et al. (2013) state that IPD consist of two key aspects, first all key stakeholders sign a multi-party contract. Secondly, this signing should be done before the design phase even have started. This means that all the key stakeholders together develop a project plan jointly. The stakeholders that participate in the agreement can vary depending on the project and can consist of the client, contractor, architect, consultants, subcontractors, and suppliers.

2.3.3 Concurrent engineering (CE)

Concurrent Engineering is the use of a systematic parallel process where all parties in the project are involved, including client and suppliers (Anumba and Evbuomwan, 1997). In construction, CE can be achieved in the design process by considering all phases concurrently. The aim of Concurrent Engineering is to reduce lead times, reduce cost and improve quality. Other benefits that have been established around Concurrent Engineering involves improved communication between designers, managers and other professionals that plays a part in the design phase. This is something that often is vital for the AEC industry (Anumba and Evbuomwan, 1997).

To reach the above described goals and benefits with concurrent engineering some constraints need to be handled. One constraint concerns the project meetings and the issue of appropriate representation. Anumba and Evbuomwan (1997) stress that it is of significance that the project team members are on a seniority level to take vital decisions. The project members must also possess all the vital practical aspects and

the context of the construction. Further, Anumba et al. (2002) express that part-time, dispersed teams should be used as project structure because of the unpredicted construction environment which demands a flexible project structure.

Integrated concurrent engineering (ICE) is another collaboration process that is based and developed from the concurrent engineering concept (Belay, 2013). The origins of the ICE collaboration process can be found in US and more specific it was developed by NASA (Chachere, 2009). ICE can be described as a multi-disciplinary process which aims to organise a design team enabling stakeholders from different disciplines to collaborate. By doing this the design team concurrently develop an integrated project design rapidly (Kunz and Fischer, 2009). Moreover, Garcia et al. (2004) express that ICE emerges since a lot of tasks tend to be very complex and have reciprocal interdependence which can be more effectively handled through extreme collaboration. The ICE environment features all needed stakeholders working simultaneously in design "sessions" with the help from modelling and visualisation tools in order to facilitate collaboration (Garcia et al., 2004). The project stakeholders will work physically together and will do this until the goal have been reached.

2.4 Synergies between BIM and collaboration forms

In a critical analysis, Kelly and Ilozor (2012) argue that BIM and IPD literature often points out potential synergies and benefits gained from coupling BIM with IPD, often linked to BIM being an enabling tool for IPD. However, Kelly and Ilozor (2012) mention that finding literature challenging or verifying these synergies is difficult. Further, believing that there is a lack of scepticism, as several articles points out the potential BIM and IPD possess to change the industry, but potential does not mean that actual change happens. It is suggested that further research should be conducted, which should include data from traditional projects in addition to data from projects using BIM and IPD, also an analysis of the interaction between BIM and IPD (Kelly and Ilozor, 2012).

Issues in using BIM as a collaborative framework is a major obstacle for full BIM adoption (Porwal and Hewage, 2013). IPD is believed to facilitate the use of BIM in construction, but there are constraints and difficulties in applying IPD, which can be linked to traditional contracts and leadership. A BIM partnering public procurement framework is suggested to ensure best value in public construction projects. It proposes that the parties involved in the early design stage should include clients project manager, client consultants, contractors, and sub-contractors. Throughout the rest of the design phase, proper coordination between designs carried out by designers and contractors is important to create a collaborative work environment. The increased popularity of IPD can be related to the requirements by clients to use BIM as a tool in construction project management (Jones, 2014).

Mason and Brook (2015) stated, based on a literature review, that the failure of partnering was due to lack of shared understanding, missing shared ground rules, lack of inter-organisational communications, and unclear roles and responsibilities. Based on this Mason and Brook (2015) assessed BIM as a way of overcoming these barriers and in that way, deliver partnering. Questionnaires were sent to several different practitioners, as to get a cross section of the industry. It is suggested that BIM can cover some of the multi-faced requirements of partnering but not all of them. It is

stated that the majority believes that early contractor contribution is of the highest importance when achieving value in projects and that it is best delivered through BIM (Mason and Brook, 2015). The benefits of BIM in ECI collaborations are related to the management of rapid information exchange that is needed to create value, which BIM facilitates. On the other hand, some argued that it is possible to use BIM and not partner. This belief was mostly described by contractors, which are not always present in the design phase where no ECI contract is used. Therefore, designers may be partnering with the other designers or clients by using BIM, but there is no partnering present with the other parties in the supply chain. This leads to a BIM model being tendered without any input from the contractor, meaning that any partnering benefits may only be gained after the tender process. In turn, this restricts BIM from being used to its full potential, as it does not include construction sequencing and cost information, which is connected to knowledge possessed by the contractor. If 3D drawings are the only things contained in the model, BIM is only used at level 1. Mason and Brook (2015) conclude their paper with the following: *"The study shows that above all, BIM facilitates ECI and improved buildability. These are significant benefits that can be delivered through partnering and are enhanced by using BIM. In this instance therefore, BIM does facilitate partnering [...] Furthermore, BIM cannot deliver partnering if the client's team does not involve the supply chain until the traditional tendering stage."* (Mason and Brooks, 2015, p. 8). In other words, BIM have the possibility to facilitate some of the key aspects of partnering, but not all.

Through a literature review Rowlinson (2017) discusses the process changes that is required by organisations to successfully implement BIM and IPD. It was found that IPD rarely was used except for large property developers, which already has integrated IPD within their main organisations. The problem of BIM implementation was connected to the focus on software instead of the process and design culture. Rowlinson (2017) argues that cultural issues are hindering the implementation of BIM and IPD, and believes that evidence of success is an influential factor for a worldwide adoption. Further, pushing large public organisations to undertake IPD and BIM methods, and claims that it is of foremost importance in order to change existing procurement routes into ones that facilitates collaboration, information exchange, and trust within the context of a technological model.

The ICE collaboration process which is an extreme form of collaboration often using a co-located cross functional design team can be seen as a key factor when working with visualisation models (Garcia et al., 2004). Garcia et al. (2004) stress that the usage of the ICE process together with Virtual Design Construction (VDC) will lead to a more effective process and a product of higher value. To clarify, VDC together with integrated work processes is interpreted in this master's thesis as the concept of BIM, thus BIM is a visualisation process stretching over the project life cycle.

Further, Tjell and Bosch-Sijtsema (2015) acknowledge the same relation, that an important factor which collocation supports is the use of different visual means, such as BIM models. This type of visualisation representation has the ability facilitate information and knowledge transfer between members of a design team. Although, Tjell and Bosch-Sijtsema (2015) clarify that the positive effects is depending on the engagement from all involved actors but also that all relevant actors participate in the

design meetings. When project members are not actively engaged, sharing visual information will be difficult to perform among the involved actors.

2.5 Theoretical summary

Early contractor involvement is a two-stage collaboration process which refers to an early involvement of the contractor in the early design phase, to increase the projects buildability. In the first stage, the Client together with the contractor develop the project design and jointly agree on a target price. If an agreement on the target price can be made, the contractor will be awarded the contract for stage 2, the construction phase. How early the contractor will enter the relationship in an ECI process depends on the competence of the client and the complexity of the project.

If ECI is carried out the intended way it is believed to have the potential to decrease adversarial relationships, increase understanding among parties and create higher project value. To achieve this the contractor needs to be involved early enough, get manageable risks transferred from the client and possess the competence needed. The client also needs a certain competence and give the contractor proper compensation for contributions. Trust between the client and the contractor is a key factor to create an open communication, which is needed in close collaboration. Obstacles regarding ECI is referred to the transaction cost setting up the process, and that it needs to exist a common belief that the ECI will pay off in the end. Further, obstacles are connected to collaboration problems such as right people on the right place, trust, adversarial relationships and commitment to the project.

Building information modelling is an ICT approach developed to increase and make the information sharing more efficient in construction projects. The BIM model represent both the physical and the functional characteristic of the building and can work like a supporting function during the design and construction phase. BIM can also be used in the operation phase of the facility, meaning that BIM have the ability to increase the efficient throughout the whole project life cycle. Moreover, BIM should be seen as a process which encourage integration between project stakeholders and not just a software providing a 3D model. Although, achieving full BIM adaptation has been problematic, with issues connected to culture, learning barriers, and a disbelief to its efficiency.

Using BIM together with collaboration forms, such as ECI, have the possibility to facilitate the BIM process since it gathers key competences in the early design stages where there is a need of efficient communication. Likewise, BIM can facilitate the collaboration by providing efficient open communication and rapid information sharing that is needed in a collaboration project. Using visual means as BIM in a co-location situation have the possibility to increase project effectivity in the design phase.

3 Methodology

The methodology of which the master's thesis is built upon is presented, explained, and argued for in this chapter. The methodology chapter should strengthen the quality of the thesis, as it allows readers to reproduce the master's thesis with this methodology as a guideline. This thesis uses a qualitative and abductive methodology consisting of a literature review, and a multiple case study with interviews as data collection method. Both authors contributed equally to all parts of this master's thesis, resulting in a fair and equal division of work.

3.1 Research approach and design

A qualitative research method aims to view the relationship between theory and practice. Bryman and Bell (2011) describe the process of a qualitative research approach through a 6-step model.

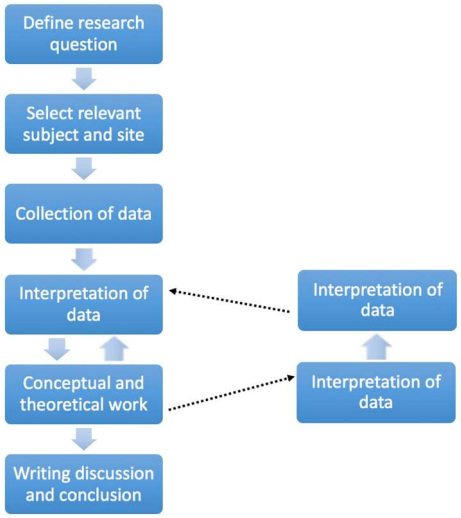

Figure 3 The 6 steps of a qualitative research approach (Bryman and Bell, 2011)

Further, a qualitative research design was chosen as it provides the possibility to explore and interpret the selected context, which suits for this master's thesis (Bryman and Bell, 2011). In comparison to a quantitative research design, a qualitative focus on words rather than quantitation. A qualitative design also allows the researcher to have a more process oriented research which means that the study change and adapts to how things evolve over time (Bryman and Bell, 2011). Since this master's thesis aims to investigate a chosen context regarding BIM and ECI in two specific cases the qualitative design was seen as most appropriate to achieve a satisfying result.

In order to develop this master's thesis an abductive research strategy was chosen as it enables new theory to be added during the process. Dubois and Gadde (2014) express this approach as a continuous interplay and movement between theory and empirical data. In practice, this means that the researcher is able to go back and forth between theory and empirical findings which means that it takes a non-linear path. It is rather a systematic combining, matching theory and reality (Dubois and Gadde, 2014). This strategy also suits research that aims to discover new things and new relationships and variables. The abductive strategy was preferable due to that new and unanticipated issues could show up in the multiple case study, which could require changes in the

theoretical framework. Further, as ECI is new to the Swedish AEC industry it is beneficial to use a strategy that enables new discoveries to be found.

Moreover, the research has been conducted as a multiple case study covering two similar projects. According to Bryman and Bell (2011) a qualitative research approach corresponds to a comparative design including a multiple case study. The strength by using a multiple case study compared to a single is the ability to compare the two cases with each other. Further, it also creates a better base for proving a theory as more data tend to increase the strength of the conclusion (Bryman and Bell, 2011). Although, it should be mentioned that some critics have been pointed out when conducting a multiple case study. Dyer and Wilkins (1991) state that the researcher tend to focus less on the specific context of the cases and more on the comparison between.

The two cases were chosen due to two major reason: the two projects have been procured in a ECI collaboration contract, and both projects are implementing BIM in the processes. Further, the two case projects are of a limited number of projects using ECI on the Swedish market.

3.2 Literature

The purpose of the literature review was to set a theoretical framework providing a context in which the empirical results could be placed. Establishing a theoretical framework, concerning the topic at hand, provides a knowledge base on which the research approach be grounded on (Bryman and Bell, 2011). Further, knowledge gaps in the existing literature can be found, providing validity to the research questions.

The literature review in this thesis was based mostly on scientific articles and conference papers, but a few books were used as well. All literature was found in bibliographic databases, with the primary ones used being SCOPUS, Summon Chalmers Library, and Google Scholar. Search words included: *ECI, BIM, early contractor involvement, building information modelling, IPD and BIM, partnering and BIM, ICE, VDC, Concurrent engineering.* Literature regarding the context of the multiple case study was acquired from the STA's documents and public announcements.

Number of citations, publication date, and comparability to the Swedish AEC industry, were selection criteria used to filter through and to find relevant literature. More recently published literature was preferred as the topic is rather new. Older literature was also used, although it was required to have a higher level of citations as a validity for it to be relevant. However, all literature was required to be written in a context, which could be somewhat fitted to the Swedish AEC industry. Further, all literature were reviewed critically before added to the theoretical framework, as it is argued by Bryman and Bell (2011) that it is of importance to interpret and critically review what has been said, when using it for one's own argument.

In order to gain a base on which the research questions could be more specified, the initial stages of the literature review focused on developing a broad knowledge on the subject of ECI and other collaboration forms. With more specific research questions, it was possible to go deeper on the subject and find relevant theories and views

regarding synergies between collaboration forms and BIM. By means, it was possible to develop an appropriate research method as well as providing a scene where the results could be discussed. Through the abductive approach, it was possible to conduct further literature research during the time of data collection, as the result provided additional insights in need of theoretical exploration.

3.3 Interviews

The interview process was based on seven different stages explained by Kvale et al. (2009).

1. *Thematising*: During this stage, the purpose of the study was developed together with research questions.

2. *Planning*: An interview guide was created and prepared based on the purpose and the research questions of the study. Further, the interview process was planned regarding the seven steps e.g. which people should be interviewed.

3. *Interviewing*: The interviews were conducted.

4. *Transcribing*: The interview material was prepared for analysing, which implicated transforming the recorded interviews to written text.

5. *Analysing*: The transcribed interview material was analysed and sorted into categories. Interpretation were also made to add details to specific parts of the interview.

6. *Verifying*: The interviews validity, reliability and generalisation possibilities were confirmed. The validity considered the interviews and if they sought out to investigate what they were intended to do. The reliability checked the trustworthiness of the interview findings. Finally, the generalisation part focused on how the answers agreed with broader research.

7. *Reporting*: The interview result was reported and communicated in a scientific manner. The result of the interviews was presented in the result chapter.

3.3.1 Interview design

The interview study was conducted through a semi-structured interview. The semi-structured interview type is often seen as good compromise as it both gives a structure to the interview but also flexibility (Bryman and Bell, 2011). The interviewee has the freedom to answer the questions in any way that is preferable for the interviewee. This means that the interviewee has the possibility to diverge from the theme and focus on what the person is interested in. At the same time the interview is structured and follows a prepared guideline, but this guideline does not need to be followed strictly as in a structured interview. The semi-structured interview form was chosen primarily because of its flexibility character that can provide an interesting discussion around the subject (Bryman and Bell, 2011).

3.3.2 Interview guide

An interview guide based on the theoretical framework was prepared and given to the interviewees a couple of days prior the actual interviews, see Appendix A for the complete interview guide. This, to provide some level of structure of how the interviews was carried out and to assure that the desired topics were covered. It was done in accordance to what was mentioned by Bryman and Bell (2011). They argue that the most important aspects of the questions in an interview guide is that it allows the researcher to gain the desired information from the interviewees, and that it allows the interviews to be flexible. Questions should not be formulated in a way that hinders alternative views as this goes against the nature of qualitative research. Further, questions should be articulated in an understandable way for the respondents, and should not be leading. A major advantage of using an interview guide is the possibility to have the questions reviewed by another party prior to the interview, which strengthens the validity of the data collection.

11 interviews were held with professionals from various aspects in the two cases, this included; project managers, design managers, contractors, BIM managers and client representatives. The interviews lasted for approximately one hour and were originally held in Swedish and was delicately translated into English afterwards, as to not alter the meaning and to stay true to what was said during the interview. The interviewees were purposively chosen based on relevancy to the research question, as they had to actively be working with the ECI collaboration, and they had to be from different organisations. This, because the respondents had to have experience of using ECI, but at the same time be from different organisation to provide a larger spectrum of alternative views, which enriched the data collection. The sampling was theoretical, meaning that the sampling was based, through an iterative approach, on the theoretical framework and what needed further exploration (Bryman and Bell 2011).

The interviewees are presented anonymously and grouped according to the case, see Table 1. In addition to the case specific interviews, two interviews were carried out with strategist regarding BIM and procurement at the client organisation.

Table 1 List of interviewees

Case A	**Case B**	**STA**
Design project manager A	Design project manager B1	BIM-strategist
Client A	Design project manager B2	Business and supplier development strategist (STA strategist)
Contractor A	Client B	
Subcontractor A	Contractor B	
	BIM manager B	

3.4 Data analysis

The data analysis was conducted according to Kvale et al. (2009). First the collected interview material was analysed and ordered to be more manageable. To categorise the interview material coding was used with different keywords. If the interview material focused on the BIM context one keyword were used and for ECI another was

used. After this, different answers from the interviewees on similar question could be compared with each other to build up the discussion.

3.5 Ethical aspects

Bryman and Bell (2011) discuss upon the issues of lack of informed consent, whether there is an invasion of privacy but also whether deception is involved. These issues were considered by the interviewees as they were presented the interview guide. Further, the interview guide presented the purpose and the method used in the study. This, as Kvale et al. (2009) stress the importance of informing the interviewees about the purpose of the study, but also the chosen method. All of the interviewees had to give their permission for an audio-recording of the interview. Kvale et al. (2009) argue that consequences made by the study and the possible harm to participating interviewees needs to be addressed. Therefore, motivating an anonymous presentation of the data gathered in the interviews. This method was chosen in order for the interviewees to elaborate and speak freely in their answers.

3.6 Discussion of the chosen methodology

Prior in this chapter, the chosen methodology has been argued for. However, there should still be a discussion whether the most appropriate methodology was used. An example can be found in the multiple case study, as the research could have been made more extensive if there were more than the two cases to investigate and compare. Although, this was not feasible due to the lack of Swedish projects using the same collaboration method as the case study projects.

Both the number of interviews that were conducted as well as the sampling of interviewees, could have had an impact on the results. Further, the researchers could be influenced by the interviewee's answers and opinions, thus becoming biased. Likewise, the researcher’s biases could affect how the data from the interviews is interpreted. It should also be mentioned that the projects in the cases are ongoing and are in the early design phases, meaning that the views and opinions perceived in the interviews might change as the project continues. However, it could be considered advantageous that the interviewees are working in the design phase, where ECI has its focus, as they have the collaborative process fresh in mind.

Trustworthiness of a qualitative study differ from a quantitative as it can exist more than one right answer that suits the investigated context and the social reality around (Bryman and Bell, 2011). In order to gain trustworthiness in a qualitative study Bryman and Bell (2011) express the importance of following the set-up rules during the research process to achieve a reliably result. The result should also be sent to a person that have knowledge in the investigated subject to get the right picture and solve misunderstanding. In this master’s thesis, the participant validation was made by sending the result to the supervisor to confirm that the researcher had understood the social reality accurately.

4 The Multiple Case Study

This chapter aims to explain the two investigated cases, A and B. Further, it describes the context of the STA regarding BIM and ECI. Both cases are two separate parts of a main project that has been divided into five separate parts. The main project is a major infrastructure project carried out in the city of Gothenburg. A Design and build contract together with ECI, and with BIM requirements were used in both cases, which were requirements from the STA.

4.1 The client, STA: s context

In the city of Gothenburg, a large infrastructure project is being carried out. The project has the aim of improving traveling in Gothenburg and the western parts of Sweden, to provide increased capacity for commuting trains, and to enable further expansion of railroad traffic in the region. It consists of 8 km of railway going through the city centre with 6 km being beneath ground, together with 3 new stations (Trafikverket, 2014b).

STA decided to tender two parts of the project (Case A and B) as a design and build contract with ECI. The reason being to utilise the contractor's knowledge in the early phases, for choosing production methods and developing a price. The contract is split into two stages, where the contractor is paid by the hour in the first stage, see Figure 4. When a target price is set, the contract goes into its second stage, where the payment method changes to a self-cost based principle with a target price and incentives (Trafikverket, 2014b).

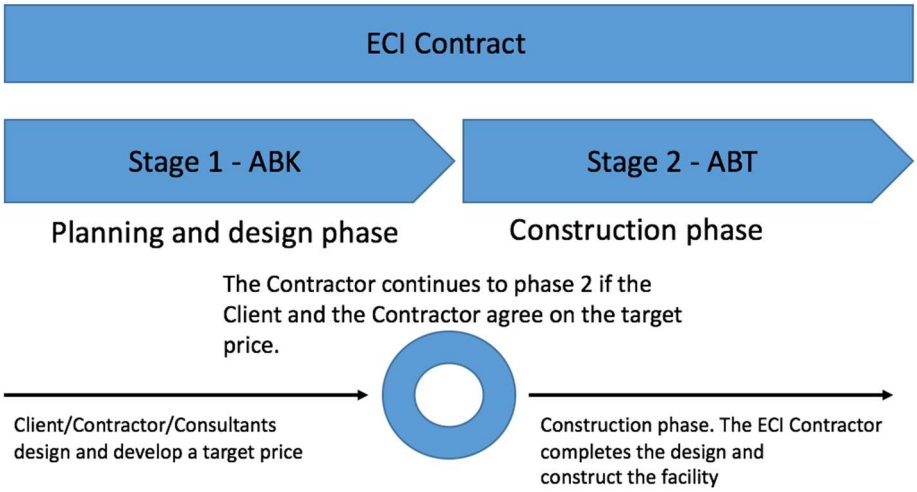

Figure 4 The ECI contract model, remodelled (Karlsson and Emanuelsson, 2016)

4.1.1 Project risks

STA consider the number one risk in both Case A and B to be the chosen procurement strategy since the lack of experience in using ECI by all involved parties. According to STA the risk is associated with that ECI as a collaboration form can impact the quality, the time and the price of the project if it is not used properly and to its full potential. To minimise these potential risks the STA organisation stated that the

knowledge gap regarding ECI needed to be filled by investigating similar projects, both in Sweden and abroad. The procurement should also start early to give time for the ECI process (Trafikverket, 2014b).

4.2 Case A

The project in Case A aims to increase the capacity and heighten the reliability in the existing railway network in the central part of Gothenburg. The railway area that will be improved is one of the most important railway nods for the West Swedish railway system and are used by both accommodation trains and cargo trains. Today five major railways interact in this area and most of the tracks meet at the same level (Trafikverket, 2014b). To increase the capacity in this railway node, but also in preparing the railway system for the major infrastructure project this area needs to be reconstructed in order to have tracks on several levels. The reconstruction considers ten new railway bridges, one footbridge and 10 000 meters of new railway but also a large number of railway temporaries (Trafikverket, 2017b). Case A requires a high competence from those involved regarding logistic and traffic control of the rail traffic. Further, the rail and signal system works is included in this contract for Case A in comparison to Case B where these works will be tendered at a later date. This is based on that Case A will be conducted in a very high traffic railway area, thus it is preferable to include the railway work at the same time. The time schedule of Case A has been set to six years with construction starting in 2018 and completion in 2023/2024.

Through a tendering process, the contract was awarded to Contractor A together with Subcontractor A and Consultant A. Consultant A carried out the engineering with input from Contractor A and Subcontractor A, who was responsible for the rail and signal system works. Case A was in the first stage of the ECI process, at the time this thesis was written, with the focus being on developing a target price.

4.3 Case B

The project presented in Case B consists of a new central station beneath ground together with connecting railroad tunnels. Case B considers a lot of work of the same type, mostly ground and concrete work (Trafikverket, 2014b). The technical challenges in the case are connected to the geotechnical conditions in the area, as it is mostly clay to a depth of 100 meters. Further challenges are the depth and width of the open shaft that is needed, while being in a highly-trafficked area.

The contract was awarded, through a tendering process, to Contractor B who was working together with Consultant B1 and Consultant B2. The structural engineering was carried out by Consultant B1, while the geotechnical engineering was conducted by Consultant B2. At the time in which this thesis was written, Case B was in the first stage of the ECI process. The current goal was to develop a target price for the project to go into the second stage and start construction.

4.4 Professional client

The STA has a long-term strategy, which is also incorporated in the cases, of becoming a more professional client. Meaning that the STA aims to become less involved in how projects are carried out, and focus more on what projects should contain (Ek Österberg, 2016). The desired outcome is to increase the competition on the market, and to address the low efficiency and lack of innovation in the industry. With the STA being the biggest client, the strategy is believed to have great potential effect on the industry. However, the desired outcomes might not be achieved as of the increased complexity of projects. Tendering projects with design and build contracts is one of the major techniques, which promotes the professional client role. These types of contracts are more complex and are seen as a way of tendering for a specific competence. This view is particularly present in ECI collaboration, and is described as a way of putting the professional client role in its most stretched out form. Although, markets with more complex services are often known for having a more extended collaboration between client and service provider, and here the competition might be lacking as the tendering bids are more difficult to compare. Further, as design and build contracts come with greater risk for the service providers, there might be fewer tenders, which also goes against the wish of more competition.

With the professional client role, the STA wishes to distance themselves from the actual execution from the project, and focus on the goals and requirements. Later, it is up to the client to check if they have acquired what was ordered and that it is of desired quality. However, the greater distance between parties has resulted in more contractual arguments. To minimise arguments, STA has the ambition to have collaboration in all phases as an underlining theme of all projects, with an open dialogue already in the tendering phase. Ek Österberg (2016) discusses the paradox of wanting to increase distance and at the same time wanting closer collaboration. She mentions that the paradox might not be a paradox at all, that being a more professional client defines the role, while close collaboration describes the interaction between the different roles. Being a professional client is more about establishing a culture instead of presenting a practise. Still, Ek Österberg (2016) points out that it is required by the STA that their action goes in line with their strategy, providing the example of consultants being confused why they are in meetings with the client if they are emphasising distance by using a fixed price contract.

4.5 ECI guidelines

An interview was held with a business and supplier development strategist at the STA, who was a part of the development of the professional client role as well as the implementation of ECI in STA's projects. This, to understand how the STA defined ECI and their role on the market. The strategist argued that it is important for the STA to move towards the supplier market, with the goal to get more value as there is a lot of competence on the market which the STA does not possess. The strategist further explains that there must be more focus on the unity of the whole infrastructure project.

In the interview, the strategist explained that from January 1st, 2015 the STA decided that every new project procured after this date should be conducted with a new mandatory work process called "Samverkan Bas" (Basic collaboration). These new

workways should be used regardless of procurement form and compensation model. Samverkan Bas is explained as new workways that should facilitate collaboration in order to achieve common goals and the right attitude in the project. Further, Samverkan Bas includes a joint risk sharing, conflict solving methods, continuous follow-up and possibly collocation of the involved parties if necessary for the specific project. Moreover, a collaboration manager should be elected, either one external manager, or one appropriate from the project organisation alternatively someone in the involved parties' organisation. The STA strategist claims that this person should be the right collaborative manager for that specific project and that specific project environment.

From Samverkan Bas STA developed another contract model called "Samverkan Hög" (Extended collaboration), which is the early contractor involvement model. Project circumstances and input parameters regarding uncertainties and complexities decide if the project should use Samverkan Bas or Samverkan Hög. In April 2016, the STA determined that Samverkan Hög should be tested and executed on a handful of projects in order have time and resources to follow-up each project. The two investigated cases in this master's thesis are using Samverkan Hög, and therefore ECI, the STA strategist explained.

It is mentioned that the STA has received inspiration from abroad regarding ECI. The market in Australia, Britain, and the Netherlands have been sources of inspiration. Even though there are similarities between these markets and the Swedish market, there are big differences as well. Some differences are cultural, but most are connected to the limited supplier situation in Sweden, where there are few but large contractors who dominates the market.

Compared to Samverkan Bas, Samverkan Hög focus on providing better conditions for the collaboration process through a more extensive background investigation of the project. This is achieved by having the competence of identifying the project complexities and uncertainties in a very early stage and from this, establish a project organisation based on the needed competence and collaboration skills. This stage of the project life cycle is called TG0 according the STA strategist and he stresses this as the most important to achieve a successful project result. Further, these two key factors (complexities and uncertainties) needs in some cases by identified 5-6 years before the construction start. Although, the STA strategist mentions that no project yet have used this model completely with an early identification, including the two ECI projects investigated in the case study, since the infrastructure industry is not yet ready. The STA strategist lifts that there exist no clear boundaries when the contractor should enter the collaboration with the client. In some cases, the contractor can enter even before any type of railway planning documents have been developed, thus helping the client with this process.

Regarding ECI, the strategist argues that it is of importance that the client is involved and has the competence to push the project forward and understanding the big picture. The competence is also key in being a successful professional client, and argues that ECI collaboration and being a professional client goes hand in hand and is a great combination, especially in the first stage. The strategist further highlights the importance of clear roles in an ECI collaboration, and that the professional client role is a result of ECI and the requirements that follow. It is explained that collaboration is

about how to interact between the roles, and that being a professional client simply clarifies the client role.

> *"Many believe that ECI and being a professional client are direct opposites. But I can assure you, that is not the case."- STA strategist*

The STA strategist expresses that the ECI concept has immense potential and if the project is properly done according to the STA Samverkan Hög guidelines savings above 10 % can be done compared to the current situation. The future plan of collaboration from the STA perspective is connected to the different activities described in Samverkan Bas. These activities will be developed even more but the big step forward is if the experience from the two ECI projects with Samverkan Hög is positive. The positive experience and workways can then be distributed to more projects in the industry and hopefully this will push the industry in the right direction. The strategist wishes that the industry ends with the adversarial relationships in projects and start collaborating instead.

4.6 **BIM**

In both cases, BIM will be a central work process used to govern the information flow throughout the whole major infrastructure project by using already established BIM processes, technology, methodology, and classification (Upphandlingsstrategi, 2014). The STA defines BIM as a database including information about the project such as three-dimensional geometry, materials, quality, cost and production methods. Further, BIM also includes the process where the data model is created and maintained.

The aim of BIM in both cases is to reduce the amount of drawings, generate more precise calculations, and through 3-D modelling facilitate effective meetings between project members and effective production. The 3D model's should also create a better understanding and better overview about the project and achieving a more secure project review (Trafikverket, 2014b).

STA is the largest client in Sweden and conducts every year several infrastructure projects in the billion class. Since STA is the leading party in the infrastructure industry the organisation have the possibility to lead the industry to implementing BIM throughout the Swedish AEC industry (Trafikverket, 2017a). To achieve this STA decided to set up requirements regarding BIM in all new procurements from 2015. The overall goal from STA is to establish BIM throughout the whole project lifecycle, from planning to maintenance and management.

4.6.1 BIM maturity levels

To explain the BIM maturity in the AEC industry STA developed a model which can be seen in Figure 5. Initial this BIM staircase model was developed by the British Standards Institute and it have been remodelled by STA to suit the Swedish context (Trafikverket, 2014a).

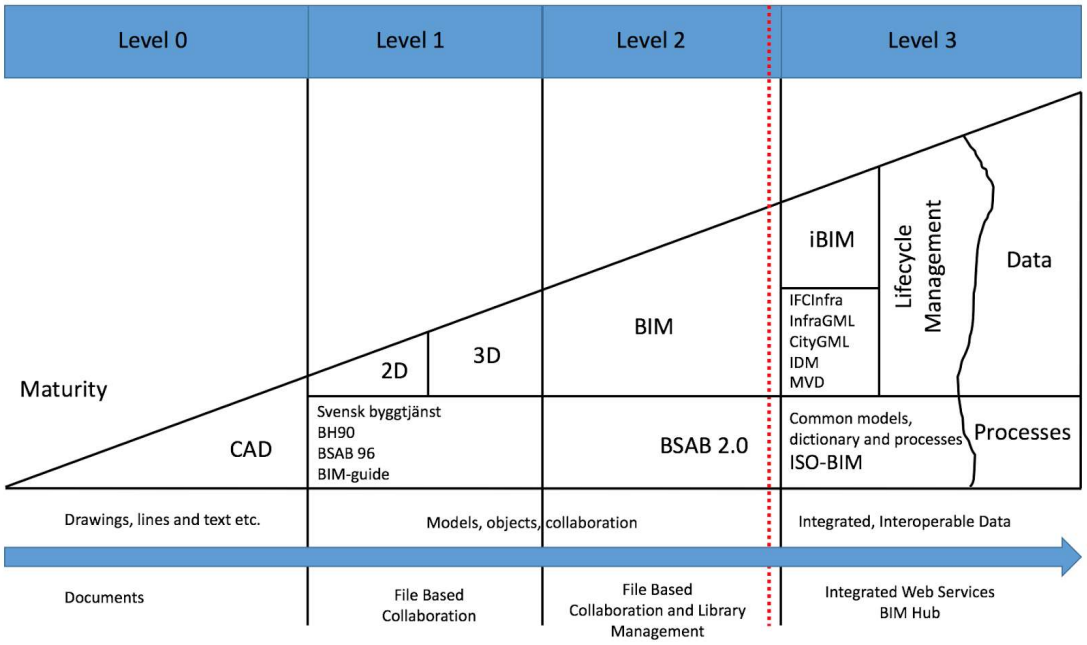

Figure 5 BIM-staircase, remodelled (Trafikverket, 2014a)

Level 0: The first level of BIM, level 0, implicates the use of unstructured CAD and the information exchange is commonly made through 2D-drawings or in digital form such as PDF according to AB 04.

Level 1: The second level, level 1, includes partly unstructured CAD in 2D or 3D where some sort of information standard is used according to requirements set by STA. Further, some visual coordination in a shared data environment should be used.

Level 2: This level is reached when uniformed structured object-based information is used for the project which should follow some requirements set by STA. Further, the projects should be visualised in 3D and integration between parties in one organisation is possible. The information exchange between contract parties is commonly made through interface.

Level 3: In the last level, a completely open process is adopted with structured object-based information. BIM should be present during the whole project life cycle even in the maintenance phase.

4.6.2 BIM guidelines

An interview was held with a BIM-strategist at the STA. This to gain an understanding of the STA's view of BIM. Through the interview, it was mentioned that standard requirements were set in 2015, that all projects must deliver a 3D model

enabling clash control. Today STA works at level 2 in the BIM staircase. However, the BIM-strategist argued that the requirements were not specific enough. By not specifying the requirements it was left for own interpretation by the service provider, and in some cases resulting in unusable models. More specified requirements are what the model should incorporate and the level of detail. Although, it is mentions that the consultants are improving but they must realise the potential of BIM. This being of importance since the STA has the goal of replacing traditional drawings with 3D models, to make reviewing more effective. Furthermore, the BIM-strategist argues that BIM should be considered for the whole project life cycle and that the long-term goal is to reach level 3 in the BIM staircase. Although, mentioning that the ones responsible for the maintenance are not setting enough requirements, which leads to BIM-models that cannot and are not used in the maintenance stage. The BIM-strategist pushes for the requirements of the maintenance to be the factors forming how BIM is used in projects. Adding, that the maintenance part has been outsourced before, but is now taken back to the STA.

When discussing how the role of being a professional client and BIM interfere with each other, it is acknowledged that having a lot of requirements goes against the principle of distancing themselves from how projects should be carried out. Further stating that if too many requirements are implemented this can hamper the service providers' freedom of work thus impact innovation. However, the BIM-strategist believes that the pressure from the STA is necessary as the industry has been too slow in implementing BIM on their own.

Regarding the role of BIM in project with ECI, the BIM-strategist argues that the BIM-model should be a central part to gain an effective information flow in any close collaboration project. Further, the importance of being able to work with the BIM-model in real time during meetings, is also emphasised. Pointing to Concurrent Engineering as a way of integrating all disciplines in an effective way.

The BIM-strategist expressed that one obstacle regarding BIM is the lack of a common classification system in the AEC industry. To solve this issue a new digital classification system has been developed by 150 specialists in the industry called CoClass. STA aims to implement the system in 2018 and include it as a requirement when contracting all service providers. It is believed that the CoClass could solve the communication problems in the industry which are present but also help BIM to reach its full potential as the system is completely adopted for digital modelling. The CoClass system includes all information about the project, through the whole life cycle and will be the vital part for communication between all actors.

5 Result

This chapter presents the empirical findings. The data is analysed, divided, and presented in different themes associated with ECI and BIM and based on the structure of the discussion during the interviews. Below, each theme is displayed, and the findings from the two cases is presented separately. Key findings have been marked in bold to highlight significant findings used in the discussion.

5.1 Conflicting perceptions of roles and incentives

There are different perceptions and expectations on the different roles of the parties involved in the ECI collaboration. Some of this ambiguity is derived from the ECI collaboration and the new professional client role, which is a common theme found in both cases. This has caused uncertainty about different issues regarding which party is in charge and has the responsibility of certain areas. It is a common belief among the interviewees (contractors, consultants) that the professional client role is a step back from collaboration, meaning that the client aims to become less involved in the project. On the other hand, the client organisation expresses that there does not exist any conflict between ECI and the professional client role. Instead the client means that the professional client role is perfect match with the ECI collaboration.

The client expresses concerns regarding the target price, which are connected to the contractor and their incentives. There is a belief that the contractor's **incentives** are connected to making as much profit as possible. Client B mentions that, in regular cases, when the contactor gives a price in competition there are always incentives keeping the price down. The only way for the client to hold down the price is through reviewing and having high competence in order to discuss different solutions, which can be made cheaper. In turn, this requires a high level of contribution from the client in the project. Client B acknowledges this situation and process as a big challenge in an ECI collaboration. Although there are conflicting opinions, both Contractor A and B clearly state that this is not the case and that they sometimes need to defend their view of an ECI collaboration. Three factors defending the contractor are presented, which the contractors argue to be important for understanding their situation and their incentives for achieving the best result possible.

"No one benefits from a miscalculated target price" - Contractor A

Less profit with less risk - Both Contractor A and B clarify that, in close collaboration projects, the incentive is to have an assured profit. Meaning, an acceptance of less profit if it comes with less risk. Having projects generating stable profit is more feasible for the shareholders than having some projects with large profits and some projects with no profit, which are the characteristics of traditional procurement methods.

The biggest client on the market - Both Contractor A and B express that there is no incentive to build an unhealthy relationship with the client organisation, being the most prominent client on the market. Having a reputation about only focusing on highest profit possible is not beneficial for a contractor.

Future of the market - Contractor B believes, with the globalisation of the market, their organisation will never be able to win a tender for lowest price. Tendering for other criteria than price is the only way, for Swedish contractors, to win tenders in the future. If the client were to experience negative results with these kinds of collaboration projects, they will move back to tendering for lowest price. Contractor B further explains that this would lead to *"A slow death for the company"*.

From Client B's perspective, the contractor should like to work in these types of contracts since it will give the contractor a more stable revenue than a design and build contract. But so far in this project the client believes this is not the case, the contractor still makes calculations as usual with different supplement charges.

5.1.1 Case A

The professional client role has in some cases been difficult to relate and connect to the ECI process, since there are **conflicting expectations on roles and responsibilities**. The Design Project Manager A (DPM A) expresses that having a professional client role and using ECI can send two different signals. Using ECI, which requires involvement, and professional client role implying a distance from the project. Contractor A considers the professional client role a step back from collaboration. The DPM A explains that, in the past, the client organisation had more technical design support being able to review what had been drawn, and while the support still is present it is significantly smaller.

Client A believes that ECI requires more involvement from their party as well as the others, and that having a professional role in an ECI collaboration is about being involved in the right issues. Meaning, that the professional client role means that the client should not be involved in every part of the project in detail, instead the focus should be on the right parts. It is more about having the self-monitoring process and determine that the right quality system is used.

All interviewees in Case A highlight the **importance of clear roles** in collaboration projects, and that this must be defined early in the process. Contractor A, DPM A and Subcontractor A finds themselves in a new situation with **more responsibility**. Meaning that they cannot turn to the client for answers in many of the issues which they previously could. Subcontractor A argues that the challenge is to make this efficient, to not find themselves in a situation where no one makes decisions. Further explaining, that at the same time the client wants to have a say in many issues and this can sometimes hamper the design process. DPM A believes that it is easy in this new work process to struggle with the new role and end up in the old and comfortable ones instead. Client A confirms this **ambiguity regarding the roles** of the contractor and the technical consultant, but explains that, overtime, this has become clearer and all members now understand their roles to a further extent. Client A highlights the clash of cultures, where the contractor is used to fast decisions while the technical consultant wants time to analyse and evaluate. Client A believes that it is important for the contractor to take responsibility for the consultants and the subcontractors even though the project is in close collaboration. Explaining that, in the beginning, the contractors relied on the technical consultants to find solutions themselves, but now have realised that they must be more involved and be more governing.

"It took some time getting used to, when going to the client with an issue and getting the answer, "what do you think?" instead of "do A or B" [..] it is a challenge to make this a key to efficiency instead of slowing the process down." - Subcontractor A

ECI puts high demands on the involved actors with the new work ways, and it is important that you not **fall into old roles and traditional work ways**. Contractor A argues that not all involved may have understood the collaboration model, and that these people might only have a single order in the project. Although, Contractor A stresses that all members with greater responsibility must have the right mindset regarding collaboration.

5.1.2 Case B

There existed different views in the beginning of the project regarding how the ECI collaboration should be carried out and what this means in practice. Design project manager B2 (DPM B2) lifts that the client has been less involved in the design phase than expected. This misunderstanding has led to the technical consultants waiting for information from the client. The DPM B2 gives an example from a kick off before the project started where the technical consultants delivered notes to the client with specific information, which were required to get started. The client accepted the notes and explained that the information should be distributed, but no information was delivered. The technical consultant tried to remind the client but no information was given. From that point, DPM B2 argues that it was realised that it was up to themselves to retrieve information. This process consumed a lot of time that could have been used for other things.

Contractor B highlights the importance of having whole organisations understanding new implemented processes, that it is not only clear to the top management who are the ones deciding what processes should be used. The same counts for the contractor organisation, it is important that their whole organisation understands what is expected from the client. Contractor B claims that there is an **uncertainty connected to the incentives** of the different actors in the project, with the example of the client suspecting the contractor to push the target price up and only have the incentive to have as high profit as possible.

Client B acknowledges that it is a situation where the contractor is allowed to calculate a price without competition, which is one of the major disadvantages of an ECI collaboration. Further, that the contractor is unaffected by the target price becoming more expensive. Client B stresses that the contractor has incentives for the target price becoming as high as possible, as the contractor is a private company, therefore driven by profit.

"There is a suspicion in the project where the client believes, not necessarily that we actively try to raise the target price, but a suspicion that we are not actively trying to lower the target price. There is a difference in the nuance, should we work actively towards raising the target price it is worse than if we would work actively to lower it. There is, definitely, a suspicion that we leave stones unturned regarding lowering the target price." - Contractor B

Contractor B connects the suspicion to not having designated enough time in the beginning to **discuss expectations, prerequisites**, and what ECI means to all actors in the project. Further, explaining that it is key to develop a common belief of how the collaboration and the project should be carried out.

> *"It is a very common mistake, you tend to be very quick to start working and solving tasks, when you should take a proper amount of time to thoroughly discuss the softer aspects." - Contractor B*

DPM B1 believes that the expectations on each other in the projects have not been clear enough. That the benefits of ECI, to use each other's knowledge in the early stages, can only be utilised if the expectations and goals are discussed properly.

> *"I enter the project in the belief that I will be a design project manager with certain tasks, but the contractor, who hired me, thinks differently. I might expect certain things from other technical areas that is not apparent to them. With the client, we also have a long journey ahead of us. We have a lot on the table and we are aware of each other's strength, weaknesses, and expectations but we still manage to fall into our traditional roles time after time." - DPM B1*

DPM B1 finds the way the client acts and ECI to be a bit contradicting. Meaning that the client is involved in checking that they deliver what was promised, when it was expected that the client would be contributing towards finding the best solutions possible for the whole infrastructure project and not only the specific case. For example, the client wondered how their technical specialists would be used, which should not be necessary as the client should not need to review to a further extent as they were together in the process. Both DPM B1, DPM B2 and Contractor B push for the client to **shift focus** to the unity of the whole infrastructure project, which are parts out of hands for the consultants and contractor. Meaning, that the client should put more focus on the questions outside the project and provide the right prerequisites for the contractor and consultants to carry out the design and the construction. Further, DPM B2 argues that it would be preferable if there existed an overall plan for the whole infrastructure project when it comes to future maintenance. The best solution would be if the same maintenance systems were used in the whole project, but this is not decided yet. Contractor B stresses the importance of the border issues between the other projects in the area, and if the issues are not properly managed it can become very costly.

> *"Our mission is to make sure that everything we do lives up to the requirements, is of the right quality, and that the technical solutions work. In ECI, you should benefit from each other [...] but the process builds on an open dialogue and being there for each other "- DPM B1*

Contractor B believes that the client pushing for the usage of their own specialists goes against ECI and the professional client role, which both focuses on utilising the competence available on the market. Both Contractor B and DPM B2 argues that the client organisation should have their own project managers and use consultants for technical specialists instead. This, to properly drive the projects through the client requirements. Contractor B sees risk in the clients many hired consultants. Connecting

the risk to the hired consultants not having the same dedication, the same perception of the project, and does not have to take the same responsibility as ones directly employed by the client organisation.

> *"You must dare to let go of the control, that is what I believe, from my point of view. Certainly, the client thinks differently, and you must respect that. But from my point of view, I think that it is a very brave and good decision to carry out the project as an ECI, but you have not taken that courage into the project, to let go of the control to us and our designers. You still want to take part with your own specialists. [...] you have* ***not understood your own role*** *completely. Its new, both the professional client role and ECI is new for the client, of course it is not optimal from the start. It would be strange if it went smoothly from the start when you do something you never done before, in a gigantic project." - Contractor B*

Regarding the new professional client role, Client B expresses that the involved parties tend to **misunderstand the meaning of the new role**. The new role means according to Client B that the client should just be a client and not focus on finding solutions.

Regarding the increased responsibility for the contractor that comes with ECI, Contractor B argues that the new processes that follow are not always fully understood by the whole contractor organisation. Explaining, that their organisation sometimes **falls back into old roles and traditional workways**, and highlights that it is important to understand that in this case the contractor organisation is also the designer and must solve the issues. Client B acknowledge that the contactor is not used to their new role in the design phase and it seems as if they do not know what should be delivered. In regular situations, the client gives the contractor technical specifications which the contractor should calculate a price on. In an ECI project the contractor should both deliver the technical specifications and put a price on construction. This means that the contractor also needs to govern the involved consultants with which contractor do not have a lot of experience. Client B believes that the contractor is not organised for this type of governing.

5.2 Project organisation structure, communication and information system

Through the interviews, it was noticed that both cases have gotten inspiration regarding the design of the project organisation from another ECI project in Sweden. However, the design of the project organisation has been remodelled during the process to fit the needs in the respective case. It was also expressed that there is a lack of guidelines regarding how the ECI project organisation could be structured. This has in turn created uncertainties and ineffective meeting processes due to that in some cases too many participated in specific meetings and in some cases too few. In both Case A and B a common project office is used. All interviewees perceive this as something positive, which facilitates collaboration and the projects benefit from.

5.2.1 Case A

The project organisation in Case A consist in total of more than 330 people. 270 from the technical consultant, 30 from the contractor, 30 from the subcontractor and 6-7 people from the client. There were **no evident guidelines** of how to structure the project organisation, and it has been remodelled during the process. According to Contractor A, they were not prepared for how much work that has been put into structuring the project organisation, making up a communication plan, and finding an efficient document sharing process. Further, DPM A argues that this process has taken a lot of time that could have been used for the design instead and that this can, in the end, impact the surety of the target price.

The collaboration manager in Case A is from a firm outside of the project organisation. This was not the original idea since the contractor had their own collaboration manager in the beginning, but after requests from the client, the collaboration manager was brought in from a neutral company. However, Contractor A mentioned this as something positive due to this party being able to evaluate the project through a neutral perspective.

Subcontractor A argues that everything has been new in the project, with new roles making it difficult to staff after the requirements that are needed. This has in turn lead to that new roles have emerged during the project. Further, DPM A, Contractor A, and Subcontractor A believes that the client organisation lack resources in terms of people in this project. Client A affirms the **lack of resources** and explains that the client organisation cannot cope with the workload derived from the ECI collaboration.

Communication has been an issue according to all interviewees in Case A. This is believed to be partly due to the large project organisation, where four different organisations with different in-house communication systems are collaborating. Some of these communication issues are solved by **co-location** through the use of a **common project office**. Even though the common project office improves collaboration and makes communication more efficient, it brings issues. One of them being information not always distributed in the intended way. DPM A gives the example of rumours that are easily spread across the different organisations during coffee breaks. Contractor A gives another example where issues are solved during coffee breaks, although the decisions are not efficiently distributed to the whole organisation.

> *"Issues that are solved at the coffee machine must be mirrored to the rest of the organisation. All decisions and notifications must be documented in protocols or decision logs, you cannot have verbal distribution with a project organisation of this size" - Contractor A*

Many of the client **routines do not fit ECI** since they are derived from previous projects. Contractor A gives the example of the information sharing system that is used in the project, a system that is provided by the client, is insufficient and not user friendly. Stressing, that documents from meetings were hard to find in the system which in turn could harm that information distribution.

All interviewees in Case A firmly believe that the **common project office** benefits the project greatly as it makes communication more efficient. Client A lifts that the

common project office has improved the communication and enables shorter decisions routes. Although, all interviewees also agree that the common office was provided too late, and that there would have been more beneficial if it were to be provided earlier in the process. Contractor A, further argues that the collaboration could have been made even more efficient if the office could fit more people.

Issues regarding communication during meetings were lifted in the interviews. In the beginning of the project the meetings were attended by almost everyone due to people not wanting to miss anything, resulting in ineffective meetings. With the project organisation growing, work meetings tended to become information meetings, it is important to have the right size on the meeting forums to keep them efficient. Contractor A explains that the meeting system had to be adapted as the process carried on. DPM A lifts up that it is important, regarding information distribution, that the right people attend the right meetings in order to get a smooth process.

5.2.2 Case B

The project organisation consists of around more than 190 people, 6-7 people from the client organisation, 35-40 people from Contractor B, 45 from Consultant A, 97 from Consultant B and a couple of other consultants from smaller firms.

It has taken some time setting up the structure of the project organisation which has resulted in a lot of administrative work. Some experience has been used from the ECI project abroad but there **exist no guidelines** how to best perform an ECI collaboration according to Client B. DPM B2 makes the same point that the project organisation has not been based on any guideline it has instead been developed during the process in order to suit the specific project. Although, DPM B2 argues that one important actor who are missing in the project organisation is the subcontractor responsible for the rail - and signal system works.

DPM B1 highlights issues at the client organisation when higher level management decides certain things and the **decisions are not implemented throughout the whole organisation**. For example, if the client organisation has a project manager that is not open to using models, it will not be used. Additionally, the client organisation hires several consultants in many roles making it even more difficult to make everyone work in the same direction.

DPM B1 argues that the client organisation is **lacking resources** to an extent that was not expected. However, Contractor B argues that this is not completely the case. Explaining that the client has few members sitting together with them in the common project office, but several specialists placed elsewhere.

> *"They are few placed up here, which is our contact area. Then they have hundred specialists one floor down. It depends how you count, if they are too many or too few in their organisation. "- Contractor B*

DPM B2 lifts the importance of having the right person at the right place in the project organisation. A person that is very into calculations but **lack communicational skills** should not have a collaborative role in the project. Further, DPM B2 argues that people were chosen to the project organisation based on their

experience and knowledge to manage the many complexities in the project. Moreover, DPM B1 believes the involvement from the project members is more based on their personality than the contract form and that more responsibility is motivating. Contractor B stresses that it is important that everyone is **willing and is suited to work in collaboration**, when carrying out projects with extended collaboration. Facilitating the collaboration through out of work activities has been a strategy, however not everyone participates in these activities, according to DPM B1.

Contractor B mentions that having a common office is not a prerequisite for the project but it does facilitate the collaboration. DPM B1 argues that the **common office was provided a bit late,** and did therefore not get the right connection between the collaboration management and the project management in the beginning.

5.3 BIM usage and promotion

The interviewees in both Case A and B highlight the importance of BIM and the possibilities that follow. It allows for more efficient communication, facilitating collaboration. Further, all interviewees believe that BIM and ICT tools is the future and required for the infrastructure industry to become more effective. BIM is also seen as a work process that can attract new talents and employees to the construction sector, since, one of the big problems for all construction companies is the staffing issue. BIM is a way of increase the status in the AEC industry.

5.3.1 Case A

DPM A sees no disadvantages with BIM and explains that it is a way of describing the project in a better way than before. Client A confirms this and highlights that the BIM model is a useful visualisation tool for design meetings. Further, Client A believes that BIM simplifies for subcontractors who might not be looking into CAD-files from consultants, but can easily check in the model if there are complications.

Client A highlights that all actors have seen the **value of using BIM**, and that it might be derived from ECI as it requires efficient communication with the close collaboration and the many parties involved. Although, the value of using BIM in comparison to the cost is difficult to estimate. Contractor A and Subcontractor A explain that they see value in using the model when making calculations for the target price, but that it will not be used in the construction phase completely to the extent that is possible.

The BIM usage had to be adapted to the BIM requirements from the client. Client A indicates that it is important to be clear from the start what aspects of BIM should be used, to assert that it is implemented throughout both stages of the project. However, Client A state that maintenance does not have any BIM demands, causing BIM requirements **not to be adapted to the whole project life cycle.** Having a common BIM model for all the parts of the infrastructure project is desirable, according Client A. This requires the different models to be linkable, which in turn requires even more specific requirements on the usage of BIM from the client.

The BIM model in Case A was provided from the technical consultants, and the software was developed by them as well. The BIM software is connected to a cloud service, which everyone in the project has access to. Further, the model is connected to a time schedule and cost is going to be connected to some extent as well. Contractor A stresses that the use of BIM must result in data useful for the construction phase. An example is provided, of having the excavation data going directly to the machines which in turn can report back what has been done. This is supported by DPM A who pushes for more automotive control with the use of BIM.

Consultant A partially delivers rough design drafts and price calculations are based on what is delivered. A delivery was received by the contractor before Christmas 2016 and the next and last one was received 1st of April 2017. It is further explained that everything is available in the BIM model and that price calculations are based on the model and that without the model, the calculations would have taken a longer time. Contractor A did not expect that the deliveries made by Consultant A were possible and that they have made several budget check-ups based on this, which was believed to be impossible to deliver.

All interviewees in Case A acknowledge that the **adoption of BIM can take time**, because of the old workways that must be changed. It is a **cultural problem**, that not all project members can handle the BIM models and are not interested in it either, and that this is more common with project members who mostly have experience with traditional work ways. Regarding the promotion of BIM to the project members, Client A clarifies that there are courses for those who want to learn more about BIM in the project and how it can be used. Client A believes that it is important to introduce how BIM can facilitate the process and how it can be used in an easy way, showing that BIM can be user friendly. Subcontractor A highlights that they had **no previous experience of working with BIM** but still found BIM to be a useful tool for illustration and information sharing, and that it simplifies clash control. It is also claimed that it was easy to understand and that no extra courses for the employees had, to this point, been needed.

5.3.2 Case B

DPM B1 and Contractor B see major advantages with BIM connected to the way it creates a common picture of the project for all involved, **facilitating the collaboration.** DPM B2 argues that BIM is a great tool to control different conflicts between installations.

Project Studio is used in the project, which is a meeting structure and place that is held once a week where the responsible from each technical area is present. It is further explained that the **model is not used as much as expected during the Project Studio**. DPM B1, argues that the reason behind the lack of model usage during the Project Studio is linked to the project being in the early stages and therefore there are many other issues that are being discussed. Issues regarding the model are discussed in the Model Studio, which is a meeting held the day after the Project Studio. Here the ones responsible for the model from each technical area meet and goes through what was discussed during the Project Studio. The model is updated once a week after designs are provided from the technical consultants.

There is a predominant positive attitude towards BIM, but there is always **resistance**. DPM B2 express that a lot of individuals in the project do not possess the necessary skills when it comes to digital tools**.** This has led to that some people tend to not use the BIM model and in some cases people do not even know how to open the software. Instead they use the old workways with 2D drawings. Even though it is explained that, in this project, the BIM model has higher contractual ranking than paper drawings.

> *"There are always those who believe it is enough to just make a drawing on a napkin, they are schooled that way."* - *Contractor B*

DPM B1 admits to only using the BIM model to get an overview, not using the model to a further extent. DPM B2 lifts up that it takes time to build up the 3D model which makes it quite expensive. This means that it is more preferable to just put in the right things in the model rather than everything. BIM manager B explains that you do not want to put something in the model if it must be removed or changed later. DPM B2 pushes that, in this case, the old workways are faster and cheaper when it comes to changes in the design phase.

> *"It is much easier for me to review quickly on paper. Using the model is very easy in practise, but when I'm pressured in general I want it to be as it always has been, still I'm a whole lot younger than most in this project."* - *DPM B1*

Both BIM manager B and DPM B2 argue that **the model must be central**, that sections etc. must be exported from the model. It is further explained that this is a process that must be more implemented and understood among the project members. BIM manager B explains that not everyone in the project is using BIM, but that they are **pushing for everyone to use BIM**, which have given results. Through surveys it was found that project members' tendency to use the model instead of regular drawings is increasing.

> *"Now people come to us, telling us 'can't you show us in the model, it is much easier to see there' but the first time they saw the model they could not understand anything 'what is and what isn't concrete?'. It is difficult in the beginning, but it is a process that you have to get used to."* - *BIM manager B*

DPM B2 pushes for more implementations, that it would be great if the BIM model were connected to a timeline to be able to follow and review the progress of the designed construction phase. The cost factor is not integrated in the model yet. BIM Manager B explains that the time aspect is not currently in the model, although it is going to be added, the same goes for the cost aspect.

5.4 ECI: advantages and obstacles

The attitudes towards the concept of ECI is predominantly positive, with increased commitment and learning for the involved actors. Most issues presented are connected to inexperience of extended collaboration. It is believed that dealing with the problems at this stage will make up for a more efficient second stage.

5.4.1 Case A

Consultant A lifts up that the great advantage with the ECI process in the design phase is the **buildability inputs** from the contractor. Since the involved consultants tend to not have worked with production they sometimes miss the whole pictures when designing. DPM A explains that in normal cases technical consultants make design documents and two years later the same documents will be used in the production stage when constructing. In these cases, the technical consultants often do not get any kind of feedback from the contractor but now in an ECI collaboration the contractor gives direct feedback to the consultant regarding buildability. All interviewees in the case experience the direct feedback as very positive and that it contributes to increased buildability.

> *"I think it is very stimulating for the designers to get feedback faster, I also believe that you put in more effort to not get the 'do like this instead' from the contractor." - DPM A*

Contractor A also lifts up that the involved parties **learn a lot** from each other in an ECI process as there is quick feedback and an open dialogue between the different organisations. Explaining, that this pushes and develops the whole AEC industry in a new and more efficient direction.

> *"If you work two years in an ECI project, you learn as much as four years in a traditional project, you learn the buildability parts very quickly." - DPM A*

Regarding the collaboration between the different organisations DPM A discusses that it feels like everyone involved in the ECI belongs to a small company itself, where everyone works together to reach a common goal. The ECI collaboration **increases the commitment** from the involved parties, which can be connected to a "pioneer" feeling since ECI is new in Sweden. It is further described by DPM A that the worst kinds of projects are the ones where there is a hostile "us versus them" attitude.

> *"Together in the group, consisting of the client, the subcontractor, and the technical consultant, we are supposed to come up with designs to price. It puts demands on all actors involved but also on the individuals, as there is no one to ask for help, other than the ones in the group where we are placed." - Contractor A*

Client A highlights the major benefits of ECI, in this project, has been the new solution that was more efficient and more secure to build. This caused the original drafts to be scrapped, and if the contractor would have been **involved earlier**, a lot of money could have been saved. It is further explained that the original drafts were drawn before the use of ECI was considered. Subcontractor A acknowledges problems with this. Arguing that the time it has taken to start over with the new solution is affecting the level of detail of the designs, since the end date for the first stage is not changed despite the new solution.

> *"That's the biggest advantage I have seen with the ECI contract. That we have a completely new solution [...]" - Client A*

Time pressure has been present during the project's first stage. DPM A argues that there has been a **lack of time** when it comes to finding intelligent solutions with the help from the feedback. More time in this stage would been preferable in order to collaborate even more on certain issues. The deadline for the target price, that has been confirmed to 1st of June 2017, has been difficult to change. DPM A expresses that the Client did not have the whole perspective when setting up this deadline, that four different organisations should collaborate in a new way. This resulted in that a lot of time in the beginning of the project was wasted because of the new situation. For instance, it took about 3 months before the common project office were established and the involved parties could start collaborating the intended way. On this the client did not have any form of completed manual regarding how the project should be performed and organised which took time from the design work. Contractor A argues, in hindsight, that they would have involved more experts regarding document distribution to establish routines around the project much faster.

Contractor A stress that compared to a traditional project the ECI project in Case A does not have any technical specification document which the contractor can put a price on. Together with the other parties this should be developed. Contractor A argues that this puts a lot of **pressure on the project organisation** and all people involved as there exist no party that have the solution to all issues. Further, finding the work environment stressful due to the ambiguity in the project. However, Client A believes the **major advantages with ECI will occur in stage 2** since all the issues causing stress will most likely be resolved.

DPM A highlights the importance of clarifying what work ways should be used in stage 2 as no involved party know how changes should be managed. For instance, if something unknow appears in the ground during the construction phase. Although, DPM A acknowledge that this can happen regardless procurement method but the interesting question is if the ECI way of thinking will be used or if every party fall back to more traditional roles.

The importance of ECI was expressed by Contractor A, that it would be difficult to carry out the project without the ECI process due to the complexities that were involved in Case A. This is highlighted by all interviewees in the case. DPM A believes that **ECI suits complex projects** in need of intelligent solutions. Subcontractor A expresses the same feeling and states that ECI suits bigger projects and not smaller where the cost can become higher than the benefit.

Contractor A believes that there will be more ECI projects in the future. With hopes from their organisation that the **experience from the project** makes them more attractive on the market. Partly to win contracts, to provide a safety for the client that they understand the concept of ECI, and that they help to evolve the market. Contractor A believes that experiences from ECI can be useful in other projects as well, even if ECI is not used.

> *"**ECI does not only develop our organisation**, it also develops the other involved as they are a part of the processes. I also believe that it develops the parties in other project that are not ECI, you get a better understanding of each other's roles and tasks. [...] When placed in other projects, there is an*

understanding of the challenges the other actors have and allows you to help them instead of blaming them for not doing their job." - Contractor A

5.4.2 Case B

All interviewees in Case B see major **benefits in involving the contractor,** allowing them to influence the project in the early stages. Contractor B connects the benefits of ECI to the short decisions routes. Explaining that by being involved, working together, and being able to contribute to the design, it is possible to achieve more production friendly and cost-effective solutions immediately. Having the production perspective is especially favourable in this project since the buildability aspect is one of the major issues of the project. Client B mentions that it would be preferable to have Contractor B involved in the project even earlier. On the other hand, Client B stresses that if ECI in the end of the project results in a higher price than a Design build contract, there is no meaning to continue using ECI. Contractor B hopes that the client realises the potential of ECI, that you **cannot expect it to work flawlessly the first time** and continue to use extended collaboration in future projects.

" In the end, it is all about the cost and if we could build the project cheaper with a design and build contract, why should we use an ECI contract then?" - Client B

DPM B1 mentions that it also is beneficial for the contractor that they learn from other actors regarding work ways and procedures. Both BIM Manager B and DPM B1 concludes that you **learn a lot** from each other, and you get a product of higher quality. DPM B2 believes that ECI is a winning concept when everyone understands their role and responsibility. It leads to the project being exciting and developing because of all different competences working together in a collaborative environment. The common project office is necessary to achieve this, thus making it possible to carry out this type of collaboration project.

DPM B1 experience difficulties regarding the collaboration, since almost no one is used to it. Contractor B states that the **ECI collaboration is not working optimally** at the moment, and that there are areas of improvement. Contractor B explains that the ambiguity of the project creates frustration and stress at the project members. Although, DPM B1 believes that having to deal with these problems now will result in a more efficient second stage of the ECI process.

"If you have a lot to do, you can often make a to-do list to get a better overview of what you have to do. Many tend to work like this, 'Okay, I have a lot to do, but I have put it down on paper, and now I start working and crossing things off the list', but in this project, making a to-do list have not really been possible due to the ambiguity of what the goal is and what we are supposed to deliver in the end, it creates frustration." - Contractor B

"We will experience many benefits in phase two. Because then we will have done correctly from the beginning and already have taken the blows from this way of working." - DPM B1

It would be beneficial to have **more communication between the projects** presented in the case study, according to Contractor B. Explaining that having structured meetings between the projects, where experience regarding the ECI process can be shared and through that be improved.

> *"Have they found a clever solution, how to do certain things or how to work, not the technical parts but the process. Then we should not sit here and waste time on inventing the wheel over and over."* - *Contractor B*

6 Discussion

The following chapter presents the discussion and analysis based on the empirical findings in the previous chapter and how it is related to theory. Although, the analysis is partly done in the result section as well.

6.1 Bridging the perceived roles and expectations with ECI

Theory lifts that clear requirements and expectations from the involved parties will impact the efficiency of the design phase (Mosey, 2009). Both openness and flexibility from the project members are required. Through the case studies it was found that a lot of uncertainty regarding project roles and responsibility has been present which has hampered the ECI process. It was expressed that the benefits from ECI, in terms of sharing knowledge between the involved actors in the design phase, could only be gained if the expectations and different goals were discussed and solved. Further, it was expressed in the case studies that not enough time had been used in the beginning of the project to discuss different expectations and what ECI means for everyone involved. It could be suggested that if more time was spent in the beginning of the present project, i.e., managing the uncertainty, these issues would not be present to the same extent. Although, it should be mentioned that the case study projects are the first ECI projects for all the involved actors, there is no experience of ECI in the project organisations. This might explain the unclear roles and expectations. At the same time, this adds to the argument, that due to inexperience, there should have been focus on finding a common ground in the beginning.

In the case studies, there is a belief that the professional client role and ECI are contradictions. Where the professional client role means distancing themselves from the project, and ECI requires more involvement. However, the STA claims this is not the case, that the professional client role and ECI are a perfect fit. Meaning that being a professional client is about being very much involved, but in the right parts of the project, with more focus on the unity of the project than technical details. Literature (Wondimu et al., 2016) describes that client competence and involvement can influence the efficiency of the ECI process. Where having both technical competence as well as procurement competence, and being more involved as a client is a success factor. Theory pushes for the client to provide clear requirements and expectations in an ECI project. Further, clients who do not wish to participate in the project, and only state their performance requirements leaving the design and construction up to the contractor to solve, should not consider ECI as a suitable contract (Mosey, 2009). Thus, depending on how the professional client role is viewed, it could either be a perfect fit or a mismatch for ECI. It could be argued that if the professional client role is carried out in accordance to what is described by the STA, it should fit ECI. Furthermore, several actors from the case studies are pushing for the client to focus on the entirety of all the combined projects in the major infrastructure project. There are different opinions regarding what the role of the client should be and what the client should bring to the ECI collaboration in terms of providing information infrastructure as well as resources. Theory falls short regarding what specific tasks the client should have in the ECI process. However, Wondimu et al. (2016) are explicit when it comes to having clear roles and areas of responsibility, and have a properly defined scope. It could be the case that the client has a clear role although not enough resources to

carry out the tasks. Further, since literature implies that the client offering technical competence is relevant, this should be considered. However, as there currently is an ambiguity regarding the professional client role in relation to the contractor and consultant's role, it becomes relevant to create a common view.

In the case studies, ECI has introduced the involved parties with new roles and new responsibilities that everyone is not comfortable with, as this often tends to mean new areas of responsibility which the client used to govern. It is further explained there is a tendency for project members to fall back on more comfortable and traditional work ways and roles when there are setbacks. In other words, there is not only ambiguity regarding the client role, but the role of the other actors as well. This calls for discussing and clarifying the roles and responsibilities for the other actors as well. Therefore, considering the roles and responsibilities of all actors, it might be beneficial to have an external collaboration manager throughout the ECI process. One who can evaluate the collaboration without biases and can assert that the discussion of roles, responsibilities and expectations of all actors are considered.

Further, both theory (Mosey, 2009) and empirical findings state that a very important factor in an ECI collaboration is to have the right person on the right place, since collaboration tends to fall back to personal chemistry when choosing project members for the project team. Meaning that it is important that people who do not fit in the current project organisation should be replaced and repositioned in order to achieve a good ECI collaboration. This adds to the argument of having an external collaboration manager who can help set up the project organisation. An external part who sees to what is best for the collaboration, and who can replace dysfunctional project members more easily.

6.2 Gaining the benefits of ECI

Literature (e.g., Mosey, 2009) acknowledges high transaction costs for setting up an ECI collaboration, which can hinder the ECI implementation if not everyone involved believes that it will pay off in the end and accepts the transaction costs. This situation has been evident in one of the case studies as the client is not sure if the ECI project will become less expensive than a design and build contract. In the case studies, no guidelines for ECI exist, and there are concerns regarding the current routines and information sharing systems set up by the client, since most are derived from previous projects and therefore do not fit the ECI process. Further, an unpreparedness of the workload needed to set up the project organisation and information structure was found. It could be viewed that not enough time has been spent to properly set up the ECI collaboration. This has affected the collaborations in the case studies in several ways. Firstly, soft aspects such as expectations on one another have not been properly discussed, which has led to uncertainties regarding the incentives and expectations. Secondly, the information sharing systems have not been proficient for the projects in the case studies. Currently, there is a belief in the case studies that the ECI collaboration is not working optimally at the moment. Although, it is also believed that dealing with problems connected to the collaboration now will result in a more efficient second stage of the ECI process. This conforms with what theory describes as a major benefit of the different collaboration forms, dealing with problems early as they are cheaper and more easily managed in the early phases of projects (Eastman et al., 2011). Therefore, this supports that ECI must be considered as a long-term

investment by the involved actors, that the benefits of ECI are gained as the process continues. In other words, daring to put up with more costs in the start of the project will result in more value in the end.

Wondimu et al. (2016) stress that in order to achieve success in an ECI collaboration much depends on how early the contractor is involved in the project and the best option is to push the contractor involvement early enough. Meaning that the contractor should be involved not too early and not too late, even though Wondimu et al. (2016) does not specify when the contractor should be involved in more detail. It could be argued in the case studies that the responsible contractor could have been involved even earlier. The STA organisation pushes that the most important factor of an ECI project is the need for an extensive background investigation. This investigation should be done to identify the complexities and uncertainties in the project and based on the findings a project organisation should be established. It could be argued that in connection to this, there should be discussions when it would be beneficial for the contractor to enter the project in order to get as much value to the project as possible. Therefore, it is relevant for future ECI projects to reflect on when the contractor should be involved in the project, and based on the case findings it might be beneficial if the contractor is involved earlier.

The knowledge and competence input from the contractor in the case study projects has been seen as something very positive from all involved parties in the case studies. This clearly conforms with literature (Rahman and Alhassan, 2012), pushing that one of the biggest advantages with the ECI is the contractor competence input to increase the buildability of the project. For instance, in Case A, the technical specification documents were scrapped due to the contractor presenting a more efficient and safe way for the project to be built. This indicates that the ECI benefits the case study projects in terms of buildability. Hence, early input from the contractor may detect changes that prove to be essential to the extent that the project would otherwise not be buildable and thereby result in both time and money savings. This, since the changes would then be necessary regardless of the procurement method and therefore have happened later instead, resulting in the changes becoming costlier. Furthermore, since theory (Rahmani et al., 2013) acknowledge that ECI is about involving key competence in the early stages of the project, Case B could miss out on important construction knowledge as the rail and signal system contractor is not involved at this stage. This conforms with what was found in the case, where uncertainties were derived from not having the information related to the rail and signal system works.

The competence exchange between the actors is not only distributed into the project organisation and the project itself. In the case studies, several interviewees argued that an ECI collaboration is an intensive learning process which pushes the whole infrastructure industry forward. Meaning that competence on how the different actors perform their tasks is also shared between the involved organisation. For instance, the consultants learn how the contractor works in a much faster way as direct feedback is provided constantly. Therefore, it could be suggested that the close collaboration which the ECI process represents has the possibility to increase the understanding between different actors in the infrastructure sector.

Literature calls for efficient information sharing in an ECI collaboration (Mason and Brook, 2015). The case findings describe issues with the information sharing that have been present in the project related to the common project office and information sharing system. Referring, for example, to the coffee breaks where rumours are being spread and issues are being solved, but the decisions are not distributed properly to the rest of the organisation. It could be argued, that having a functioning information sharing system suited for the ECI collaboration and the use of a common project office, could minimise rumour spreading and allow for decisions to be more easily distributed. By not having the proper infrastructure to allow issues to be solved during coffee breaks, the common project office loses some of its purpose. Therefore, providing an efficient way of distributing information and decisions that perhaps were not made at an official meeting increases the benefits of a common project office and should also facilitate the ECI collaboration.

Rahman and Alhassan (2012) argue that commitment and engagement from the involved parties will impact the performance of the project. In the case studies, it is indicated that the engagement has been high in the project organisation which should be seen as something positive. It was also found that the high engagement could be connected to the ECI process itself since the new way of working established a pioneer feeling, but also that the close collaboration was seen as rewarding and enjoyable.

6.3 Barriers towards BIM implementation

Wondimu et al. (2016) stress that proper competence of the actors is important in an ECI project, and a certain experience is required. Therefore, project members from the involved organisations have to possess this experience. In the case studies, it was described that the project members from the different organisations were partly of a senior rank. Further, cultural issues regarding the use of BIM was described, where it was argued that the more senior members of the project organisation were the ones more unwilling to use the BIM-model. Gu and London (2010) highlight cultural issues hindering the implementation of BIM. Therefore, it could be argued that the requirement of more senior project members with experience in an ECI project is hindering the usage of BIM, as it brings forth cultural issues as more senior members tend to be less willing to use BIM-models. The cultural issues could also hinder the ECI process and therefore the potential synergies to BIM. Since senior project managers can be stuck in particular types of project management and might have difficulty seeing new possibilities to facilitate collaboration and information. This brings the discussion that more senior members might not always be the best project managers for new collaboration methods and ways of working.

In the case studies, it is described that maintenance aspects of the infrastructure are not considered in the BIM-model, resulting in BIM not being considered for the whole project life cycle. This does not align with theory, elevating BIM adaptation in the whole project life cycle to reach efficiency (Yan and Damian, 2008). Furthermore, it does not align with the overall goal from the STA to establish BIM throughout the whole project lifecycle. Although, in the case description it is presented that the BIM requirements are derived from the STA's BIM staircase, where they place the BIM usage in the case study projects on level 2 bordering level 3, see Figure 5. BIM through the whole life cycle together with integrated information management are

some of the aspects considered at level 3. In the case studies, there are complaints regarding the lack of maintenance perspective, as well as complaints regarding the information sharing system not fitting the projects at hand. It could be argued, having a functioning information sharing system in combination with BIM could make for a more efficient project. Further, by also involving the maintenance aspect, BIM could support the development of the industry as well as the competences of the project members and the STA. Although, it should be considered that there is a general lack of experience in using BIM through the whole lifecycle in the Swedish AEC-industry, and not only in the infrastructure part. For future projects, involving the maintenance aspect must be considered to fully integrate BIM throughout the whole lifecycle of Swedish AEC projects.

Azhar (2011) pushes that BIM is something more than just a software which can be the interpretation in the construction industry. BIM is a process and hindrances with BIM implementation are connected to management issues rather than technology issues (He et al., 2016). The success of BIM is often related to how the project organisation works where BIM experiences among the involved actors is something important. It was found in the case studies that various kinds of management issues are present in the current project organisations in both Case A and B which hamper the BIM process. Further, many of the involved actors in the case studies have little or no BIM experience at all, which also will impact how effective the BIM process will proceed. Even though BIM has been on the market for a while, the infrastructure industry has been slow in implementing it. The STA began to set BIM requirements on all their projects 2015, which might explain the inexperience regarding BIM. Sebastian (2011) describes barriers connected to the learning process regarding BIM implementation, were evident proof of more efficiency is necessary to promote the BIM usage to project members. In the cases, the BIM managers were focusing on promoting BIM to the project members, which had been successful. This conforms with literature (Sebastian, 2011) which lifts up that management is needed to improve the project members' BIM skills. However, it could be argued that the full implementation of BIM was far from reached since, for example, many still relied on 2D drawings. Further, by continuously promoting BIM, the potential can be realised and allow for further utilisation, aligning with the STA goals of BIM.

6.4 Creating synergies between BIM and ECI

The use of ECI in the cases has resulted in a gathering of the many key competences in an early stage of the projects. Theory describes issues in using BIM as a collaborative framework, and that this is a major obstacle for full BIM adaptation (Porwal and Hewage, 2013). IPD is presented as a way of facilitating the collaborative aspects of BIM, as it has the focus on creating a collaborative environment where key actors in the project are involved in the early design stages (Porwal and Hewage, 2013). Therefore, it could be argued that ECI facilitates BIM as it creates a similar collaborative environment as IPD does. Further, according to Mason and Brook (2015), BIM facilitates ECI through the rapid information exchange that it provides, which is needed to create value in an ECI collaboration. Potential synergies between BIM and ECI should be considered as ECI facilitates BIM, and BIM facilitates ECI. These synergies should be present in the case study projects, since it is mentioned that the value of using BIM is realised as it provides efficient

communication, which is said to be required in ECI. At the same time the collaborative setting of ECI is allowing for further BIM adaptation.

Through the case studies, it was found that there are uncertainties regarding the incentives of the contractor. With the client believing the contractor is working as they would in a more traditional contract, trying to achieve the highest profit possible from the project. Meanwhile, the contractor explains that this not the case, providing several arguments why this assumed incentive is not beneficial for them. Proper contractor compensation is, according to literature (Wondimu et al., 2016), another success factor of ECI. Promoting the use of a target price, providing a win-win situation as it communicates trust, risk sharing and efficiency. The client is uncertain that the use of a target price is always a win-win situation as the contractor is allowed to calculate a price with no competition, leaving them with no incentive to keep the target price down. These uncertainties could be derived from a lack of trust between the client and contractor. Literature (Wondimu et al., 2016) describe high trust as a success factor in ECI, leading to more openness and communication making the client more willing to give responsibility to the contractor, allowing for more contractor contribution. It could be argued that the involved actors in the case should focus on building more trust among each other, facilitating openness and communication. Having the actors' incentives clear and understood will lead to a more efficient project, as the focus can be shifted from adversarial conflicts to what actually is the aim of an ECI project, to benefit from the knowledge of the contractor. Further arguments could be made, that BIM is to some extent filling the trust-gap as it provides, according to theory, openness and communication through the transparency of the model. By promoting BIM and its possibilities, trust issues might be manageable by simply having an extensive model used in the intended way, facilitating open communication.

Moreover, Sebastian (2011) also describes problems with BIM, often connected to the traditional workways which tend to result in adversarial relations between actors. It could be argued with the support from theory that ECI has the possibilities to reduce this conflicting situation by promoting and facilitating the collaboration process. Thereby, it could be suggested that ECI helps the implementation and usage of BIM by making the involved actors to aim for the same direction.

Tjell and Bosch-Sijtsema (2015) state that co-location has the ability to support and facilitate the use of visual means such as BIM. It was found in the cases that this type of extreme collaboration in the ECI process are used, as common project offices are provided where all vital actors work together as one project organisation. It could be argued that this co-location which have been established has great potential to promote and facilitate the use of BIM. Further, it was found in one case that project studio is used in one of the projects, which is similar to the concept of ICE meetings (Garcia et al., 2004). Even though there exist good conditions to use BIM as a central part in the project studio it was found in the case study that the BIM-model was not used as much as expected. It could be argued that the co-location together with BIM and the project studio bring major possibilities that if used to its full potential, will lead to what theory describes ICE to delivers, a product of higher quality with less failures (Garcia et al., 2004).

It could be argued that ECI has the possibility to integrate the cost aspect further into BIM. The cost aspect is integrated indirectly since the contractor, during the early design process, makes calculations on what is designed in the model in order to reach a target price. It could suggest that the cost aspect is present in the BIM process even though it is not directly stated in the model, since design changes due to cost are now more likely to be made. Compared to a BIM project without ECI, a design and build contract, the contractor makes calculations and gives insight after the design phase thus not involving the cost aspect to the same extent and allowing for more detailed design changes to be made based on cost.

The STA organisation argues that they have the responsibility to push the AEC industry forward when it comes to increased innovation and efficiency since they are the biggest client on the Swedish market. To push the BIM usage forward in the AEC industry STA decided in 2015 that every new project procured should have BIM requirements. However, Vass and Gustavsson (2017) acknowledge different challenges for a public client to act as change manager when it comes to BIM. A major challenge being the lack of a common view in the need for and the benefits of implementing BIM. Further, the challenges are connected to creating incentives, creating new roles, include maintenance department and providing education and learning. These challenges need to be managed before STA can act as a change manager and change the work processes and practices in the AEC industry. Despite the challenges, it was found in one case that Subcontractor A who never had worked with BIM before, was introduced to this new way of working through the ECI contract. This indicates that ECI can promote the implementation of BIM in the AEC industry since this collaboration form includes a lot of actors in the process. It can be argued that through ECI, the STA can accelerate BIM implementation to the AEC industry. Moreover, ECI and other extended collaboration forms may have the possibility to include the maintenance aspect into the collaboration process making BIM and the life cycle perspective more reachable.

6.5 Recommendations for the case study projects

Based on the projects in the case study there are recommendations that might improve the ECI and BIM situation in the Swedish context. It is evident that there must be a focus on managing the collaboration, to create an environment suitable for an ECI collaboration and BIM processes.

- Clarify roles, expectations and responsibilities in the project organisation. Since this has not been properly discussed prior to the start of the projects. These are, for instance, expectations on each other, expectations on ECI, incentives, areas of responsibility, etc. Further time should be spent on developing a project organization structure fitting the specific context.

- Managerial issues tend to fall back on personal chemistry, which lifts up the importance of having the right person on the right place in the project organisation. This selection of people should be done in a very early stage of the project, based on the level of uncertainty and complexity. An external collaboration manager can provide a neutral perspective, allowing it to be done without partisan influence.

- BIM should be the central part of the project to solve communication issues and create trust as it provides transparency through the model. BIM should be interpreted as a process which promotes an integration between project stakeholders. Further, in order to reduce cost during the operation and maintenance phase, BIM should be considered for the whole project life cycle.

- The co-location opportunity should be used when possible to its full potential when it comes to BIM usage. A common office should be provided early to start the collaboration process as soon as possible.

- The Client and all stakeholders involved in the project should gather the information acquired from the ECI project and take advantage from all the knowledge gained for future ECI projects. This can hopefully improve future ECI projects, since they do not need to start from scratch again.

7 Conclusion

This master's thesis investigates how ECI and BIM function together in a large Swedish infrastructure project. Through a qualitative multiple case study covering two ECI projects where BIM is used, it can be concluded that BIM and ECI can both facilitate and hinder one another. Further, there is a need for managing the collaboration to bridge the different perceptions of ECI and unclear roles in the projects, which are hindering both BIM and the ECI process. This master's thesis highlights the managerial aspects in need of consideration for achieving successful ECI projects where BIM is used.

What are hindrances and possibilities using ECI in Sweden?
Hindrances found in the case study can be connected to the involved actors having no experience of ECI. No clear guidelines for communication and project organisation structure existed to manage the inexperience. From this, unclear roles and expectations have emerged leading to project members falling back to more comfortable and traditional work ways, less suited for the ECI collaboration. There is ambiguity regarding the roles and responsibilities of all actors, which must be managed to achieve an efficient ECI process.

Contractor input during the early design phase can be confirmed to add value to the project since competence regarding buildability aspects is considered at this stage. In order to achieve as much value as possible from this competence, the contractor should be involved early enough in the ECI project. Case study findings shows that ECI also distributed knowledge between organisations participating in the projects. Leading to a higher understanding about other actors' work ways and contributions. It is indicated that this understanding will follow through into other projects, thus pushing the AEC industry forward. Moreover, it can be concluded that ECI projects in Sweden have a high level of commitment among the involved project members which can facilitate the collaboration process.

What are hindrances and possibilities for using BIM in ECI?
There are cultural issues where more senior staff, required in ECI, are hindering the BIM usage in the projects as they are more bound to traditional workways. Although, the ECI collaboration together with the BIM requirements from the STA, is forcing BIM usage, which has resulted in more project members realising the benefits of BIM. In other words, ECI brings forth more experienced project members and the BIM requirements force an increased use of BIM, which has resulted in the more experienced and senior members realising the potential of BIM. However, this does not happen by itself, having proper management promoting BIM will facilitate the adoption process. This calls for having project managers who believe there is a need and are open to use BIM and new workways.

A lack of trust can be connected to the perceived incentives of the actors involved. Trust is needed in close collaboration since it brings open communication, which is a key factor in the ECI collaboration. BIM can bridge this trust gap since it provides a platform for open communication and transparency. Increased BIM usage and also considering using more aspects of BIM, for example implementing cost in the model, will lead to more information being openly shared. However, the lack of trust leading

to adversarial relationships is also a hinder to BIM. Building a relationship with high trust will benefit both the ECI collaboration and BIM, and should therefore be the focus. Further, it can be concluded that ECI can help the STA accelerate BIM implementation to the AEC industry as close collaboration facilitates the adoption.

How can the future use of BIM in ECI projects be improved?
BIM should be considered for the whole life cycle of ECI projects. Although, there is a general lack of experience in the Swedish AEC industry of integrating the maintenance aspect into BIM. In the case studies, the maintenance aspect is neglected in the BIM requirements. Therefore, there must be focus on integrating BIM throughout the lifecycle of project in order to utilise the potential of BIM to a further extent.

To achieve synergetic effects from using ECI and BIM, there must be a focus on establishing a proper scene. This includes setting up proper information sharing systems, clearly defined roles, to discuss and understand each other's expectations, and have management who promotes and is open to use BIM and new workways. This also connects to the importance of having the right person on the right place in the project organisation. Using an external collaboration manager is believed to better facilitate the discussion of roles and expectations. Further, being co-located brings potential of even further BIM adoption. To conclude, this will result in an environment where BIM and ECI do not only cover each other’s gaps, but instead provide real synergetic effects.

7.1 Recommendations for future research

For future research, the relationship between BIM and ECI should be evaluated for the whole project. Mainly, since this master’s thesis only focuses on the first stage of two ECI projects, and extended collaboration and BIM have the characteristic of delivering value by being considered for the whole project, this being both the first and the second stage of the ECI process. Further, the detail level of the design at this stage might affect the BIM usage, which could be different with the more detailed design in stage two.

Another interesting idea could be to study how co-location, which extended collaboration often provides, can facilitate the use of BIM and its adoption. Further, the managerial aspects should be considered as another research topic, since many issues in the case studies are mostly connected to the lack of shared perception of roles and a common view of the project.

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9 Appendix

Interview guide for Design manager, Contractor, Subcontractor, Client

Bakgrundsfrågor

1. Vad är din position?
    - Företaget, projektet
2. Vad för typ av projekt har du tidigare jobbat med?

ECI

3. Vad är dina tidigare erfarenheter av samverkansprojekt?
4. Hur fungerar ECI i projektet?
    - Vad upplever du för fördelar och nackdelar?
    - Hur skiljer sig arbetet jämfört med t.ex. partneringprojekt?
5. Innan detta projekt, vad var din inställning till ECI?
    - Har din inställning till ECI förändrats under projektets gång?
6. Vilken typ av projekt lämpar sig ECI till?

BIM

7. På vilket sätt har BIM använts i dina tidigare projekt?
    - Vilka aspekter användes? (3D projektering, med mera.)
8. Hur används BIM i nuvarande ECI samarbete?
    - Kan du ge exempel?
9. Vilken typ av projekt anser du BIM lämpar sig till?

Projektet

10. Hur fungerar samarbetet mellan projektmedlemmarna?
    - Finns det samarbetsavtal, riktlinjer m.m.?
11. Vilka kompetenser bör närvara vid projekteringsmötena?
    - Är närvarande involverade kompetenser tillräckliga eller överflödiga?
    - Underentreprenörer? Leverantörer? Beställare? När bör de närvara?
12. Hur anser du engagemanget till projektet vara från alla parter?
13. Hur har ECI samarbetet samt BIM påverkat kravbilden som ställs på projektorganisationen?

Avslutningsvis:

14. Hade projektet kunnat genomföras med en annan upphandlingsform, exempel?
15. Tror du denna upphandlingsform kommer öka i popularitet?

Interview guide for STA-strategist

Bakgrundsfrågor

1. Vad är din position?
2. Vad är din roll hos Trafikverket?
3. Hur fungerar Trafikverkets "renodlad beställarroll"?
    - Vad är målet? Vad vill man ha ut av den?

Samverkan

4. Vad anser du vara nyckelfaktorer för lyckad samverkan?
5. Hur ser Trafikverkets plan ut när det gäller samverkan i framtiden?
    - Hur är Trafikverkets organisation förberedd? Är branschen förberedd?
6. Hur ser du att utökad samverkan kan underlätta för BIM?
    - Vilken plats har BIM i samverkansprojekt?
    - Vad är nyckelfaktorerna för att BIM ska lyckas?

ECI

7. Hur definierar ni ECI?
8. Vad baserades ECI:s riktlinjer på?
    - Hämtades kunskap från andra länder?
9. Hur kan ECI utvecklas hos Trafikverket?
    - Vad kan förbättras?
10. Kan kostnaden överstiga nyttan för ECI i vissa projekt?
    - Dvs, är ECI lönsamt för alla typer av projekt?
11. Fanns det några krav på hur projektorganisation skulle se ut i ECI projekten (Centralen och Olskroken)?
12. Ser du någon konflikt mellan renodlad beställarroll och ECI-samverkan?

Avslutningsvis

13. Hur hade du velat förbättra dagens samverkan?

Interview questions for BIM-strategist

Bakgrundsfrågor

1. Vad är din position?
2. Vad för typ av projekt har du tidigare jobbat med?

BIM

3. Hur definierar ni BIM?
4. Hur har BIM fungerat i Trafikverkets projekt?
    - På vilket sätt används BIM?
    - När används BIM?
    - Hela projektets livscykel?
5. Hur har ser Trafikverkets plan ut när det gäller BIM i framtiden?
    - Hur är Trafikverkets organisation förberedd?
6. Hur ser du att BIM kan underlätta för samverkan?
7. Vilken plats har BIM i samverkansprojekt?
    - Kan det underlätta ECI?
8. Kan kostnaden överstiga nyttan för BIM i vissa projekt?
    - Dvs, är BIM lönsamt för alla typer av projekt?
9. Många inhyrda, har de BIM vana?

Avslutningsvis

10. Hur hade du velat förbättra dagens BIM-användande?