The Impact of BIM on Design Phase Productivity

The West Link Case Study

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

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ABSTRACT

Building information modeling (BIM) or Building information management is a technological and organizational approach with potential benefits to the construction industry. BIM can be divided into several aspects, including scope, visualization, integration and automation. By using BIM, the client, consultants and contractors gains many advantages in aspects of communication, time, cost and the quality of the outcome. In this master thesis, an examination of the productivity gains a project can attain by implementing BIM in the design phase is conducted. The thesis uses a case study approach for this examination, where the "West Link" Project was used as the case. Research was further narrowed down to the "Central Station" Bid-pack. This specific Bid-Pack was chosen as it uses a new procurement strategy that enhances the integration process. The case study has been supported by interviews with the client (Trafikverket) and the contractors (NCC), collecting data from Trafikverket's database, using the results of surveys conducted by Trafikverket on employees and from direct observations. The master thesis has also developed several KPIs that has been seen to be repeated consistently within the research and are of importance to Trafikverket. These KPIs has been used as an indicator of the current performance of BIM. The Macleamy Time/Effort curve has also been used as a way in assessing the collaboration between stakeholders. The study is of high importance to Trafikverket as it is the first time they implement BIM in such a big scale. It can also be considered important to other clients willing to implement BIM in their organization without prior knowledge of assessing its advantages. The study finds that by using BIM in Trafikerket, paper documents can be reduced, collaboration, information sharing and trust issues can be enhanced. BIM has created closer collaborations between the client and the contractor. The study also shows that there has been an increase in costs and delay in schedule which can be related to the lack of maturity and psychological barriers within the employees of Trafikverket.

Key words: BIM, Collaboration, KPI, Productivity, Sweden, UK, Macleamy, Trafikverket, West Link

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SAMMANFATTNING

BIM har många namn vissa använder begreppet Building information model medans andra använder Building information management. Det är en process som har stora fördelar i byggbranschen. BIM kan indelas i 4 delar dessa är omfattning, visualisering, integration och automatisering. Genom att använda BIM i olika projekt så har byggherren och entreprenören stora fördelar gentemot varandra såsom kommunikation, kostnad, tid samt kvaliteten. I detta arbete har vi undersökt om produktiviteten kan gynna ett projekt under ritnings fasen. I arbetet har vi undersökt Västlänken som fallstudie närmare specifikt är det centralstationen som är ett av 8 större projekt i Västlänken. I detta totalentreprenads projekt är Trafikverket byggherren, man har även infört ett nytt upphandlingsstrategi då man använt sig av BIM. I metoden har man använts sig av intervjuer med berörda personer i Trafikverket, NCC samt enkätundersökning. I detta arbete har man stött på och utvecklat ett flertal nyckelindikatorer som har upprepats konstant under arbetets gång. Man har använt indikatorerna för beräkning av BIM prestation samt Macleamy kurvan som beräknar tid/ansträngning. Denna studie har varit i stor vikt för Trafikverket eftersom det är första gången man implementerar BIM i en sådan stor skala, detta arbete kan också anses vara viktigt för andra beställare som vill implementera men inte har kunskapen eller vet fördelarna med BIM. I uppsatsen har man kommit fram till att BIM i Trafikverket kan reducera många ritningar, närmare samarbete mellan beställare och byggherre samt utbyte av information. BIM har även frambringat ett större tillit till de berörda i projektet och beställaren har fått en mer konkret inblick i arbetet. I detta arbete har man även funnit att kostnader har ökat samt förseningar, det kan relateras till psykologiska barriärer mellan de anställda och en viss typ av brist av mogning när det gäller erfarenhet.

Nyckelord: BIM, Sverige, UK, Produktivitet, Macleamy, Trafikverket, Centralstationen, Samarbete, Västlänken, KPI,

Contents

Preface

This thesis work is the final part of our studies in Chalmers University of Technology that concludes our studies in the Master Program of Design & Construction Project Management at the Department of Architecture and Civil Engineering, Division of Construction Management.

The work on the thesis was done during the spring semester of 2017, in collaboration with Trafikverket, The Swedish Transportation Agency, under the supervision of Chalmers.

During our studies, courses taken has always emphasised on a sustainable future and in finding new innovative methods of management. From this perspective, the urge for the search of new technologies that can improve the construction industry was the main aim.

Firstly, we would like to thank Christian Koch for all his input, his valuable and constructive critiques and his motivation, the person who has guided us through the entire process and development of this thesis, the person who was one of the main inspirations towards the search in Building Information Modelling.

We would also like to thank Trafikverket for giving us the opportunity to collaborate with them and bring a practical dimension into our thesis. Our special thanks go to Henrik Franzén and Niklas Lindberg for sparing a lot of their time in supporting our thesis and in providing us with most of the information requested. Many thanks goes to Camila Rydén, Katrina Delvert, Roger Wennberg and Josef Habbe, for giving us the opportunity to interview them and note their comments and discussions aspects that has greatly supported the thesis.

Finally, we can never show our gratitude and thankfulness to our Families that has, throughout the journey of two years, never failed to give us all the support needed to reach the point where we are now.

Mohamad Iyad Al-Khiami & Ali Zangana
Gothenburg, 2017

Notations

BIM	Building Information Modelling
IPD	Integrated Project Delivery
ECI	Early Contractor Involvement
AEC	Architect Engineer Consultant
CAD	Computer Aided Designs
CIM	Civil Information Modelling
DB	Design Build
DBB	Design Bid Build
KPI	Key Performance Indicators
LOD	Level of Development
PD	Pre-Design
SD	Schematic Design
DD	Detailed Design
CD	Construction Documents
PR	Procurement Stage

1 Introduction

1.1 Background

Building Information modeling is defined according to Eadie et al. (2013, p.145) as "The process of generating, storing, managing, exchanging, and sharing building information in an interoperable and reusable way. It requires the development and use of a computer generated model to simulate the planning, design, construction and operational phase of a project". Several models relating to various disciplines including architectural, structural and mechanical are created. The models simulate the whole construction cycle containing a great amount of information including but not limited to 3D geometry, procurement, different construction activities, costs and time schedule (Azhar, 2011). Because of the models created, information such as quantity take offs, materials required and scope of work can be extracted. These are only a few advantages of many that will later be discussed. With the amount of information being exchanged and understood, the three main objectives of any construction project can be achieved that is, increased quality, reduced time and cost (Azhar, 2011).

Application of BIM allows the early detections of clashes prior construction, coordination of material ordering, delivery schedules and generation of shop drawings. Those benefits facilitate faster production and high quality documentations both of which can act as benchmarks for future development (Azhar, 2011).
It provides the client with a whole new experience, giving them the ability to visualize and integrate themselves into the project. Such experience will aid clients in deciding whether any change orders is to be made prior to construction where change is easier and cheaper, hence, enhancing the flow of the project (Azhar, 2011).

Even though BIM is a concept that is meant to be used throughout the lifecycle of a project, from the design phase and up to the maintenance, operation and even facility management (Azhar, 2011), its major application was found, according to a survey conducted by Gilligan & Kunz (2007) to be in the design phase.

Taking a holistic perspective of BIM will increase the effectiveness of the project managers and highlight their role. A Holistic perspective also means that stakeholders are of great importance and their contribution and collaboration with each other in the project greatly affects the final result (Bryde et al., 2013). With all the information available, proactive decisions can be taken, careful monitoring of the project can be done, resulting in reduced costs, reduced time and improved quality. BIM has exploited the opportunity of using new procurement strategies involving more collaboration and communication between Architects and contractors during the whole project and particularly in the design phase, gaining trust and uniting their goals to the completion of a project successfully. Integrated Project delivery (IPD) showed itself as a new method of procurement. It is gaining its fame as a strategy that utilizes the full potential of BIM within the AEC industry (Eastman et al., 2011). It emphasizes the need of communication and collaboration between the owner, architect and contractor to fulfill the client's requirements and expectations of the final outcome (Eastman et al., 2011).

According to Macleamy (2010) time/effort curve that will be discussed into details later, suggests that in the traditional method of procurement, most of the effort is exerted during the construction stages where it is difficult to change and control cost and time respectively, in contrast to BIM, were more effort is put during the detailed design phase. Parties during that phase are in full control of the project. This proves that the full potential of BIM can only be reached when stakeholders understand the need of information exchange (Macleamy, 2010).

Though, along with its advantages comes disadvantage or reasons why some organizations still do not have BIM implemented. One of the main issues are problems in its adoption, since BIM as mentioned earlier, is not only a tool to be used, but is a whole new thinking and approach away from the traditional self-oriented method, involving more collaboration and communication. It might be faced with resistance from employees and demotivation from others. Another reason is due to the high cost and acquaintance in the software (Chougule & Konnur, 2015). Moreover, the need of a standardized format to be used between architects and the design platform is still not defined (Chen et al., 2013). According to (Bryde et al., 2013) the overall effectiveness of BIM has not been completely realized.

1.2 Purpose

As BIM is seen to be the future of the construction industry, more and more organizations are implementing it into their systems and country's policies. Many of the researchers still struggle to find an accurate definition of BIM, thus finding whether it is productive or not can be a challenging task. The purpose of the thesis is to examine whether BIM has contributed to increased productivity by conducting different productivity methods. A case study will be used in the empirical part of the thesis where theory is put into practical. The case study is the West Link project performed by TrafikVerket. The Central Station Bid-Pack will be used as the main focus in assessing the productivity of BIM on. Details will be explained later in the empirical section. How did BIM affect Key performance indicators, communication between different disciplines, and its effect on the Time/Effort curve during the design phase.

1.3 Delimitations

The thesis involved the collection of data from Trafikverket and NCC employees about the West Link project (Central Station Bid-Pack). As the project is still ongoing and of such a high complexity, there has been several limiting factors that are important to note. One of the main obstacles faced was that a lot of the reports and data were considered confidential and could not be shared.

The Central Station Bid-pack is yet to be completed in regards of Design. Only the Pre-Design and the Schematic Design has been completed. No data is yet recorded for the next phases.

The thesis involved the data collection of several KPIs. Not all the KPIs were measurable. Change orders were not coded, meaning that change orders that are related directly to BIM was hard to be identified. Clash detections and RFIs were not recorded, neither by Trafikverket or NCC. An estimation of how many were there had to be done. To gain a high enough accuracy, many of the employees involved directly in these issues has been asked to conform a specific number. Unfortunately, the numbers remain limiting.

1.4 Thesis Outline

In this section, the disposition of the thesis will be explained. First, it will be divided in six different chapters.

The first chapter will give an introduction of the topic. A background will be given, summarizing the different points that will be discussed in the thesis. Then, the purpose and limitations of the research.

The second chapter will involve all the theoretical framework. In this chapter, different BIM definitions are given including an introduction of what CIM is. Also, an introduction to how BIM is done in the UK in comparison to Sweden. Following that is an elaboration of the various collaboration methods, procurement strategies and BIM characteristics. Later, defining what productivity is and various methods in measuring it.

The third chapter sums up the methodology part. In this chapter, a description of how the approach has been made towards the thesis. Explaining how the research has been narrowed down. How the data has been collected from Trafikverket and reasons why the Central Station bid-pack of the West link project has been chosen to conduct the thesis on. It also involves how the Central station bid-pack is assessed upon the KPIs and Time/Effort curve. How the surveys have been used and interviews conducted are also discussed.

Following the methodology chapter is a description of the case study. First an introduction of Trafikverket is made. Following it with an introduction of the West Link project and the Central Station bid-pack.

Results and the conclusion with some remarks and recommendations are the final two chapters in this thesis. It sums up the findings and what to be done in further studies if the thesis to be continued.

2 Theoretical Framework

2.1 Defining BIM

2.1.1 What is BIM

BIM has been defined differently in different publications, according to Barlish & Sullivan (2012, p.149), “BIM is a software application, for others it is a process for designing and documenting building information, for others it is a whole new approach to practice and advance the professions which requires the implementation of new policies, contracts and relationships amongst project stakeholders”.
It is important to understand that BIM is not only a tool that can be used to create models but is a process that involves the integration and collaboration of all stakeholders.

BIM has a lot of names but is better known by most people as “Building Information Modeling”. Some people also consider the name “Building Information Management” because of the last letter in the name BIM (M). BIM is a game changer for the business, with a global implementation in the future in every country (HM Government, 2012). Along with the implementation of the process, new job opportunities will be available and new dimensions within the construction industry will be open, unfortunately, it will also create risks.

Before going any further with BIM, it is important to understand it by going back in time to see where it all began (Barnes et al., 2014). It started with what is called computer aided design or CAD in the 1950s and 1960s where some large industries had the potential of having mainframe computing. Large industries started to produce their own 2D drawings, and each of these industries had created their own software’s manufacturing 2D drawings. Time passed by and CAD became increasingly known in the industries and explicated so that a product could be manufactured from the computer directly and pre-stages of preparation became insignificant. In the 1970s the commercial of CAD was inevitable and the CAD industry was in the rise, some of the major reasons were the availability of mini-computers which became cheaper than before, improved technology combined with big advances in the software industries. The technology of CAD improved over the years due to the appearing of less expensive mini-workstation during the 1980s, the situation became much easier for the industry when the personal computers increased. In 1990s CAD was further developed with integrated graphical analysis and simulation that extended the information by showing the materials, building systems, geometry and how a construction building would act during hard conditions (Barnes, Davies, & Nigel, 2014).

During the early 20th century many software developers collaborated and created a major advancement in the CAD-modeling industry, the creation of softwares led to the formation of 3D modelling. Sub-models are created along with the 3D models, forming what is called the 4th and 5th dimensions, that is, time and cost respectively (Barnes et al., 2014). Time and cost are the two most important factors in a project; in

2007 a major data collection was brought by Stanford University collecting information from 32 projects showing the benefits of BIM. The result showed that by using BIM the reduction of project time could be saved up to 7%, up to 40% elimination of unbudgeted change (Azhar, 2011).

Today BIM is continuously improving, providing more parameters and detailed information in not only cost and time, but also energy consumption and collision detections (Barnes et al., 2014).
According to Succar et al. (2012), there are a large numbers of government agencies that require a 3D model by contractors creating a demand for BIM in the construction industry.

Several reasons are behind why BIM is expanding in the construction industry worldwide (International, 2007). One reason is that the traditional 2D and 3D CAD drawings are becoming insufficient and not designed to handle the amount of information that is required in many projects. The traditional CAD drawing tools exclude the very important information such as, bid, timeline, materials and bills etc. BIM can gather, share and deposit information from all the stakeholders creating a more efficient working “method” when compared with the traditional way of handling (International, 2007).

BIM is not a computer program nor is a 3d CAD, it's a process combined with technologies where different stakeholders from different professions work in a multidisciplinary environment together, sharing information and collaborating with each other for a common project with less errors, faster and cheaper construction.
The definitions mentioned allows the division of BIM into Scope (Succar et al.,2012), Visualization, Integration and Automation (Kunz & Fisher, 2012).

1. Scope
2. Visualization
3. Integration
4. Automation

<u>Scope</u>

BIM can be used in the beginning of the project, during the design phase, construction phase and for the operation and maintenance, in brief, it can be implemented throughout the whole project life cycle (Succar et al., 2012). This also supports what (Eadie et al., 2013) mentioned where it was stated that BIM implementation expands through project inception, feasibility, design, construction, handover, operation and maintenance, in other words, preconstruction, that is the detailed designs and tender, construction of the project and operation. (Eadie et al., 2013).

Though, according to Eadie et al. (2013), BIM has highly been used during the initial phases of a project and slowly fading away during later processes.
Due to the great potential that BIM possess and the broad capability of it, BIM can then be categorized and divided in terms of its scope, or in terms of the extent it is being used.

Visualization

Visualization is when 3D models are created by the project team based on the metrics that has been developed and discussed within. Through visualization, the level of development of the models are determined. Though it can vary depending on the audience and the degree of competencies of the employees.
The Visualization stage would provide a kick start and an initial image of the future result (Kunz & Fischer, 2012).

Integration

The third important aspect in BIM is the process of Integration. A mutual definition between researchers was perceived, that is the importance of sharing the information developed from the models between stakeholders (Succar et al., 20120) (Kunz & Fischer, 2012). Models need to be shared between different disciplines and into various softwares through common formats. This sharing between models improves the process and the quality of the project. In order to do that, an integrated network must be developed that provides a strong infrastructure for a project organization to share information in an interoperable way (Kunz & Fischer, 2012).

Organizations must allow the share of information and incentivize that through the creation of Multi-party collaboration contracts. This will require a change in the way contracts are written, making them more collaboratively friendly by introducing partnerships and other methods of collaboration. BIM can be considered as a policy change (Kunz & Fischer, 2012). Succar et al. (2012) discussed a similar aspect to Kunz et al. (2012) regarding BIM maturity and capability that will later be elaborated on in the thesis in the BIM Characteristics section.

Automation

Automation, on the other hand, is the performance of routinized jobs within a model. In other words, according to Kunz & Fischer (2012, p.6) "Automated methods are used to perform routine design tasks or to help build subassemblies in a factory". This requires the change from the common procurement strategies into Design – Fabricate – Assemble. Thus, creating elements that are used commonly in construction and simply putting them into a design then storing in a library of elements created for the organization (Kunz & Fischer, 2012).
Automation brings great advantages, increasing design efficiency, effectiveness and decreasing design duration and possibly construction duration.

Understanding the four different aspects and assessing the BIM implementation in a project with it, provides an improved image of how BIM is being operated. It is important to note that the three points discussed by Kunz & Fischer (2012) are not standalone stages, in fact they are emerged and relate with each other. For example, the process of using softwares is not only a method in which it can only be categorized under Visualization. Software usage can be put under Integration and Automation as well, as they are a requirement in all three.

2.1.2 CIM

1. Understanding CIM

BIM in many cases, proved itself in the building market through cost reductions, higher productivity and improved overall performance. Though, many people perceive BIM as a process that is limited to buildings, in fact, according to (Cheng, Lu, & Deng, 2016), buildings in the abbreviation BIM refers to the verb of building, that is constructing and not the specific structure. This means that BIM can also be used in Civil infrastructure projects to seize the same benefits attained by buildings.

The Term Civil Information Modeling (CIM) has risen in the AEC market referring to civil infrastructure projects implementing BIM. Other terms that represent civil infrastructures include “Horizontal BIM” and “Heavy BIM”(Cheng et al., 2016). It is important to understand that there are some differences that must be considered for BIM users when adopting BIM in civil projects.

2. Differences

Civil projects are categorized into five categories Transportation, Utility, Energy, Recreational and water management infrastructures, unlike buildings where there is not any categorization (Cheng et al., 2016). Some of the structural components found in a BIM project are not found in a CIM one. Terminology representing buildings and civil infrastructure is different (Cheng et al., 2016).

In the development of the model, different softwares are used, buildings are created vertically, modeling one floor and replicating it to the rest while civil projects requires more work to be done as it is considered as a horizontal structure affected by the whole terrain and not only a specific area. Though, the way data is managed and information is exchanged between BIM and CIM are considered similar (Cheng et al., 2016).

2.2 BIM Characteristics

Within the Abbreviation of BIM hides a vast amount of characteristics, some of which are known and others yet to be found. According to the research performed, BIM characteristics can be divided into three different points.

1. BIM Capability
2. BIM Maturity
3. BIM Level of Development

These terms are developed by Succar et al.(2012) that can also be related to what has been mentioned in the definition of BIM, see Chapter 2, section 2.1.1 in reference to Kunz & Fischer (2012).

2.2.1 BIM Capability

BIM Capability Stages are defined according to Succar et al. (2012,p.124) as “The basic ability to perform a task or deliver a BIM service/product”.
BIM Capability stages are used as guidelines in organizations implementing BIM, it defines the minimum BIM requirements that is, the major milestones that must be achieved for an organization to be considered in a specific stage.

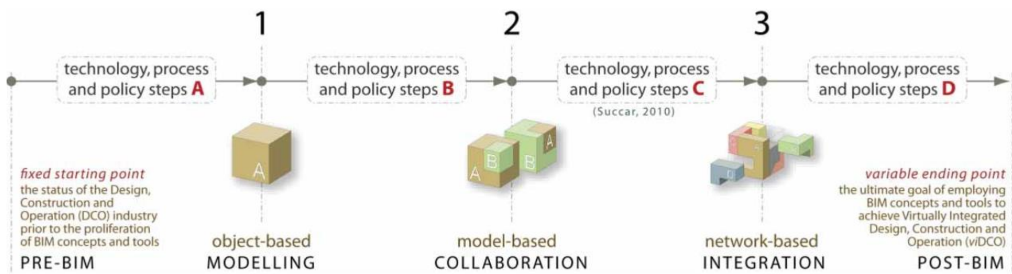

Figure 2.1 Figure showing the three BIM capability stages, adapted from Succar et al. (2012).

There are the three BIM stages,

1.BIM stage 1: object-based modeling
2.BIM stage 2: model-based collaboration
3.BIM stage 3: network-based integration.

Before and after the stages we have so called Pre-BIM and POST-BIM. Pre-BIM represents the situation of an organization prior to the use of BIM, while Post-BIM represents the full adaption and Potential of BIM in use in an organization. Full adaption though, is something that is an open ended and ongoing process that still requires a lot of research and development (Succar et al., 2012).

To implement and fulfill BIM stage 1, the team/organization must distribute model-based softwares such as Revit and Archicad for the project. To fulfill BIM stage 2 a team/organization must appoint a multidisciplinary team where they work and collaborate together. Once a collaborative environment has been developed, BIM stage 3 is the next stage an organization should aim for. Here, the team/organization share information with several other disciplines. This can be achieved through the creation of a common server that stakeholders exchange models between them, thus creating a common library where everything is transparent and visible (Succar et al., 2012).

Any of these stages cannot be achieved unless you work towards them, these steps are defined as competency sets. The competency sets can be divided into three main points

1. Technology
2. Process
3. Policy

As mentioned in the previous paragraph, when you have all the required competencies, BIM Stage 3 can be achieved (Succar et al. 2012). What is mentioned here goes hand to hand with Kunz & Fischer (2012) that divided BIM into Visualization, integration and Automation. Both researchers stated the need of having an integrated process and a change in policies, contracts and organizational strategy for an organization to perceive all BIM advantages.

2.2.2 BIM Maturity

As Succar et al. (2012, p.124) describes it, "BIM maturity refers to the quality, repeatability and degree of excellence within a BIM capability". For an organization to be considered highly mature in BIM, the hybrid mixture between humans and technology must be of a high standard. This high standard is translated to more control over variations between target and actual results, that is in cost predictions and time schedules (Succar et al., 2012).

The achievement of excellence within each BIM stage, reaching milestones that organizations are aiming towards, is what can then be said as BIM mature (Succar et al., 2012). Similarly, Kunz & Fischer (2012), also emphasized on the need of achieving excellence in BIM implementation. They stated the need of developing the human aspect of BIM through the development of the employee's competences and their understanding of BIM and interpretation of models (Kunz & Fischer, 2012).

A simple maturity model is presented below at BIM capability stage 1.

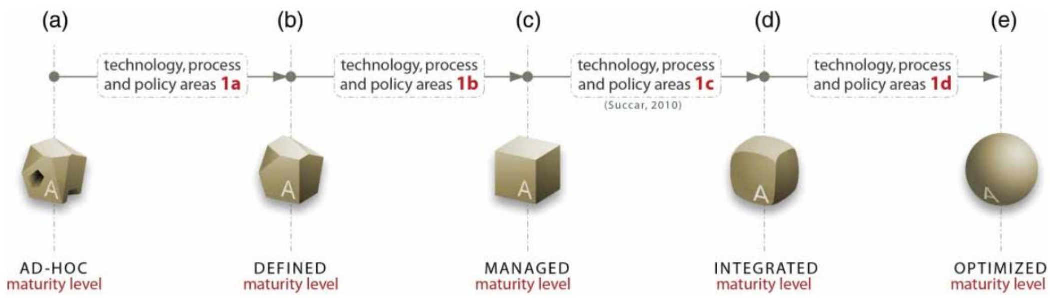

Figure 2.2 BIM maturity levels at BIM stage 1, adapted from Succar et al. (2012).

The stage starts with an AD-Hoc environment where everything is scattered and is yet to be configured. Through the incremental steps that creates more competencies, you slowly shift into the defined maturity level, continuing through until reaching the optimized maturity level. Once this has been reached, a new stage can then be entered, where similar steps must be made to achieve the highest level of maturity within the stage (Succar et al, 2012).

2.2.3 BIM Level of Development

As construction proceeds during the execution of a project so will the objects. Objects together, with other parts will grow and shape into smaller details reaching a sense of maturity with time becoming more clear (Coates, 2013).
LOD can clearly be explained as information regarding objects that project team members could use the information to resolve those issues that appears during the design stage (Coates, 2013).

Some Countries has their own Policy regarding the level of details, some of them involves levels from 1 to 5 where 1 contains the least amount of information. Sweden does not have any classification of their own for LOD (NCC, Svenskbygg, & SBUF, 2013).

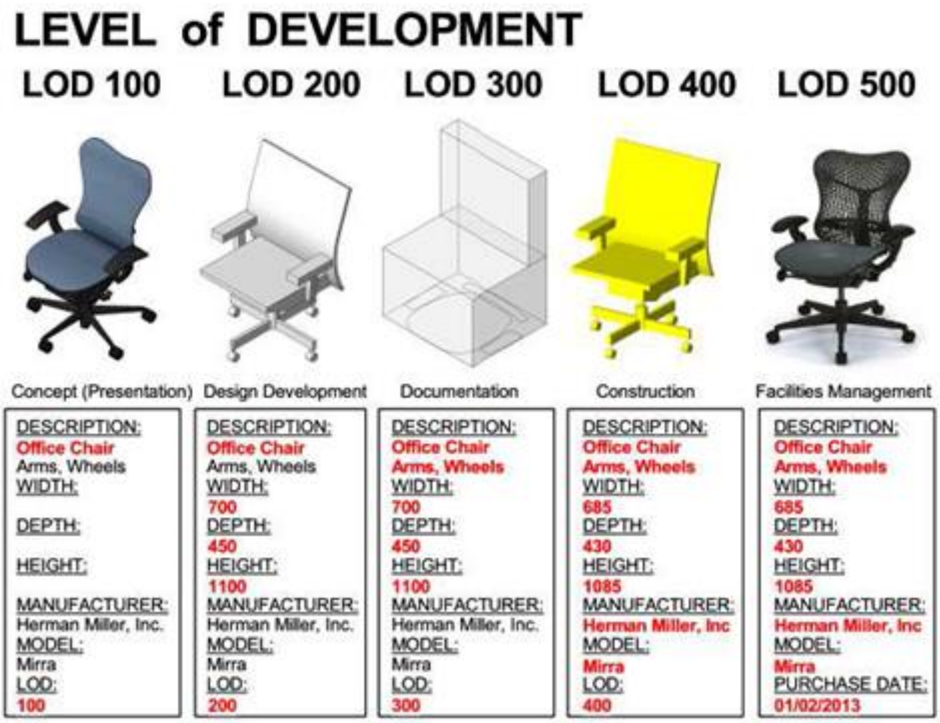

Figure 2.3 Levels of the models 1-5, adopted from Latiffi et al. (2015).

The decision of what LOD to be used is based on client demands from the contractors and the consultants, usually depending on the size of the project.
LOD100 shows an object with no information LOD100 is often used for cost estimation and pre-planning. LOD100 could be developed to LOD200 where in this stage, a little bit more detailed information becomes available, see Figure 2.3, depth, width and the manufacture of the product are details that could be found, it is here in this level the schematic design phase has its course (Latiffi et al., 2015).

LOD300 is a bit more precise when it comes to location, shape and quantity (Latiffi et al., 2015). Beside that LOD300 has also a non-graphic data collection when it comes to cost and time regarding the project. The next level is LOD400 and is little bit more adapted for fabricators and contractors and the reason behind it is that the information is presented as a specific system.

The last level LOD500 is a full representation of the building or the facility and contractors and clients are now ready to operate without any obstacles.
According to Latiffi et al. (2015) most of the public sector is behind when it comes to achieve LOD500, they are in LOD300 in most cases while the private sector has managed to achieve more and is considered to use the full potential of LOD (Latiffi et al., 2015).

The LOD is therefore another aspect that must be considered when BIM is in use. The decision on whether a LOD of 1, 2, 3 etc, requested, depends on the deliverables that are required within the stakeholders (Kunz & Fischer, 2012). Therefore, it is important to develop a scheme of understanding of what a client is to expect from a contractor delivering BIM models.

2.3 BIM in UK & Sweden

UK is considered as one of the leading nation in the world in terms of BIM, the government of UK has demanded 3D-model by all contractors in 2016 in public sector procurement (NCC et al., 2013). The government of UK has their own vision of BIM and sees the effectiveness and productivity by the following: "Government as a client can derive significant improvements in cost, value and carbon performance using open sharable asset information" (HM Government, 2012).

UK has created a so called "National BIM Library" where involved employees can download CAD items for the project, and the files are all in IFC and DWG formats (Ncc et al., 2013). The national BIM library is produced by the national building specification and is a free service for users around the country. The whole idea is to spread the use of BIM to everyone by making it easy and free. The National BIM Library is continuously developing by expanding the library through the addition of new objects and development of others. All the files that are uploaded on the server have fulfilled the requirements of the British rules and regulations (NCC et al., 2013).

The Cabinet office and Department for Business, innovation and skills are the two agencies in UK behind the BIM implementation program in the country that started in 2011 (HM Government, 2012). The aim of the program is to adopt the BIM technology into public and private sector procurement.
UK has a tradition to become an export market when it comes to construction services, in 2012 the construction export services was estimated to 7.6 billion British pound to secure the global strategy of the nation BIM implementation then was indispensable. Another major reason for the implementation was to not get behind the technology worldwide and not letting other international construction industries settle in UK becoming competitors against the British companies (HM Government, 2012).

The model in Figure 2.4, shows the British model program for success in the future, the now arrow shows the 2012 position. The plan was to implement BIM by 2016 and further develop to IBIM, a so called “Integrated Building Information Modelling” through the whole life cycle (NCC et al., 2013).

According to HM Government (2016) the UK industry has gained 840 million pounds of saving by using BIM implementation level 2. The government of UK mandated that all public procurement use BIM level 2 by 2016. The next generation of BIM level 3 or also known as Digital Built Britain is the next step in the development in UK construction industry. Level 3 of BIM are planned to operate in 2017 according to HM government (2016). Level 3 will make it possible for the owners to create and use tools and techniques to collaborate with their suppliers and make it possible for long term relationships (HM Government, 2016).

The aim of Level 3 is to integrate technologies, construction and human in one field, by sharing data models between stakeholders.
Level 3 is divided into four parts, these include:

1. Level 3A Enabling improvements in the level 2 model
2. Level 3B Enabling new technologies and systems
3. Level 3C Enabling the developments of new business models
4. Level 3D Capitalizing on world leadership

Level 3 contains numerous solutions to be put in the market, some of these solutions include:

1. Providing a platform for customers and stakeholders to show the best solutions through the whole lifecycle of a facility
2. Amend existing technical solutions
3. Developing new strategy for infrastructure, design and operation’
4. Sharing technologies with other industries across the country

The UK industry aims to gain $15 trillion of the market by 2025, of which most of the growths will be in Asia where UK have an active presence according to HM government (2016).

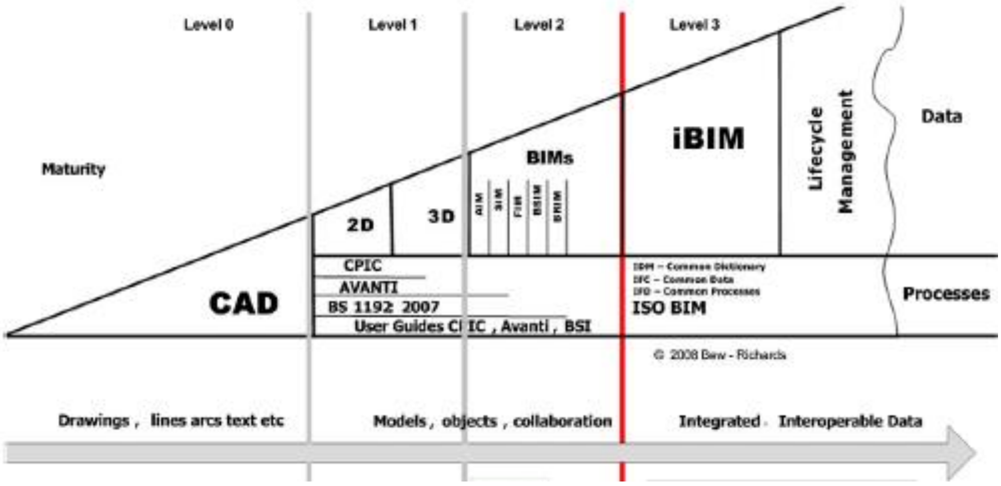

Figure 2.4 IBIM explaining the different levels of BIM, adapted from Barlish & Sullivan (2012).

The Scandinavian countries except Sweden has been in the business for a while regarding the implementation of BIM, with the help of government initiative plans, both Finland and Norway financed and implemented BIM into their industry. Finland started the process back in 2007 by demanding BIM for all public procurement. Norway had similar developments in the industry and their process started in 2010. The Swedish government has yet no ambition or taken any initiatives regarding BIM implementation. Even though there are many contractors that use BIM in the Swedish market, having the “client” on the same lane will make the whole process more sufficient and effective (Ståhl, 2012).

Despite the economic and social advantages of implementing BIM in the construction industry, Sweden has not yet been able to follow the lead as the neighboring countries have made (Ståhl, 2012). Regardless of the lack of technology in the Swedish construction industry. In the last few years, the industry has been rapidly expanding. The Swedish construction industry has an annual sale of 400 billion Krona a year, a large part of that goes on managing issues rising due to the miscommunication between the client and the contractor (Ståhl, 2012). If BIM is to be implemented, an efficient working process can be done and costs could be cut considerably (Ståhl, 2012).

Despite the lack of policies and poor performance in regards to BIM, there are organizations and agencies in Sweden that drives for BIM. One of these is BIM Alliance in Sweden (Mårtensson, 2015).
The organization works with the integration of building processes and implementation of BIM in the Swedish industry (Mårtensson, 2015).
The traditional way of constructing a building or a facility gives rise to a lot of papers, document and drawings the risk is that the information can become contradictory and the outcome are several layers of fragments, the fragments are disestablished information (NCC et al., 2013). There is a high demand of collecting these fragments to one layer of information and BIM can collect these fragments and create reasonable information of the outcome.

The construction industry is a heterogeneous market with many stakeholders working and expressing themselves differently. This could be a struggle in big project; the idea is to clarify for all “stakeholders” how to handle information through standardized procedures (Svenskbyggtjänst, 2015).The Swedish construction industry is no difference, stakeholder have their own way of formulating and renaming things, which in turn creates a demand to interpret and understand each other during the project's (NCC et al., 2013). Another obstacle in the business is the lack of common phrasing where you use the same concept and label.

Sweden is currently in a position of implementing a revised building classification of BSAB.BSAB is a classification system with a purpose to identify, organize and share information in a similar way for all construction and real estate market. The project is called BSAB2.0 and the purpose is to implement standardized construction information through the whole building process, this applies to the whole nation. The basic idea behind the new classification of BSAB is to suit BIM-models and clarify the business and avoid miscommunication in the industry (Svenskbyggtjänst, 2015). According to Jan-Olof Edgar a BIM specialist the Swedish construction industry isn’t mature and there are people considering that it’s not necessary to use the BSAB codes and the reason is that most of the industry is using 3D-models for building purposes only and not the share of information (Nilsson, 2013).

2.4 BIM Design Process

Any construction project has several stages that it goes through before reaching the final result. The Project lifecycle includes, design, construction, operation and maintenance.Since the main focus of the thesis is BIM productivity within the Design phase of a construction project, the scope has been narrowed down to the design phase only. Therefore, an explanation of the design stages and the BIM effects on these stages will be elaborated on.

The Design phase is further divided into several stages, these stages according to the (AIA Council, 2007) are the Predesign (PD), Schematic Design (SD), Design Development (DD), Construction Documents (CD). Following these stages comes the Agency Review and the construction phase then starts.

Each phase consists of responsibilities and deliverables expected from the client, consultant, contractor, designers etc.

1. **Pre-Design (PD)**

The Pre-Design (PD), also known as the Conceptualization phase, has three questions that must be answered:

1. What is to be built
2. Who will we build it for
3. How will it be built

The owners in this phase must be able to establish goals and budgets based on the capability of their organization. They should be able to create an understanding on how the project will be financed, provide required data to contractors, create an integrated team, distribute responsibilities and requirements expected from their contractors and most importantly decide the method of procurement. On top of that, the designer and contractor are expected to create a preliminary schedule, confirm opportunities proposed to physical results, and create an initial estimation of data costs and asses the constructability of the project (AIA Council, 2007).

The outcome of this phase consists of initial estimations of costs, time and quality metrics and decisions on communication technologies that will be implemented during the project (AIA Council, 2007).

Here, how BIM will be implemented must be agreed upon, the main points regarding that are as follows:

1. What types of softwares to be used, for example Teckla, microstations
2. How the data exchange will be done
3. The level of integration
4. Level of development
5. Interoperability methods

Once these points have been established, the second stage of the design phase can be proceeded to.

Pre-Design in Sweden

The Swedish building process is quite different when compared with the American model (Nordstrand, 2008). At this early phase the building process in Sweden is in preparation and investigation, this is initiated by the occurrence of local need.

In order to define which premises are required an operational description and overview of the functional requirements in the new premises are made. The reason for that is to match the client's needs and in some cases, even the property owner's requirements this phase have many names in Sweden, one of the usual names are "Tidigt skede" or early stage (Nordstrand, 2008).

2. **Schematic Design (SD).**

Schematic Design (SD), also known as the Criteria Design, according to the (AIA Council, 2007) is where the project begins to take shape. The project scope becomes more developed, schedules and cost become more precise, initial designs start taking place, decisions are being made. Eastman et al. (2011) mentions that during this phase, material specifications are also made.

In this Phase, building systems and major requirements of a building get selected. And are addressed into the BIM model. As the BIM models become more precise in this phase, the 4^{th} and 5^{th} dimensions start taking place, that is the cost and time, becoming more accurate and precise (AIA Council, 2007).

Schematic Design in Sweden

The Schematic Design in the Swedish context is the “Program Action” or “Programhandlingar”. The aim of this phase is to come up with a main strategy and the best suitable drawings, were later you work with and develop in a more detailed way (Nordstrand, 2008). The main entity responsible in this stage is the architect; other stakeholders are to some extent involved.

In this stage questioned such as where and how the building is on the plot must be answered. Other detailed questioned asses the character and the overall impression. The method in this phase/stage requires several drawings and close collaboration with the contractor and the client. Eventually a proposal is given. The results are then reported as a plan of land over the plots. The whole program may not exceed 15% from actual final cost (Nordstrand, 2008).

3. **Detailed Design (DD).**

During the Detailed design (DD), the designs become decisive, all critical building systems are established, specifications of materials are also determined, coordination among parties is at its highest level. This stage also includes collaborative meetings involving many stakeholders, resolving any inconsistencies that might arise. Schedules and cost estimations are among their highest precision in this phase (AIA Council, 2007).

Quantity take of are extracted from the models. Various softwares for cost calculations such as Sigma is used to achieve high accuracy and precision. Exchange of information is continuous. Models from different disciplines are put together in clash detecting softwares to finalize the models (Kunz & Fischer, 2012). Flexibility of the project in this phase is very minimal, as most of the documents are completed and all decisions have been made. Any changes that might occur after this stage can be very costly.

Detailed Design in Sweden

During the design work, it is always necessary to ensure that all equal requirements are met according to Swedish working environment, regulations, future operations and maintenance work (Nordstrand, 2008). This phase is called “Systemhandlingar” in the Swedish context.

Some of the documents can be used as construction permit application. For example, during this stage the dimensioning of column must be completed before the construction work begins.
Some papers contained in system documents are as follows:

- Current project schedule and planning schedule
  Geotechnical report
- Technical descriptions such as land description, construction description and material selection
- Situation plan
- Typewritings
- Drawings comprising plumbing, VA and EL.
- System calculation may not exceed 10% from real final cost.

4. **Construction Documents (CD)**

After the completion of detailed designs, the Construction Document (CD) are prepared. The main goal of this phase is to define how the project will be implemented and not what will, which means that this phase is not a process of changing nor developing in fact, it’s a process of finalizing the construction methods, schedule, costs and all the required documents used for tender submission IPD (AIA Council, 2007).

Construction Documents in Sweden

When system documents are completed, all the remaining questions and issues must be answered or solved, at this phase the client should be able to build, plan and purchase materials using the construction documents (Nordstrand, 2008). This phase is called “Bygghandlingar” in the Swedish context. It is pretty similar to the American construction documents. This is the final phase before construction work can begin, construction documents are the most comprehensive design phase, dimensioning of all building constructions and installation components must be completed.

At this phase, you determine final location of, for example, doors, material selection and other components in detail. The work is done in close collaboration with the various projectors, stakeholders and the client. Construction documents shall also report the extent of qualities and performances in such way that it could be used as basis for contractor's cost estimation when it comes to tendering processes. Construction cost calculation may not exceed 5% from the actual final cost.

5. **Agency Review**

During the agency review, all the necessary permits and approvals are made, this process has been eased with BIM being in place, as it has become more integrated into the process rather than being a separate phase with a specific beginning and end (AIA Council, 2007). With the concept of BIM, permit approvals can be considered as a stage parallel to the design phases (AIA Council, 2007).

If the traditional method is to be used then, bidding must be a part of the process, and agency review becomes a procedure of issuing permits, making the process less integrated and longer.

It is important to note that different organizations adapt and implement BIM differently depending on the maturity of BIM and competencies of the organization.

Usage of BIM in the Project Life Cycle

A survey conducted by (Eadie et al., 2013) shows how often BIM has been used in the project phases. The table summarizes the findings below:

Table 2.1 Showing how often BIM has been used in different phase, adapted from Eadie et al., (2013).

Use during the construction project stages	Often No.
Design	45
Preconstruction (Detail design & Tender)	41
Construction	26
Feasibility	21
Operation & management	6

The table shows that the highest usage of BIM has been found to be in the Design and Preconstruction Stages (Eadie et al., 2013).

2.4.1 Procurement Strategies

Two main contractual agreements are being and has been used in the construction industry, they include Design – Bid – Build (DBB) and the Design – Build (DB) procurement strategy (Yu et al., 2017).
A brief explanation of both will be discussed below.

1. **<u>Traditional – Design/Bid/Build</u>**

Design bid build also knows as the traditional method, It is the most common Contract used in Sweden and in many other countries (Borg, 2010).
The Swedish Design/Bid/Build is known as "Generalentreprenad".
In "Generalentreprenad", the client usually takes the role of a consultant, or hires in-house architects for the preparation of the design phase. In this contract, similarly to the American version, the client takes full responsibility of the design and is also responsible for the life-cycle costs (Borg, 2010).
Several contractors then bid on it and a contractor is chosen based on a certain criterion. Only then construction can start (Yu et al., 2017).

Once the designs are completed, the general contractor's role is to get the job done. The general contractor is also responsible for the management of the contracts with the subcontractors and for any problem that might be faced during the construction phase (Borg, 2010).

These roles and responsibilities are regulated by the "General Conditions of Contract for building, civil Engineering and Installation work" known as the "AB04" which is developed by "The Swedish Construction Committee" (Borg, 2010).
The figure below shows how the method is modeled:

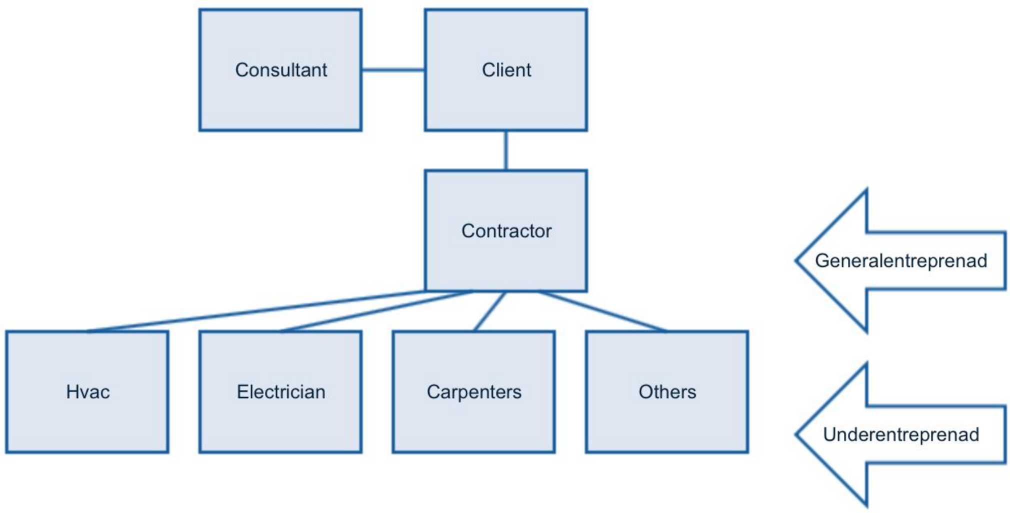

Figure 2.5 Showing "Generalentreprenad" contractual relationship, adapted from Nordstrand (2008).

This carries many disadvantages that work against what BIM aims into achieving.
As Figure 2.5 shows, the owner is responsible in handling two different contracts between two entities, that is the Designer and the contractor increasing the rigidity of the method and increasing the management costs for the owner (Yu et al., 2017).

As a result, less collaboration between the parties involved, no input by the contractor, errors and constructability issues that could have been found earlier, will only be evidenced during the construction phase (Council, 2007).
According to Eastman et al. (2011), DBB is perceived as the approach with the greatest challenges if BIM is to be implemented.

2. Integrated – Design/Build

Design/Build contract is known in Sweden as "Totalentreprenad". The client unlike DBB, gives more freedom to the contractor to choose the material, equipment and the procedure they would like to use to procure the project (Borg, 2010).
The client is responsible for one contract only, as the designer and the contractor become one entity, The result is a single contracting entity and a simplified management role (Eastman et al., 2011).
The client here provides outlines on what the expected result should be without restricting the contractor to specific ways of procurement (Borg, 2010).

The way in which the roles and duties are regulated in this contract type is through the "General Conditions of Contract for building, Civil Engineering and Installation Work performed on a package deal basis" known as "ABT06", also developed by the Swedish Construction Committee (Borg, 2010).

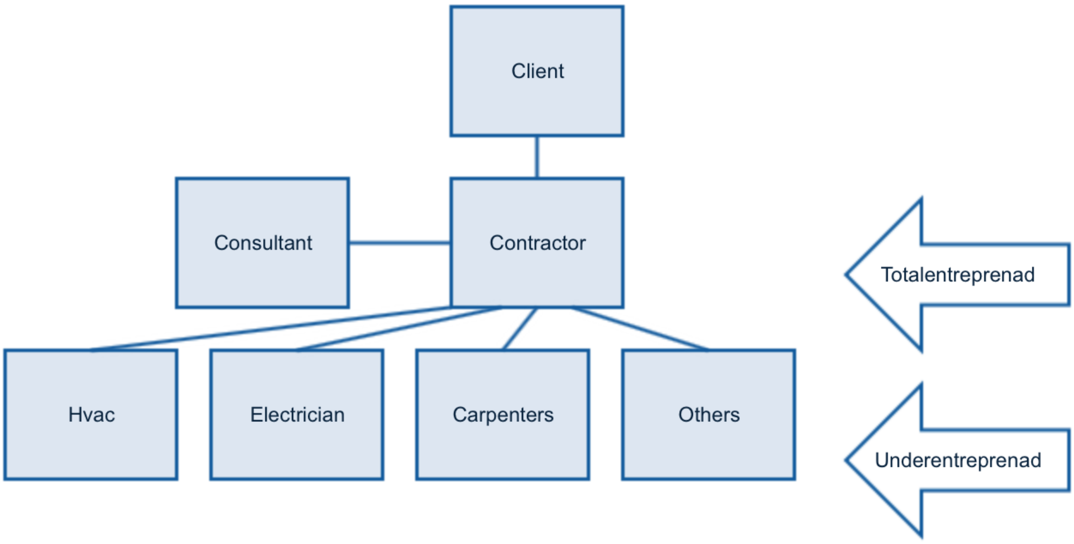

Figure 2.6 Showing "Totalentreprenad" Contractual relationships, adapted from Nordstrand (2008)

This method is thought to incentivize contractors in not only reducing the cost of the projects, but also reducing the time and increasing the efficiency (Borg, 2010).
It allows the early involvement of contractors, creating a more collaborative environment within the AEC industry (AIA Council, 2007). Thus, the design phases become more integrated and flexible, decreasing the overall time of the project (Eastman et al., 2011).

The AIA Council (2007, p.47) states, “Design-Build is contractually very well-suited for increasing collaboration among the design and construction team members”. As it is understood in previous sections that for the full potential of BIM, collaboration and exchange of information is very crucial within the project stakeholders. This also matches what Eastman et al. (2011, p.26) said “The DB approach provides an excellent opportunity to exploit BIM technology”.

2.4.2 BIM and the Time/Effort Curve

Having a DB contract along with the usage of BIM, will promote a more integrated process in which the whole procedure becomes more effective (Eastman et al., 2011). With such a system in use, the construction phases become integrated and overlapping, allowing for faster procurement (Eastman et al., 2011).

The figure below demonstrates a comparison between the traditional process and the integrated design process.

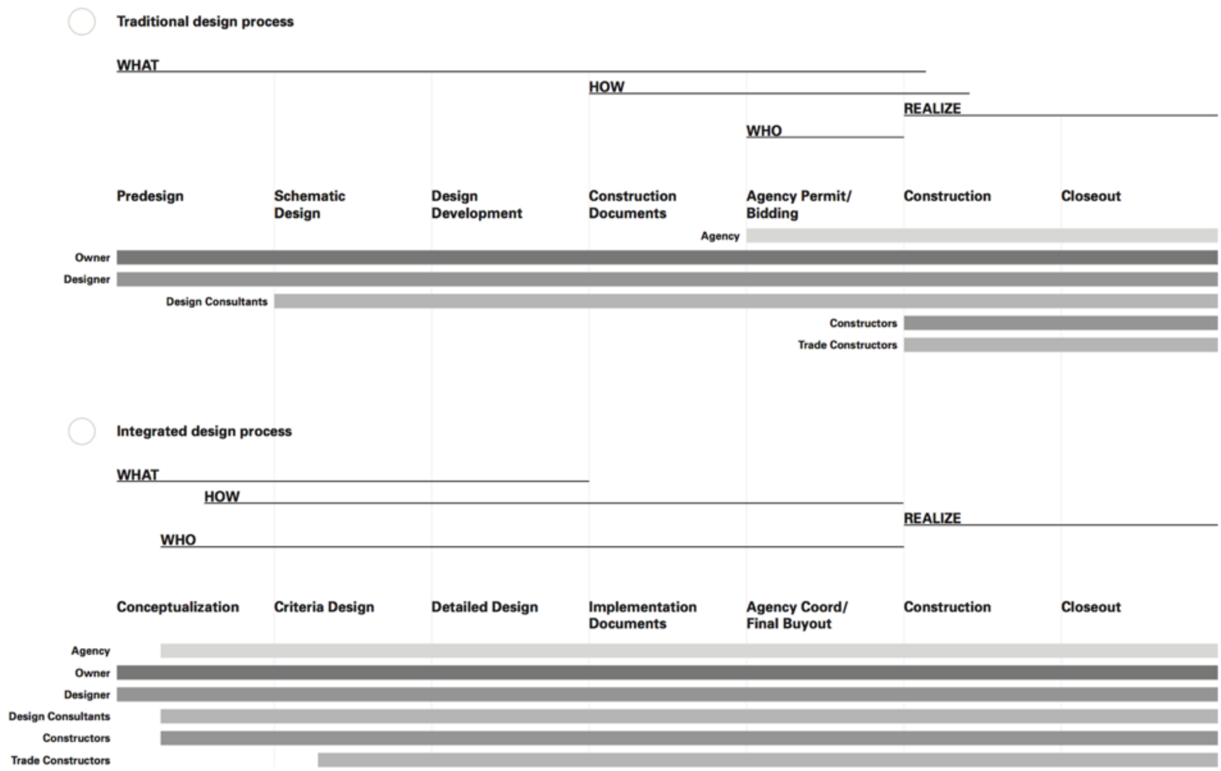

Figure 2.7 Comparison between traditional and integrated design processes within the design phases in the US, adapted from AIA Council (2007).

From Figure 2.7, you can see how the different parties become involved in an earlier stage of the project in comparison to the traditional method. designer and contractors are integrated throughout the whole project lifecycle. (AIA Council, 2007).

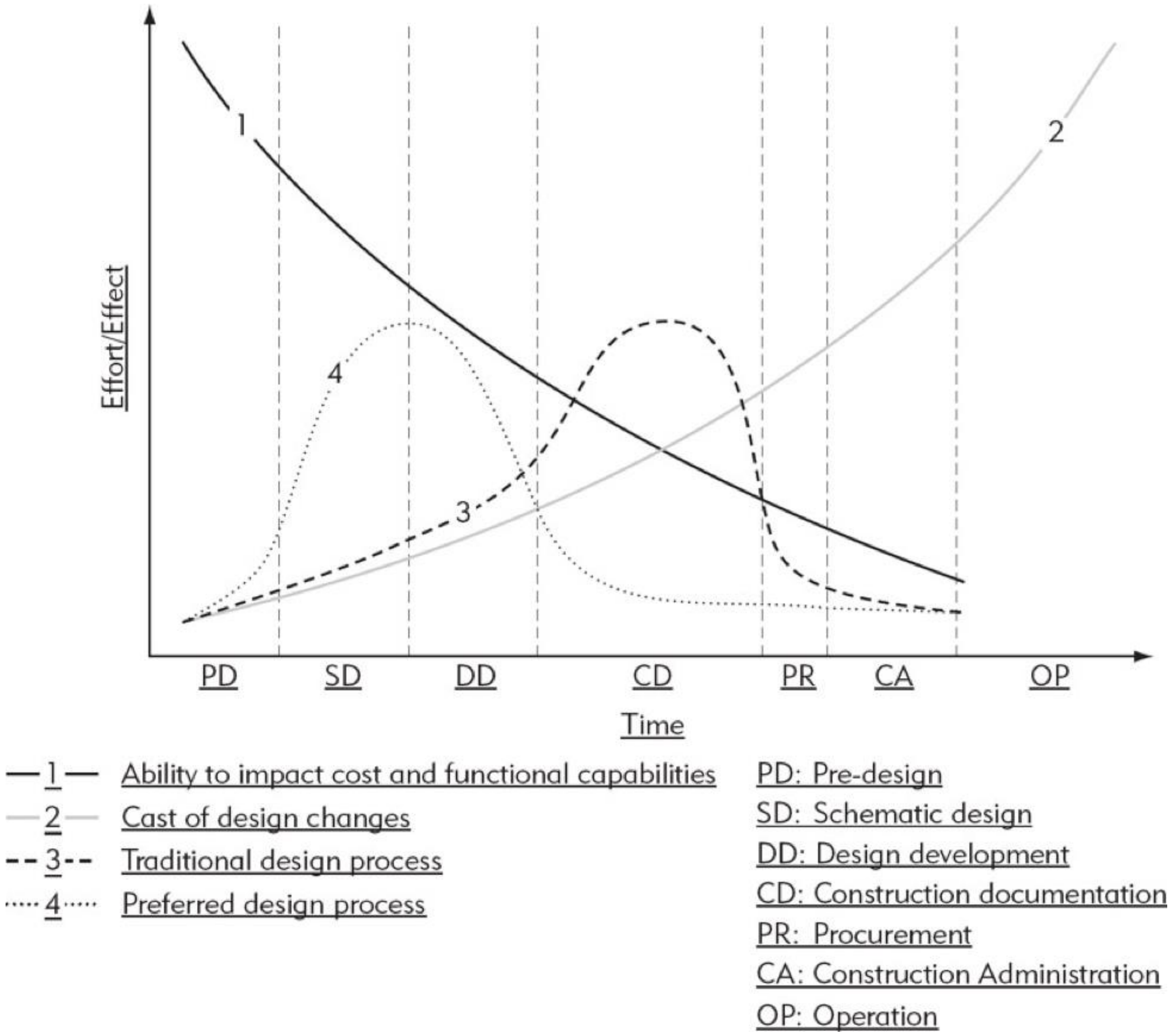

Figure 2.8 The MacLeamy Time/Effort Curve, adapted from Eastman et al. (2011).

Because of the integrated phases, more effort is committed to the design earlier in the process. Meaning that more man-hours are being put during the initial phases of the project.

As Figure 2.8 shows, the traditional method has its peak during the Construction documentation phase where changing orders is very expensive and is represented by Curve 3.

Through the empirical research conducted by Eastman et al., (2011), it has been found that architect's payment schedule is as follows:

- 15 % for the Schematic Designs
- 30 % for the Design Development
- 55 % for the construction documents

The reason behind this payment distribution is the result of a fragmented construction industry. Transparency within stakeholders is poor, interoperability and information exchange is lacking (Eastman et al., 2011). Policies from governments does not incentivize clients to perform contracts that compliments the share of information and transparency (Kunz & Fischer, 2012). Contractors contribution to the designs does not

occur until the designs are already done. The strict phases of a traditional method slow down the whole process and only kick starts the project half way through the design phase (Eastman et al., 2011).
The payment strategies and the characteristics of the traditional procurement strategy has created this specific shape of the curve.

The graph represents the relationship between effort put on design by architects and engineers and duration of the design process. Curve 1 in the graph represents the ability to impact cost, how flexible can it be to control cost. According to MacLeamy (2010), as time passes by, more details are being formulated, drawings become clearer and ability to change becomes harder, as things become more rigid and clear.

Curve 2 shows how variation orders become costlier to change as more time is put into the project, reaching a point where a change in the project can result in exceeding the budget estimated (MacLeamy, 2010).
Lu et al., (2015, p.2) describes the Macleamy curve as "it can graphically indicate the different cost and saving patterns caused by BIM adoption, which in return, can inform stakeholders as to improved BIM implementation".

The payment strategies and the characteristics of the traditional procurement strategy caused the curve to take this specific shape.
On the contrary, when BIM is implemented into the process, and due to its collaborative, communicative effects and the continuous exchange of information, the duration of construction document preparation is much lower therefore, more effort can be put earlier in the process where controllability is at its highest (Eastman et al., 2011).

2.4.3 BIM Advantages

The thesis as mentioned earlier focuses on BIM within the design phase of a construction project. Therefore, the affects that will be discussed below are what can be achieved during the design phase, bearing in mind that the impact can be on the entire project and not in a particular phase.

First, as clients are seen to gain the most advantages from BIM (Eadie et al., 2013), more attention will be given to the advantages from a client's perspective.
According to Ryd (2014, p.135) "The construction client is the entity that initiates building, construction or infrastructure projects at its own expenses. It also interprets and translates an organization's needs and requirements within construction projects".
From this definition, it is perceived that owners are the ones that have the requirements and goals they want to achieve in a specific project initially, though projects still tend to change a lot during construction as owners tends to be short sighted resulting in costs and time overruns impacting the design quality (Eastman et al., 2011).

The main advantage BIM carries to owners is the shift from a fragmented environment into a collaborative and more integrated one. This allows parties to work on a common goal, a goal the owner seek to achieve, margining the competitive relationship and internal ambitions of the involved stakeholders (Eastman et al., 2011).Through BIM technologies, owners can perceive their projects through visual simulations, which allows more precise designs to be made to the scope of work. Decisions earlier in the process can be made which results in fewer mistakes and errors in future.

The use of BIM in projects majorly improves the coordination process of models, including MEP, architectural and structural systems. The continuous review and coordination of the models results in high quality designs being produced, more trustworthy cost and schedule estimates being delivered (Eastman et al., 2011).

Because of the many advantages BIM carries to projects and since many of the owners who have incorporated BIM in their organizations are realizing the countless improvements in quality and value. Owners are revising and adjusting their contracts in a way that can include BIM processes and technologies into their organization (Eastman et al., 2011). A couple of these collaboration methods will be mentioned later. This can also be seen in the UK, where the government has issued a construction strategy that mandates the use of BIM to all projects by 2016. Through this obligation, the UK government expects a saving of 20% in procurement costs (Smith, 2014).

The advantages that has been mentioned in this section will further be discussed in regards to their impact on a construction projects and their affect on the productivity and performance.

2.4.4 Collaboration Methods

According to (Kent & Becerik-gerber, 2010), the main procurement strategy that was and is still majorly being used is Design-Bid-Build in the US. This procurement method has slowly segregated the construction sector from a one master builder responsible for the whole construction process, into many specialists that is responsible of only one part of the project. This has resulted in a fragmented industry. Multiple cultures within the industry developed, parties have their own agenda in a project disregarding Client’s requirements.

This has caused loss of interoperability and cost overruns (Kent & Becerik-gerber, 2010). Though, this separation has contributed in the development of specialists with the ability of performing complex facilities and structures. However, the separation has hampered the integration of design professionals and construction trades (Song et al.,2009).

BIM as mentioned previously, is not only a tool or a new technology, but is a complete process that involves collaboration and communication between stakeholders. Such collaboration requires new forms of contracts that insist on the need of sharing information in a transparent and trustworthy way.

1. Integrated Project Delivery (IPD)

Integrated Project Delivery is a relatively new collaboration method defined by the AIA Council (2007, p.2) as "a project delivery approach that integrates people, systems, business structures, and practices into a process that collaboratively harness the talents and insights of all project participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of the design, fabrication and construction", IPD has defined itself that can effectively ease the process of BIM adoption. IPD aims to provide the required infrastructure for the use of BIM by creating a mutual culture and goal that the parties align themselves towards, and aim to achieve (AIA Council, 2007).

Integrated Project delivery embraces itself around three basic principles, they include:

1. Multiparty Agreement

2. Early Involvement of all parties

3. Shared risk and reward

These three principles seek to unite contractors and designers in one contract, allow all the different stakeholders involved in the project to integrate themselves early in the process, and the share of any issues and problems that might rise during construction, which means parties are responsible for the whole project and not only for a specific part (Kent & Becerik-gerber, 2010). Though these principles do not have to all be included in order to consider the project as an Integrated Project Delivery collaboration method (Kent & Becerik-gerber, 2010).

This method effectively integrates the process of collaboration between designers and contractors in the early stages of a project proceeding all the way through the project reaching the delivery phase (AIA Council, 2007).

2. Early Contractor Involvement

To have a complete understanding of the Early Contractor Involvement method, a definition of Constructability must be clear. It is defined in Song et al. (2009, p.13) by the CII (1986) as "The optimum use of construction knowledge and experience in planning, engineering, procurement, and field operations to achieve overall project objectives".

The ECI collaboration method insists on the contribution of contractors earlier in the design process, as designers are limited to partial experience in that. A solution to this is input of an experienced contractor in designs (Song et al., 2011). Failure in contractor integration can result in, misconception and misinterpretations of designs thus, leading to schedule and cost overruns. Involving the contractor in the early stages brings not only construction knowledge but also provides in-depth knowledge in availability of materials, resources and prices (Song et al., 2009). Engagement of the contractor in the early stages of the process will promote the effective development of the project and proper distribution of workload (Song et al., 2009).

3. Similarities Between IPD and ECI

IPD and ECI are oriented in a way that emphasizes mainly on the integration of parties earlier in the project life cycle. Even though it was mentioned earlier that IPD involves three main principles (Multiparty agreement, Early involvement of all parties, Shared Risk and Reward), those principles were only collected through empirical studies that claimed that IPD was in use despite the fact that not all principles were present. Therefore, those three ideologies are not necessarily required for a project to be considered as IPD. partial existence of any may also be considered as IPD (Kent & Becerik-gerber, 2010). ECI then can be perceived as an IPD strategy or an ideology extracted from it as it involves the participation of stakeholders in the primary phases (Song et al., 2009).

4. Remarks and sum up

Song et al. (2009), mentioned in their article that most of the construction projects are in delay when it comes to applying collaboration techniques into their projects. The input of contractors and other parties that traditionally are not involved in the earlier stages, are postponed to later parts of the construction life cycle, mainly during the detailed design stages where the effectiveness of their input is limited(Song et al., 2009).

This conclusion matches what MacLeamy (2010) claimed in his Time/effort curve where he stated that effort in the design phases peaked in the detailed design stage when the traditional method of procurement was being implemented. The peak is a result of more parties integrating into the process, providing more input.

By engaging all the AEC into the project initially, important decisions, changes and detections in constructability, scheduling and overall quality of the project can be made on a regular basis with a higher effectiveness ratio that can directly influence the performance and the outcome of the whole project (Song et al., 2009).

2.5 Productivity

For a complete understanding of the effects BIM has on the productivity within the construction industry, a clear definition of Productivity, limitations and approaches must be made.

2.5.1 Defining Productivity

Productivity is considered as a vague term with no clear definition. Literature has continuously argued about defining the term but has failed to come up with an agreement. A standardized definition of productivity failed to be made as companies operate as separate entities that create their own measures. Though, a common definition that is found in literature of Productivity is a demonstration between output and input (Park, Thomas, & Tucker, 2005).

Durdyev & Mbachu (2011, p.19) developed a definition of productivity stating that it is "The amount or quantity of output of a process per unit of resource input". The Definition is represented by the following Formula:

$$Productivity = \frac{Output}{Resource\ input} \quad (2.1)$$

Output would be considered as units or the money value of products, whereas input would be considered as quantity of materials or man-hours (Poirier, Staub-French, & Forgues, 2015). This definition also supports Vogl & Abdel-Wahab (2015) that stated productivity as a measure of efficiency in turns of input and output.

The inputs are efforts in form of capital and workforce and the output is what you get out from it for example it could be a product such as facility, car or it could be a service. The construction industry is not homogeneous, you can't measure the output as physical stuff, it´s heterogeneous and harder to measure it as units the solution is the market price being used instead of weights (Vogl & Abdel-Wahab, 2015).

2.5.2 Productivity in Construction

Productivity is fundamental key for economic success and growth globally.
High productivity is lucrative and affects almost everyone, it gives the labors higher salaries, more profit gains and creates a higher tax revenue for the government. Another remarkable advantage with high productive in the construction industry is that consumers get often better and cheaper products this creates a so called zero-sum game in the society (Vogl & Abdel-Wahab, 2015) However, according to (Arditi & Mochtar, 2000), construction productivity shows a trend of declination since the 1980s resulting in increased costs of construction.

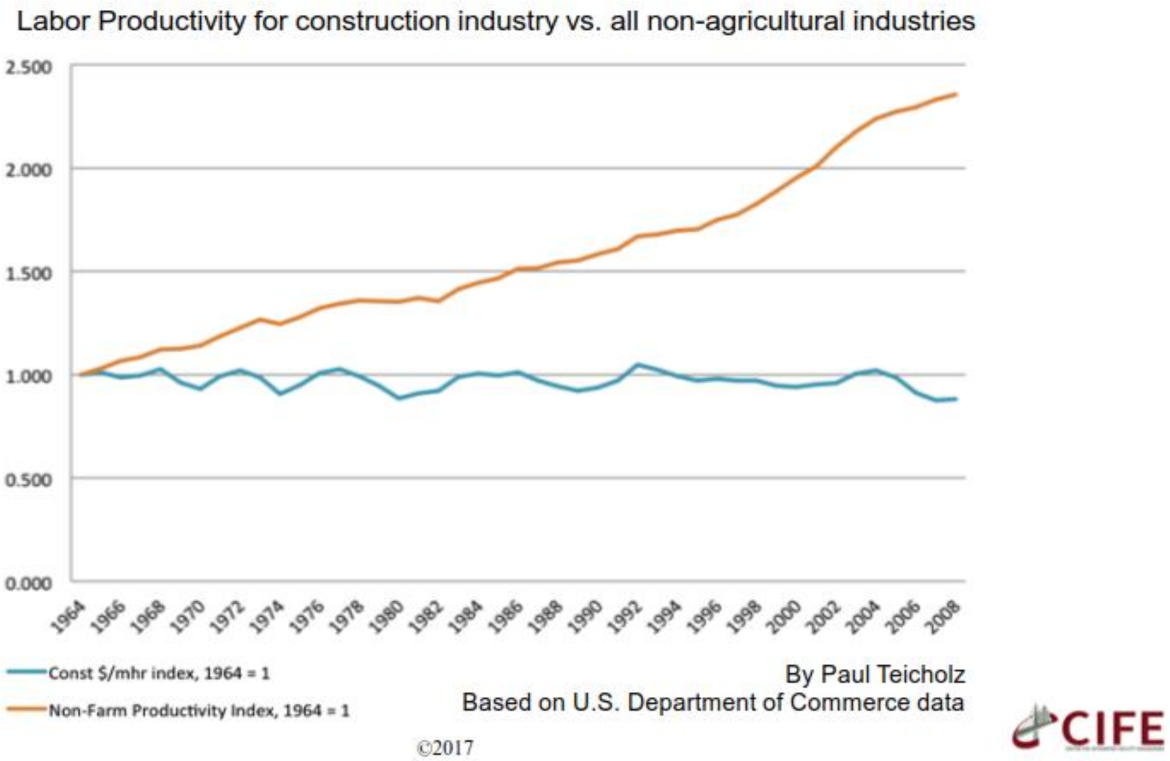

Figure 2.9 Comparison of Labour productivity between the Construction Industry & non-agricultural industries, adapted from (Fischer, 2013) *Fischer (2013).*

Figure 2.9 shows the labor productivity trends between 1964 and 2008 in the US. A comparison between non-agricultural industries and construction industries. It is obvious that the construction industry has been struggling to innovate and is in a stagnated phase. While the non-agricultural industries has been constantly improving.

In the United Kingdom the construction industry was accounted between 6-8% of the gross domestic product (GDP) in Sweden that number was 9% (Vogl & Abdel-Wahab, 2015). By changing and improving the construction industry through productivity performance would create a huge cost savings both for the clients and the contractors. This wouldn´t affect humans only it could also improve the environment significantly. According to Vogl & Abdel-Wahab (2015), 10% labor productivity would create a saving of 1.5 billion pound to put that in perspective it is equivalent to 30 000 houses per year or 30 hospitals.

Both the government and the construction industry have their own agenda by improving the productivity for several reasons and it´s a subject at a premium (Vogl & Abdel-Wahab, 2015).

2.5.3 Productivity measures within the construction industry

Productivity is a measure that can be done at many different levels, beginning with the national, industry, company, project and task level (Soekiman, Pribadi, Soemardi, & Wirahadikusumah, 2008).
There are many ways to measure the productivity in industry generally, though, it depends on the organization measuring its productivity. Since a standardized way is yet to be developed, different organizations measure their productivity differently, most of which are contradicting and controversial (Vogl & Abdel-Wahab, 2015).
In this thesis, productivity on the project level will be the main focus.

Measuring productivity is not a one-time process, in-fact it involves continuous iterations and comparisons between companies and within projects if improvements is to be made (Park et al., 2005).

Poirier et al. (2015) mentioned in his articles an action research cycle that is shown in the figure below.

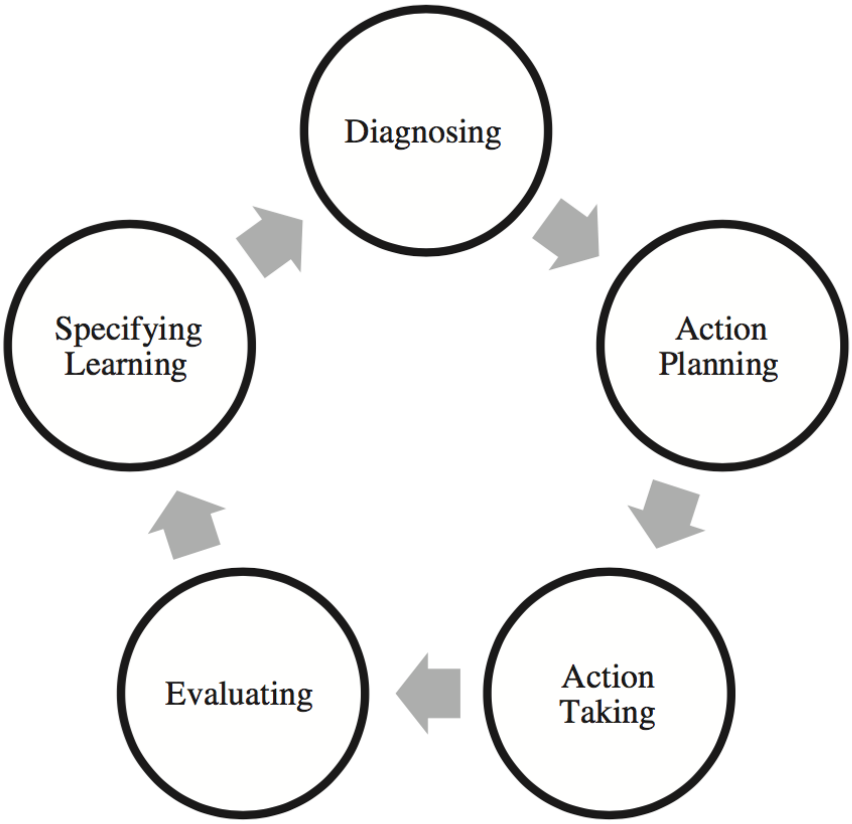

Figure 2.10 Action research cycle creating a learning process, adapted from Poirier et al. (2015).

Figure 2.10 supports what (Park et al., 2005) mentioned in his articles. Measuring, evaluating and learning from the productivity measurements create a continuous process that will contribute to the development of the organization.

A large amount of effort has been put by many researches to develop metrics that contributes for an easier procedure in measuring productivity. The CII committee benchmarked metrics such as cost, safety, rework and schedule as points to consider when analyzing productivity (Park et al., 2005).

Poirier et al. (2015) extensively researched those factors affecting productivity and what can be considered as metrics. His research has shown a trend emerging from different researchers categorizing and sub-categorizing factors that are affecting Productivity. This trend has created a certain level of scale relating the environment, industry, organization and individuals. These factors include poor management, a lack of motivation and up to major technical problems.

Conclusions extracted from the literature states that it is challenging and difficult to obtain a method that can measure the construction productivity due to various limitations that will later be discussed (Park et al., 2005).

2.5.4 BIM effects on Productivity

BIM as mentioned earlier in the paper brings great advantages when integrated within an organization, as it contributes positively to the project performance. Though, since empirical evidence and data is difficult to attain, attempts to quantify these benefits is yet to be solidified (Poirier et al., 2015).

Key Performance indicator (KPI) is a measure that can be used to assess the impact of BIM on productivity. Several researchers suggested the number of request for information (RFI), the amount of rework that should be done, variation orders occurring and how parallel the project is to the schedule. Others suggested units per man hour spent on a project and how this is affecting the rate of development and safety as important key indicators to consider when assessing the impact of BIM on productivity (Poirier et al., 2015).

According to Fischer (2013), he stated that without having what he called leading indicators within an organization, it is very difficult to analyze your performance and know whether a good performance has been reached or not. Several leading indicators were mentioned, they included Pre-Construction man-hours, issue resolution, safety, RFI regarding change orders during construction, RFI regarding variances in design and schedule as well as injuries that occurred during construction that were used to quantify the performance of their project.

Chelson (2010) supported what Fischer (2013) mentioned, RFI reductions, amount of variations in design. Change orders and schedule precision as KPIs to be measured when BIM is utilized in a project.
When assessing those KPIs, Chelson (2010) found that Organizations that has utilized BIM in their projects indicated a productivity increase of up to 40%, mainly due to the ability of BIM in compressing the Design phase. The compression and the integration of the experienced competencies along with the 3D models and many more benefits that has been mentioned earlier, allows the detection of clashes, conflicts and any

problem that might rise because of the design. The overall outcome is a net saving for the client (Chelson, 2010).

Based on the literature reviews that have been done, a checklist has been formulated down below summarizing the main KPI that BIM can affect in a construction project during the design phase. These KPIs can be used to assess the productivity of BIM.

Table 2.2 Summarizing the main Key performance indicators

BIM measure through selected KPIs	Decision Latency
	Response Latency
	Schedule Compliance
	Budget Compliance
	Number of RFIs
	Change Orders
	Stakeholder's Involvement
	Meeting Effectiveness
	Clash Detections

To achieve success within these KPIs, the stages of BIM mentioned previously (Visualization, Integration, Automation) in the thesis must be understood and developed. Development of these stages occurs when organizations fully understand what each stage represent and its affect on the project (Kunz & Fischer, 2012). Each stage is of equal importance for the whole utilization of BIM benefits and the gain of productivity (Kunz & Fischer, 2012).

Visualization achieves 3D models that gives the ability to not only clients but all stakeholders to build their goals and perceive their results beforehand. The 3D models aid in identifying errors, change orders, clashes and any issue regarding design that might occur in construction (Kunz & Fischer, 2012).

Automation on the other hand is what will aid in the compression of the design phase. When organizations become mature in BIM implementation, building elements used in construction becomes routinized and recurring (Kunz & Fischer, 2012). Therefore, an automated practice can be implemented cause faster design performance and reduced preconstruction man-hours (Succar et al., 2012).

Integration is probably the main and most important aspect between the three. If integration is not available, none of the advantages mentioned can be achieved. Integration provides the interoperability and the transparency between the stakeholders (Succar et al., 2012). When a common cloud is present where all the information can be shared, meetings become more productive, stakeholders gets more involved, decision and response latency decrease, that is the time for a decision to be made and the time you receive a response to a RFI sent (Kunz & Fischer, 2012).

Research done by Giel &Issa (2013), suggested that BIM impact on productivity mainly affects the return on investment, meaning that less rework can be avoided if clashes are to be detected earlier in the process, resulting in less changes to be made in the design process. This supports what Sack & Barak (2008) stated where they found gains in productivity due to the reduction of time in drawing production.

2.5.5 Limitations of BIM Usage

Limitations in this case can be divided into two different types. The first one is limitations in measuring productivity and the other one being limitations in measuring the impact of BIM on productivity.

Page & Norman (2014) stated a few of the factors that are affecting productivity and performance of the construction industry, they include:

1. Labor efficiency
2. Uncertainty over workloads
3. How the industry responds to demand
4. Failure to pass on price increases
5. A well developed standard for measurement
6. Poor understanding of Productivity

On the other hand, limitations in measuring the impact of BIM on productivity are numerous. Since BIM is a relatively new technology and process, lack of historical data is one of the major limitations researchers face. Also, each construction project is unique, the uniqueness of the projects restricts the ability in developing productivity rates specific for certain organizations. Coming up with a relation between productivity and BIM, relating productivity to management and project procurement strategies is a procedure that requires finding more integrating links between the two (Poirier et al., 2015).

As a result, Organizations hesitates in implementing BIM in their organization, partially because of the limitations mentioned earlier in quantifying and solidifying the potential benefits that comes along and the other reason is due to the productivity Formula that is (Output / Input). Even though research has shown a trend of improved productivity when new technologies are introduced, productivity may deteriorate as the increase in costs might outweigh the gains (Poirier et al., 2015). This goes along with what Succar et al. (2012), mentioned about BIM Maturity, where he stated that the lack of maturity in BIM can result in the investment costs outweighing the output expected.

Investment costs are what hinders the use of BIM by the construction industry causing the unorganized diverse usage we see today. These hinders can be divided into technical and non-technical parts (Giel &Issa, 2013).
The non-technical aspects include finding the right qualified employees and BIM specialist that can efficiently use BIM. Also providing the appropriate training to employees and building their core knowledge (Giel & Issa, 2013). The resistance to change from employees is also a major drawback found in organizations. Many employees see BIM as something that they have to learn just for the sake of it being a requirement and not because of its potential benefits that hides within (Henrik Franzen, personal interview, April 3, 2017). Also the need in the change of policies

and the way people work and function into a more collaborative, joint thinking environment (Henrik Franzen, personal interview, April 3, 2017).
On the other hand, the technical part includes the cost of softwares and hardware that needs to be installed which can be very costly (Giel &Issa, 2013).

2.6 Theoretical Framework Remarks

In this section, a summary of the important remarks found in the theoretical framework will be given. The summary includes the main points that has been used from the theory and projected on the case study later.

During the research, it has been seen that researchers still struggle to find a precise definition of what BIM is. Some see it as a technological approach while others see it as a completely new way of procurement involving change on an organizational level (Barlish & Sullivan, 2012). In this thesis, BIM is perceived as a process comprising technological advancements, communication tool, new procurement strategies and policy change.

Starting from this interpretation of BIM, Kunz & Fischer (2012) identified three different aspects of BIM, Visualization, Integration and Automation. Those aspects, if developed with the right competencies, can cause a change on an organizational level. Succar et al. (2012) defined three different levels of BIM, including the object-based model, Model-Based collaboration and Network-Based integration. The more competencies and experience gained in improving the models, developing the integration process, collaboration and routinizing activities, the more mature an organization become in its usage of BIM.

BIM can be implemented throughout the whole lifecycle of a project, though, its major implementation is during the design phase (Eadie et al., 2013).
The AIA Council (2007) discussed the design stages a project passes through during its procurement, these include, Preliminary Design, Schematic Design, Detailed Design and Procurement.

The design stages do not have to strictly consist of a specific beginning and ending, in fact, this restriction is what makes the process slower and prone to errors (Eastman et al., 2011).

With the usage of a Design/build procurement strategy, the design process becomes more integrated, allowing the different stages to overlap. This will shorten the design process and make it more efficient (Eastman et al., 2011).

The Procurement strategies can further be enhanced through a change in the collaboration methods. IPD and ECI are two important methods that can be used in promoting more communication and share of information (Song et al., 2009). With ECI in place, contractors become involved in the design phase, utilizing their experience to the advantage of the project.

Macleamy (2010), came up with what is called a Time/Effort curve, a curve that provides an indication of how the collaboration between the various stakeholders is commencing. In this curve, a comparison between the Traditional method of procurement with the Integrated process is presented (Macleamy, 2010). It shows that more collaboration and communication occurs in an integrated process, allowing for early detections of defects in the design, giving the design more flexibility if changes are to be made (Eastman et al., 2011).

BIM, with its 3D models provides a great opportunity for clients to visualize the future results, it also helps in gaining more insights and get the clients more involved in the project (Kunz & Fischer, 2012). BIM enhances the process of collaboration and the sharing of information, providing improved quality and efficiency into the project (Eastman et al., 2011). According to research, the application of BIM also aids in the reduction of costs and time schedule (Smith, 2014).

BIM with its many advantages, can impact the level of productivity in a project. Productivity is measured as the amount of output over the amount of input (Durdyev & Mbachu, 2011). In this thesis, the assessment of BIM productivity in the design phase has been through the examination of several key performance indicators found through research that are thought are positively affected, providing productivity gains (Poirier et al., 2015).

Fischer (2013), Chelson (2010) and Giel &Issa (2013), all suggested KPIs that can be used in the assessment. The KPIs where narrowed down to the most relevant, the ones that affects the design phase and are relevant to the case study. The KPIs included Decision latency, response latency, schedule compliance, budget compliance, number of RFIs, change orders, stakeholder's involvement, meeting effectiveness and clash detection, all which were further divided into qualitative and quantitative KPIs.

With all the potential advantages BIM possess, the adaption of it still seems to be lacking (Poirier et al., 2015). Many organizations see that the initial costs of BIM is high, employees need in order to expert BIM usage, develop their skills, through trainings and continous learning, which to organizations might be an expensive procedure, making it an unproductive strategy to implement (Poirier et al., 2015). Though, if the future advantages are to be realized, and if organizations become more mature and capable in the use of BIM (Succar et al., 2012), the return on investment will be the main productivity gain (Giel & Issa, 2013).

3 Methodology

Here, a brief description of the methodology used in the paper is presented. As it is essential for the reader to understand and perceive how the data was collected and analysed resulting in a smoother reproduction of the study.
The chapter is divided into six main points that has been used as the methodology:

1. Reasearch Approach
2. Case Study
3. KPI
4. Time/Effort Curve
5. Interviews
6. Surveys

3.1 Research Approach

Many of the researchers suggested different approaches in which assessing the productivity of BIM can be done (Barlish & Sullivan, 2012). Though, those approaches consisted mostly of qualitative data that is considered difficult to compare (Barlish & Sullivan, 2012).

Since the opportunity to collaborate with Trafikverket was available and as the main goal was to assess BIM in the design phase in Trafikverket. A reasonable approach was through a case study. One of its ongoing projects was then selected to represent the case. The project is known as "The West Link Project".
The reason behind selecting a case study as the main approach is due to the fact that it is the closest method in which a real life presentation of the current situation can be shown. According to Yin (1994, p.13) "A case study is an empircal inquiry that investigates a contemporary phenomenon within its real life context, especially when the boundaries between phenomenom and context are not clearly evident".

3.1.1 Literature Review

Before going into details in how the approach to the case study was done, it was important to fully understand what BIM is, what are the different stages of BIM, where can it be implemented, the scope of its implementation and its characteristics. When understanding all these, the predecessors and successors of them, you can then relate productivity to BIM, how BIM can improve the productivity of a project and how can it be measured and analysed, how BIM will impact the design process, what advantages it carries and how to maximize its potential.

Extensive research was carried through the literature in regards to that, all which has been presented in the theoretical framework, see Chapter 2. Many different resources have been used including journals, scientific articles, books, interviews and conference proceedings that have been accessed via Chalmers Library, Google scholar and the world-wide web in general.

Since the West link project is considered one of the biggest infrastructural projects in Sweden with great complexity, the case study was further narrowed down to one specific Bid-pack which will be discussed in depth later.
From the literature review, we could identify the main BIM characteristics, map the main KPIs used in assessing BIM productivity, use the Time/Effort Curve to develop an overview of the collaboration in the case, conduct surveys and interviews, see Chapter 2, section 2.2.

3.2 Case Study

The West Link project is a mega project involving millions of Kroners and many stakeholders. Therefore, it is a difficult task to answer the research questions put in a very short time in such a large complex project. As a result one of the bid packs has been used as a main focus of the study that is the Central station.

The Reasons behind choosing the central station as the main focus are the following:

1. 3D models are in use
2. ECI (Early contractor Involvement contract) is present
3. A collaborative environment between Trafikverket and the contractor (NCC).
4. More progress compared to the other Bid-packs
5. Contractor and Client available in one area
6. Greater Availability and accessibility to information in comparison to the other Bid-packs

With that being said, it is still a necessity for a brief introduction of each bid-pack and how each is being procured. This will be presented in Chapter 4.

3.2.1 BIM Characteristics

During the literature review, BIM capability, Maturity, and the LOD (Succar et al., 2012) were identified as the main characteristics of BIM. Following these points are aspects including the scope of BIM, visualization, the level of integration and automation (Kunz & Fischer, 2012).

To assess BIM in Trafikverket, the characteristics mentioned were used as the main approach towards this assessment. The focus of the data collection circulated around defining the amount of maturity and capability Trafikverket possess. Finding to what extent BIM is used, how the integration and the share of information functions, the amount of details the models contain, competencies among the employees and the overall attitude towards BIM, all which has contributed to the process of identifying their maturity and capability levels.

The data collection in this part was mainly through the surveys conducted by Trafikverket, interviews, direct observations and the search in Trafikverket’s data base.

3.2.2 Key Performance Indicators.

It was clear in the research that KPI had the most attention from many of the resarchers such as Kunz & Fishcer (2013), Succar et al., (2012) and Chelson (2010). The researchers suggested several KPIs, some that where unique to a specific researcher while others where exclusive. Also from the interviews done, KPIs similar to the ones suggested in the literature where also mentioned.

In this thesis, a gathering of the common KPIs was done from literature and interviews in Trafikverket. The gathering allowed to develop a list, see Table 3.1, summarizing the main KPIs related to BIM..
The list will be used to assess BIM productivity in the West Link Project (Central Station Bid-pack).

Table 3.1 Summarizing the main Key performance indicators

BIM measure through selected KPIs	Decision Latency
	Response Latency
	Schedule Compliance
	Budget Compliance
	Number of RFIs
	Change Orders
	Stakeholder's Involvement
	Meeting Effectiveness
	Paper Document reduction
	Clash Detections

To ease out the data collection procedure, the KPIs has been divided into two categories

1. Quantitative KPIs
2. Qualitative KPIs

Quantitative KPIs are the ones that could be measured. The required data was collected from the employee responsible for data collection, these include:

1. Clash Detections
2. RFI
3. Change Orders
4. Schedule Compliance
5. Budget Compliance
6. Paper Document Reduction

Qualitative KPIs are the ones that were measured through a softer approach. It included the interpretations of interviewees opinions and the results of the surveys done, these include

1. Decision Latency
2. Response Latency
3. Stakeholder's Involvement
4. Meeting Effectiveness

Table 3.2 Showing how the KPIs has been categorized

Quantitative KPIs	Qualitative KPIs
Clash Detections	Decision Latency
RFI	Response Latency
Change Orders	Stakeholder's Involvement
Schedule Compliance	Meeting Effectiveness
Paper Document Reduction	
Budget Compliance	

3.2.3 Time/Effort Curve

Another important aspect in the study is the Time/Effort curve suggested by Macleamy (2010). It represents the duration of the design phase on the x-axis and the Effort on the y-axis. Effort can be defined as the amount of chargeable time put into the design (Lu et al., 2015).

The Central Station Bid-Pack is an ongoing project and is still in its design phase. According to the Team of Trafikverket and NCC, the project has finished its schematic design (Systemhandlingar) and is starting with its detailed design. The graph then will only present the Preliminary and Schematic Design.

In order to create the curve, data was required to be collected from Trafikverket and NCC in the Central station bid-pack. A request was sent to the person responsible in archiving and recording the hours done by the engineers involved during the design process. The hours procured for each month was recorded and plotted on the graph. Then an estimation of how long the duration of the Preliminary and Schematic phase were done based on the interpretations of NCC's employee, since an accurate start and end was not recorded. It is important to note that the hours plotted involved, the hours procured for all activities, including design, purchasing and cost analysis. The information was then collected and used to draw the graph.

As mentioned earlier, the Macleamy curve is adapted to the American market. As a result a translation of the design phases into the Swedish version was done.

The data was then put into an excel sheet, and a simulation of the information was done in the form of a curve.

3.2.4 Interviews

As it was seen that the project is of a high complexity and due to the lack of complete quantitative data, an important solution was to gather some qualitative information through conducting semi structured interviews and surveys.

Interviews were chosen to be semi structured due to the fact that such types of interviews are considered to be more open, allowing the introduction of new ideas, it involves the use of a schedule that include main topics with indicative questions, though these questions do not have to be the only ones, thus providing more flexibility (Elliot, Fairweather, Olsen, & Pampaka, 2016).

Several interviews were done with employees of different responsibilities. Interviewees included were from an organizational level (Trafikverket) and on a project level (West Link and Central Station Bid-Pack).
The interviewees were:

- (2) BIM specialists
- (1) Staff Responsible of Westlink
- (1) Chief of Data Coordination
- (1) VDC group manager (NCC)

The interviews were recorded and transcribed.

The questions circulated mainly about BIM. The main goal of the questions was to perceive;

- How Trafikverket See BIM
- What Benefits do they see in the implementation of BIM
- Their future goals in this regards
- BIM capability and Maturity
- Collaboration
- How they measure productivity
- The level of integration and the process of information sharing
- The scope in which BIM is being used.

3.2.5 Surveys

The next step was to conduct a survey through which more qualitative data can be collected. Trafikverket has already conducted a survey in which many of the questions were relevant and can be used in the thesis.
Trafikverket's Survey was divided into two parts, the first one involved the whole of Trafikverket, while the second part involved the main key participants in the West Link project. The second survey was used for this thesis. As a next step, specific questions that found to serve the thesis well has been chosen from the surveys.
The questions were initially in the Swedish language and were translated into English.

Questions chosen mainly focused on how employees saw BIM, in regards to it being as a tool or a whole new process, including other question which gives the ability to assume a certain degree of maturity of BIM within the organization.

The other type of questions focused on gathering opinions of employees about the benefits BIM carried in their project, has it promoted effective meetings, more involvement and clash detections.

The results of the surveys and interviews will be mentioned in later section. Both the questions from the interviews and the Survey are given in the Appendix.

4 Project Details (Case Study)

4.1 Trafikverket Introduction

In the autumn of 2009 there was a drastic change in 2 big agencies in Sweden (Trafikverket, 2015b). It was Banverket and Vägverket, 2 well-established agencies to be closed and instead a new agency would be created. In April of 2010 Trafikverket was inaugurated with over 6500 employees and a budget of 50 billion the agency took over the tasks from the 2 previous agencies (Riksrevisionen, 2011).

Trafikverket is a Swedish agency with the responsibility of the long-term infrastructure planning for the railways, road-traffic, waterborne traffic and air traffic (Riksrevisionen, 2011). Trafikverket is the largest public client in Sweden, buying products and services for over 40 billion crones every year, the procurement are annually, they have also the responsibility to build and maintain these traffics. In the practice means that the Trafikverket has the main responsibility for all public roads and railways, to operate anytime for all the citizens. There is a national plan for the development of the Swedish transportation system for 2014-2025 and contains an investment of 522 billion Swedish crones. The budget contains maintaining, operation and investments for the whole country (Riksrevisionen, 2011). The budget will be used in collaboration with municipalities, county and other stakeholders.

4.2 West Link Project

The West Link is an 8 Km-long commuter train double track railway connection that passes through central Gothenburg of which 6 Km are to be a tunnel running underneath the city. Because of the project, 3 new stations are to be constructed, the Gothenburg central station that will be an underground station and two completely new stations at Haga and Korsvagen(TrafikVerket, 2015a)

The West Link is one of the biggest infrastructure projects to be procured in Sweden, specifically in the city of Gothenburg. The West Link is not only a part of the national plan of the Swedish transport system 2014-2025, but also a part of the West Swedish agreement that involves investments in different infrastructural projects. Therefore, a regional and local financing are included with an estimated project cost of 20 Billion SEK (TrafikVerket, 2015a).

The West Link project idea rose due to the development of the western region of Sweden. The development of the region increased the traffic pressure on central Gothenburg, which acts as a hub. The need of greater capacity was the initiative for starting up the project (TrafikVerket, 2015a)

The West Link project will provide a reliable railway traffic system in Gothenburg and Western Sweden, it will improve flexibility and safety. The project will facilitate a total of 100,000 residents and around 130,000 workers easy access to commuter stations within biking or walking distance in central Gothenburg contributing to a sustainable growth of the Gothenburg region and Sweden as a whole (TrafikVerket, 2015a).

Figure 4.1 Route of the West Link and the three stations to be constructed, adapted from Trafikverket (2015a).

The project comes up with many challenges that must be faced due to its complexity. Parts of these challenges are structural and others are cultural. The project is to be constructed in an inner city environment, where contractors must be careful not to interfere with the surroundings. Also, part of the excavation to be done is in loosely compacted clay, which can be challenging for contractors.

Below is a timeline showing how the work on the West link has commenced

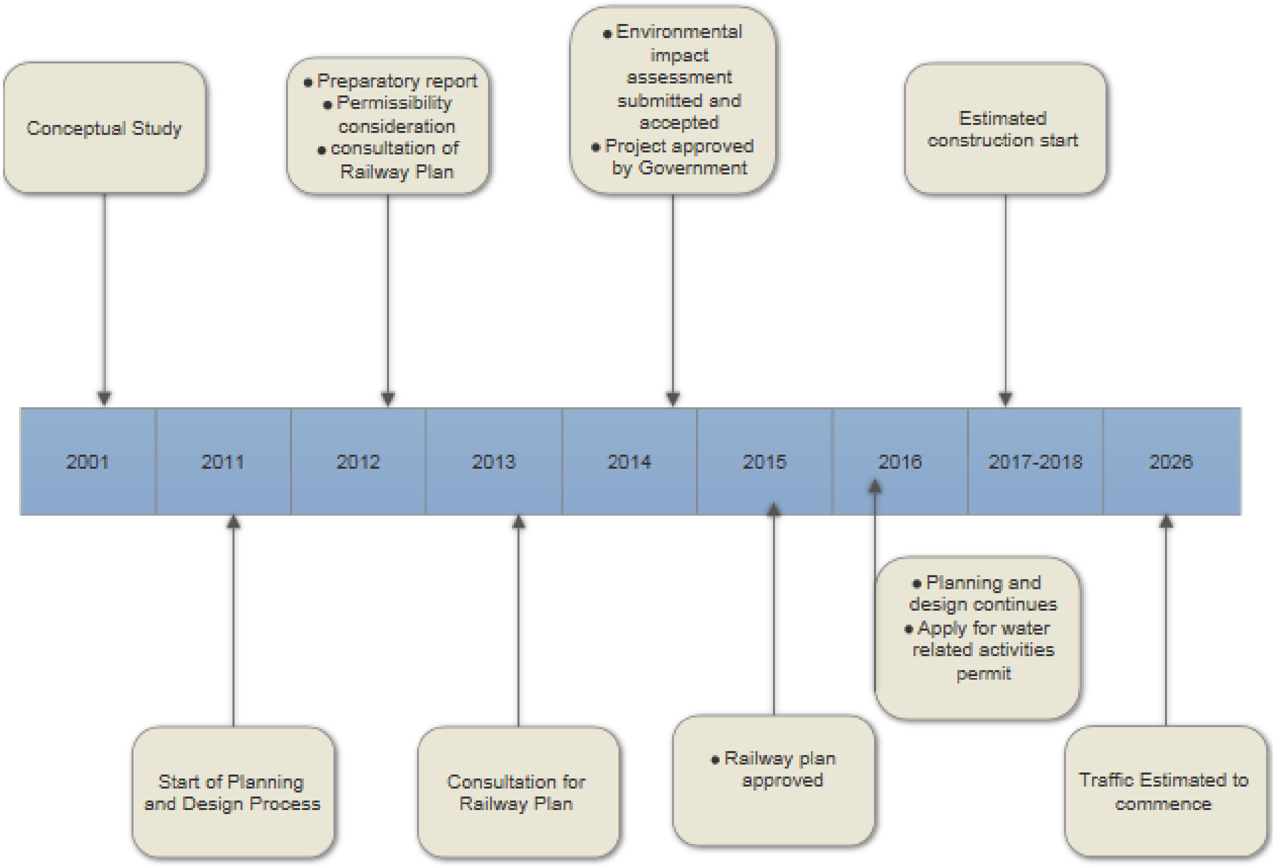

Figure 4.2 Timeline of the West Link work progression.

4.2.1 Procurement strategy of West Link

A very important factor to consider in a large and complex project like the West Link, is the contract types and procurement strategy. Trafikverket view this as a very important point that should carefully be considered as the way the contracts are packed will have a major effect on the coordination and management of the project (Brunbäck, 2014).

Trafikverket has divided the West Link project into several parts, they are

1. The production of tendering documents and designs to be used by contractors
2. Preparatory work
3. Excavation and soil management

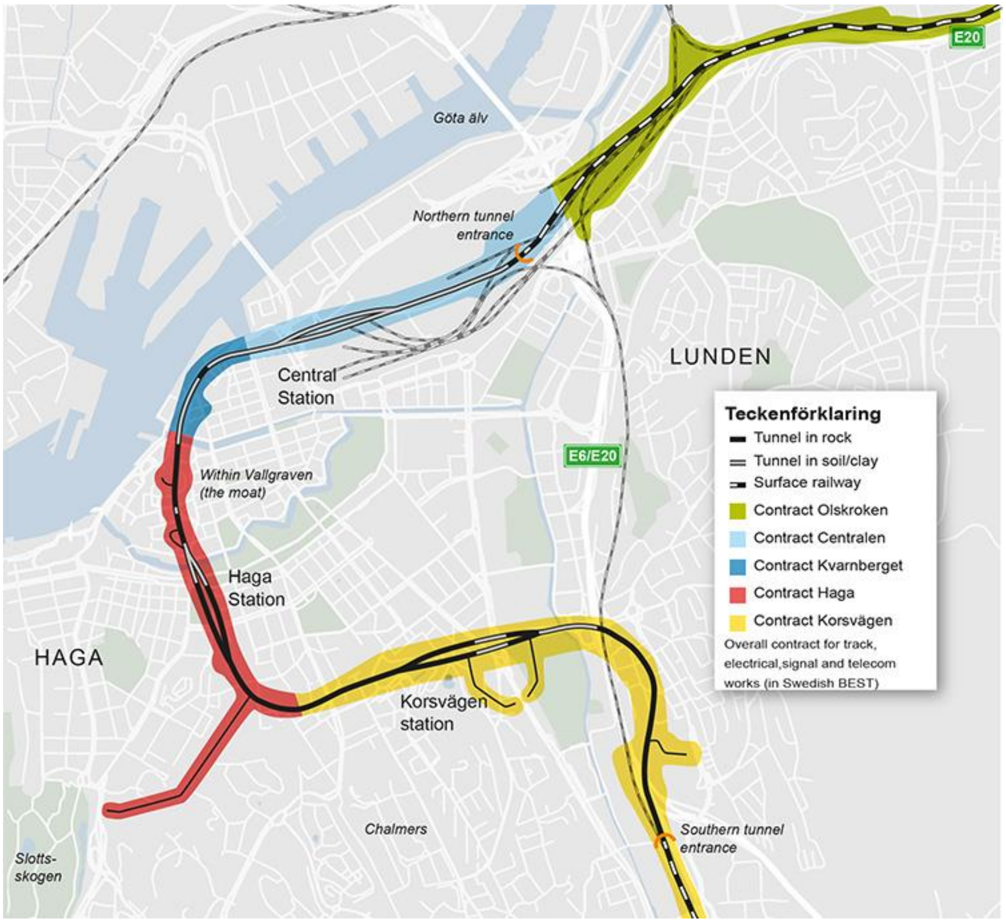

Figure 4.3 The map showings how the contracts has been distributed and handled by Trafikverket, adapted from Brunbäck (2014).

As Figure 4.3 shows, the contracts are split into 5 large bid packs and one small, a brief explanation of these bid packs will follow, they are:

1. Olskroken
2. CentralStation
3. Kvarnberget
4. Haga
5. Korsvagen
6. BEST

a) Olskroken

The Olskroken bid pack stretches from Olskroken and to the bridge crossing the E6 consisting of 15 bridges. It extends over a span of 6 years with an ECI turnkey contract (Brunbäck, 2014).

The Olskroken contract will consist of two types of payments divided into two phases. The first phase being a fee contract while the other one is a current price with a target cost agreement contract, where the client and contractor. This type of payment means that the contractor is reimbursed for the amount of work done. Though, if the prices rise above the target cost, client and contractor are obliged to share the losses within (Brunbäck, 2014).

b) Central Station

The central station is one of the large Bidpacks compared to the rest. It aims to increase the overall capacity of the central station. Along with the tunnels that has to be excavated and built.
The contract will cover all works in regards to building the station and the tunnels to be built that will connect the European Highway E6 all the way to the new central station at Lilla Bommen. Both constructions will be built with mainly concrete in open excavations and temporary supporting structures (Brunbäck, 2014).

The Bid-pack shares many complexities, partially because it is being built in an area with traffic and in public transport routes. Another reason is the stretch of line between Gullberget and Lilla Bommen geological situation, as clay is present 100m below. The preconditions add an extra point in the level of complexity (Brunbäck, 2014).

This pack expands over a span of 6 years and expected to be completed in 2024. It will consist of two different phases. First the contractor will be engaged in the design process through a ECI turnkey type of contract, were Trafikverket and the contractor, in this case is NCC will collaborate for the formation of the design process. During this period NCC will be paid fees depending on the amount of hours done.
Once the designs are complete. NCC will offer a price in which Trafikverket will accept or decline, upon acceptance of the lump sum price, construction can commence. The lump sum will be considered as a current price with a target cost agreement (Brunbäck, 2014).

c) Kvarnberget

This contract is considered fairly smaller than the others but with similar work. It is situated between Lilla Bommen in the north and Residenset South of Hamngatan. The contract mostly consists of a concrete tunnel and expands over a span of 5 years. It will be procured as a turnkey contract (Brunbäck, 2014).

d) Haga

The Haga Bid pack is one of the biggest contracts with an approximate price of 3 Billion SEK consisting of tunnels running in rocks and clay and is estimated to span over a period of 6 years. Since the bid pack consists of two forms of work, of which some in concrete and others in rock. The rock work will be procured as a performance contract while the concrete work in turnkey form. There will also be shares in contingencies within the contractor and the client (Brunbäck, 2014).

e) Korsvagen

This contract is priced approximately around 3 Billion SEK, consisting of a tunnel running from Korsvagen station and ending in Almedal. The work done will be changed from rock to soil as the tunnel proceeds in its path. The contract estimated duration is around 7 years.

The concrete work will be procured as a turnkey contract while the rock works in performance form. Payment strategy will vary through the different stages of the design and into the construction. For the rock work, a quantity payment method is transcribed, while the concrete work will be transcribed as a fixed lump sum price (Brunbäck, 2014).

f) BEST

The BEST contract is a contract running through the entire bid packs mentioned earlier, consisting of works that are technology dependent, including track, electrical and telecom works. It will be in the form of a performance contract and a lump sum price as the payment strategy (Brunbäck, 2014).

4.3 Productivity in Trafikverket

By spending billions of Swedish Kronas every year on services and products, the productivity takes a very important place in Trafikverket's business plan. Trafikverket as mentioned before is an agency which is funded by the Swedish taxpayers and in that sense, it's crucial to use the money in a correct way within the framework of laws and regulations (Trafikverkets produktivitet, 2011).

Riksrevisionen is a Swedish agency that works under the parliament as a reviewer of activities done by the state (Trafikverketsproduktivitet, 2011). They have reviewed the productivity between 1991-2009 of the 2 former agencies "Banverket" and "Vägverket" which ceased in 2010 and became Trafikverket.

One of the reasons behind the establishment of Trafikverket was that the former agencies "Banverket" and "Vägverket" had lack of productivity for a long time in the construction industry. The audit findings done by Riksrevisionen shows that the two former agencies did not have any reasonable demands on measurement and reporting of productivity (Trafikverkets produktivitet, 2011).

Riksrevisionen came to several conclusions in the audit report in 2011, they were;

1. The government needs to have a more detailed presentation of productivity, better definition, clearer requirements and goals.

2. The government should also monitor Trafikverket in a sensible way.

3. Trafikverket should now measure the productivity and report it to the government and the parliament.

These were some of the conclusions that were made in 2011 just a year after the establishment of Trafikverket and the reason for that was to show Trafikverket guidelines to be followed. According to the Swedish budget act, this requires good management of resources which in return needs activities to be monitored (Trafikverkets produktivitet, 2011).

Since 2012 Trafikverket had to go through a journey of change with the aim to increase the productivity in the contracting business (Trafikverkets produktivitetsarbete, 2014). A way to increase the productivity was a higher client role which results in higher demands on suppliers. Another productivity approach has been turnkey contracts where Trafikverket has strived for, the aim is to achieve 50% of turnkeys to 2018 and that was already achieved in 2015. Procuring consultants will later be based on fixed price and a price in combination. According to Trafikverket the consultant procurement will be fully developed in 2018.

Trafikverket required that BIM will be used in all procurement by 2015; their next step is to implement BIM in all planning, management and through the whole lifecycle (Mårtensson, 2015). Figure 2.4, see Chapter 2, Section 2.3, shows level 2 by 2015 and after the implementation, level 3 will come gradually depending on the rate practice and the development of BIM in the market.This will be considered as a major advancement in their productivity aims (Mårtensson, 2015).

The strategy is to increase the productivity by 2-3% annually, this is equivalent to half billion Kronas in savings every year (Trafikverkets produktivitetsarbete, 2014).

5 Results

This section summarizes the result that has been retrieved from Trafikverket. Note that the interviews done will be used throughout the results.

5.1 Trafikverket

The interviews conducted with Trafikverket and the contractors were to explore a wider view of BIM in the design stage, also to see how Trafikverket work with productivity in their projects. The interviews have been conducted with five persons that were important stakeholders in Trafikverket and Central Station project. The stakeholders are

1. Katarina Delvret - Chief Manager at Västlänken,
2. Niklas Lindberg - BIM Specialist
3. Henrik Franzén - BIM Specialist
4. Roger Wennberg - Data Coordinator in Central Station project
5. Josef Habbe - Consultant from NCC working with VDC.

5.1.1 BIM in Trafikverket

BIM is not an easy puzzle for researcher to define, neither for Trafikverket. When interviewees were asked on how they define BIM, different answers from the employees were given.

According to Katarina Delvert (Personal interview, March 31, 2017), BIM is all about communication, while the BIM specialists defined it as a tool used to generate 3D models. Both Niklas Lindberg and Henrik Franzén (Personal interview, April 3, 2017), would like to see BIM as a whole new process, a process involving stakeholders in an early stage to avoid delays.

One thing both Katarina and the BIM Specialists greatly emphasized on is the ECI contracts. Both Katarina and the BIM specialists defined it as two separate processes when compared to BIM. This is also reinforced by the theory of Succar et al, (2012) and Kunz & Fisher (2012) regarding the 4 stages of BIM scope, visualization, integration and automation.

The reasons behind the implementation of BIM are one of several new strategies from Trafikverket. Trafikverket would like to achieve the following with BIM:

1. To improve the understanding and overall impression of the project through 3D models allowing for effective and more reliable meetings.
2. To provide accurate quantities of for costs, materials and time
3. Reduce the amount of drawings required
4. Increase the overall productivity of the organization

According to Katarina (Personal interview, March 31, 2017) the strategy with implementing BIM started on a larger scale in 2012, several years later the strategy has not been reached out as it should, there isn't any specific plan for BIM and how to develop and proceed.

5.1.2 BIM Characteristics

Trafikverket is slowly pushing themselves in a position that they call a "Pure Client Role". Their aim is to reduce their interactions with contractors, reduce the constraints and restrictions, thus providing more freedom for the consultants and contractors to work with.

This means that Trafikverket demands models of consultants and contractors but they do not interfere with how they do it, instead, they specify certain criteria and requirements that they expect the models to contain.

When comparing Kunz & Fischer (2012) stages with how BIM is in Trafikverket, the following observations were made.

Visualisation

The visualization aspect to Trafikverket is one of the major advantages they perceive with BIM. They use several softwares to develop and review 3D models done or delivered by contractors and consultants.
Examples of these softwares include Teckla. Revit and Autocad.

It is lately that Trafikverket has required from the contractors to perform 3D models in the tendering process. Though, there still exist 2D models when it comes to for example, piling or more complicated detailed such as carrier. There is still room for improvement when it comes to such details.

Policies on what Level of details the models should be, how the stakeholders are to implement BIM and the softwares they must use are not very strict. Trafikverket has given their contractors a wide area of freedom in regards to the way they implement BIM. Their main aim is to gain insights of how the project is looking and use these models to communicate it to the end users.
The main demand of Trafikverket is the format they receive.

Integration

When it comes to Integration, Trafikverket uses two different databases called Project Wise and PPI (Projekt portal Investera).
It is an IT system that support common work processes, information management and document management. The program is primarily used for design and site information, but you could also use it as a server.

All stakeholders are connected to the Project Wise depending on which project you are involved in, if a user have the approval to do so. Stakeholders and third parties working along Trafikverket could be permitted to access Project Wise, to deliver models for example. Though Trafikverket usually inspects if that is necessary.

Project Wise is a locked system, despite that you are involved in a project or are an employee in Trafikverket you still have to apply for permission to access.
This is mainly due to the restrictions in regards to policies and confidential details that Trafikverket hesitate to share between stakeholders.

Automation

The automation in Trafikverket is not as efficient as it should, routinized and standardized work is limited. Since each project is unique with specific requirements and stakeholders, it is of a difficult task to create standardized and routinized procedures, especially when it comes to design and BIM.

5.2 Trafikverket& NCC (Central Station Bid-Pack)

This section summarizes the findings in the Central Station Bid-Pack of the West Link Project. The results of this section are on Phase one of the Central station only, since phase two has not been started yet.

5.2.1 ECI Contract

Trafikverket, in this Bid-Pack has taken the decision to procure through a Turn Key contract (Design/Build) with an ECI dimension. This being the first phase of the project. NCC was then qualified to be the contractor involved. Trafikverket assigned a Team to work closely with NCC in a common office, thus creating a suitable environment for the collaboration. Around 200 employees work on this Bid-Pack. Both of the interviewees thought that there still exists a large area for development in regards of the ECI, as it is still a new procurement strategy to both. According to Roger Wennberg (Personal interview, April 19, 2017) the ECI contract is a great opportunity to attain the contractor's perspective and opinions in the project early on, also, it is a great opportunity for Trafikverket to get involved sooner than usual. With this involvement, they would establish a greater insight on not only the project but also NCC. "It is an opportunity for Trafikverket and NCC to learn each other" (Roger Wennberg, Personal interview, April 19, 2017).
The learning process will aid in an effective and more productive results in the next phase. On the other hand, Josef (Josef Habbe, Personal interview, April 19, 2017) stated that NCC was very happy with this type of early collaboration, regardless of some issues during the setting up. Josef (Personal interview, April 19, 2017) added that having ECI will allow us to solve any major conflict or problems early on in the project thus, reducing future errors.
In phase two, a tendering phase could be considered by Tafikverket incase NCC offer is considered of a high price, this means that other contractors can bid. According to Josef Habbe (Personal interview, April 19, 2017), NCC are aiming to gain the contract. He also stated during the interview that the whole idea with ECI is to discuss the complexity regarding the project, come up with a reasonable price and create a long-lasting relation with Trafikverket.

This goes in conjunction to what the theory suggested in regards to the early collaboration by Song et al. (2009). This also matches what Macleamy (2010) suggested in the Time/Effort curve. With an integrated and early involvement of stakeholders, the whole process can be run in a smoother more efficient way (Macleamy, 2010). The availability of both entities was a major advantage to them. Since they are working in the same office, any small issue that comes on the table can quickly be solved, thus reducing the bureaucracy and the decision making process.

Table 5.1 Summary of the ECI advantages seen by Trafikverket and NCC

ECI Advantages	
Trafikverket	**NCC**
Use contractor's experience	Understand Client's needs
Increased Involvement	Gain reputation
Greater insights within the project	Effective meetings
Create Common goals	Create common goals
	Faster Decisions

5.2.2 BIM Characteristics

When questions about BIM were asked, it was seen that NCC had a clearer definition of what BIM is to their company and the way they use it in projects in comparison to Trafikverket as mentioned earlier. Though, both agreed that ECI and BIM are two very important solutions for the stagnation of the construction industry, but the existence of one doesn't necessarily means that the other must exist. In other words, having BIM which is defined as 3D models to the BIM specialists in Trafikverket, doesn't necessarily require to have ECI implemented. They then mentioned that if the two were put hand to hand, it can then produce great results.
With this type of procurement strategy, NCC hopes to construct the project at a lower price than the traditional way.

Several questions were asked to assess BIM Characteristics of NCC against Visualization, Integration and Automation.

Visualization.

NCC used many different softwares such as Teckla, Microstations and Revit to establish the 3D models. Their models consisted of different level of details depending on who is it to be sent to later. Most of the models though had the geometry and metrics well developed. Others had more details and specific to various disciplines, such as the MEP and structural. These models can be used to detect clashes and quantity take offs.

Integration

NCC shares their information on a common database shared between their employees. Also, they created what is called a Project Studio that is collaborative meetings they consistently do involving a large number of people including Trafikverket. Through the availability of most stakeholders, more ideas and suggestions can be taken from different perspectives. They thought that this type of meetings were greatly effective, regardless of its limitations and struggles that can occur such as side talks and difficulties in an organized meeting. The meetings occurs every week and there is a

larger meeting every month where NCC deliver all design models into one specific detail model and hands it over to Trafikverket.
Trafikverket required that NCC deliver the models in DWG format. DWG is a file format that makes it accessible for Trafikverket to use and analyze the outcome of the models. Though, NCC did not necessarily work with this type of format but used others such as IFC. The final model was then changed into DWG and delivered.

Automation

In regards to Automation, NCC has many elements stored in their BIM libraries that can be used as routinized and standardized work, which can in return decrease the time of the design phase. Such elements included columns and beams for the Central Station. Others involved concrete elements to be assembled in the tunnels.
Since the project is faced with many different challenges, not all the elements can be automated.
Both Trafikverket and NCC claimed that BIM is the future of the construction industry, but unfortunately it is being faced with a lot of resistance by employees. According to Josef, not all employees feel it is the future, they just think it is a new thing that we have to learn. The disparity among the employees is also another issue. Not all are competent enough to work with 3D models.
The limitations mentioned by the employees matches what was said in the theory in regards to the lack of BIM within the construction industry (Giel & Issa, 2013).

Table 5.2 Summarizing the points fulfilling Kunz & Fischer (2012) BIM stages in the Central Station Bid-pack

BIM	Central Station Bid-pack BIM
Visualization	• Softwares in use • Models Generated
Integration	• Collaborative meetings • Open Servers • Online database
Automation	• Routinized work (To some extent)

Judging on what has been discussed above, an assumption of the current situation of BIM in the Central Station Bid-Pack is made.

Beginning with BIM Capability (Succar et al., 2012), 3D models are in use to a high extent. This fulfills the first stage. The use of various collaboration techniques, such as the ECI and a common database for sharing allows the shift to the second stage. NCC and Trafikverket are still somewhat working separately, not all information is shared, neither from Trafikverket nor NCC, thus creating a missing gap between them. On the other hand, the Project studio concept developed by NCC has created a more collaborative environment between both stakeholders. The collaboration is seemed to be lacking.

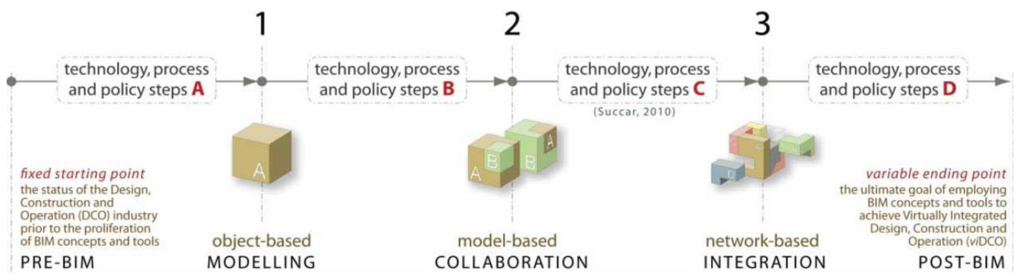

Figure 5.1 Figure showing the three BIM capability stages, adapted from Succar et al. (2012).

In regards to the Level of development of the models, Trafikverket did not require any specific LOD, the most important thing to them was the ability of them to gain enough insights of the project through 3D visualization. Though, NCC had their models shifting between the LODs, some with many details, while others with minimal amount of information.

BIM Maturity was found to be varying between the two entities. Trafikverket was not up to the level of maturity NCC was. NCC had stage one and two with high level of maturity when compared to Trafikverket.
NCC then with its competencies was seen to push Trafikverket a level up in the ladder of BIM.

5.2.3 Productivity Improvements through KPI measure

In this section, the KPIs mentioned in the methodology, see Table 3.1, will be compared with the Central Station Bid-pack.

1. <u>Quantitative KPIs</u>

- Clash Detections

According to the interviewees, the clash detection process is one of the main advantages of BIM for both Trafikverket and NCC. With the clashes being detected early in the design phases. Many problems can be avoided. Also, NCC stated that, clash detections reduce the cost of the construction phase. This is because any problem that is found during design is much easier and cheaper to change when compared to the construction phase.

Unfortunately, no accurate record of the number of Clashes detected was present, though according to Trafikverket (RogerWennberg, Personal interview, April 17, 2017), a reduction of 5% in cost has been avoided through the detection of clashes.

- RFI

Request for information according to Trafikverket, are any miss understandings by the contractor. An email is usually sent by the contractor to Trafikverket requesting for clarifications in regards to a specific issue. In the West Link, Central Station Bid-pack, the number of RFIs for the Design are not recorded due to a simple reason. Both Trafikverket and NCC are working in one office together, meaning that any clarification required by NCC from Trafikverket or vice versa can immediately be solved through a quick over the desk discussion.

Both Trafikverket and NCC added that BIM was not the main reason for this reduction, it is mainly because of the ECI contract along with BIM that has prepared a solid ground for the development of the project.

- Change Orders

Change orders made by Trafikverket to NCC were un-coded, meaning that it was hard to categorize which change order is BIM related and which is not. Also, which of the change orders were in regards of the design phase and which were not. Though, Trafikverket mentioned that the ability to visualize the project in 3D contributed greatly in reducing the amount of Change orders requested. This did not mean that no change orders were requested.

- Schedule Compliance

According to the Economic department, the time schedule of the project when compared to the estimated time is around 30 days delayed. It is expected to complete the SD by the beginning of June, but the new expectation is by the end of June.

The cause of the delay as mentioned by Trafikverket, was that BIM and ECI are two relatively new strategies for Trafikverket, the experience in that regards are lacking. Also another reason was due to few change orders requested that contributed to the delay.

- Budget Compliance

Trafikverket, according to their estimated costs are around 10% above. The 10% increase in cost are not only for the design but for the Central Station Bid-pack in general. One of the reasons behind the rise in the costs are due to the change orders claimed by Trafikverket. Again the change orders are not necessarily specific to the design. As mentioned the Change orders are un-coded and it is very hard to categorize them.

As the budget and monthly payments was data that is confidential and not accessible, no in-depth information was attained in regards to the budget.

- Paper Document Reduction

With the implementation of BIM, Trafikverket was able to reduce the amount of paper documents by an estimated percentage of 75%. The only paper documents that were not been able to computerize were the Telecommunication and signal drawings and the governmental official papers such as permits.

2. Qualitative KPIs

- Response Latency

Response latency is the time required for a response to be received from an RFI (Kunz & Fischer, 2012).
According to the interviewees, time has been greatly reduced with the availability of Trafikverket and NCC in the same area. As mentioned earlier, see Chapter 5, section 5.2.3. Through this collaboration, there has been a reduce in the bureaucracy, as the need for formal RFIs were reduced and replies were received in a very short time.

- Stakeholder's Involvement and Meeting effectiveness

According to Roger Wennberg (Personal interview, April 17, 2017), the ECI contract has contributed greatly to the increase of stakeholder's involvement in the project. He also added that with the Project Studio meetings NCC does, the involvement was also improved. On the other hand, with the great involvement of the stakeholders and the availability of 3D models, meetings were much more effective, more discussions and decision were made, as things where thought to be clearer with such involvement and models.

Summarizing

Table 5.3 Showing a summary of the KPI results in the Central Station Bid-Pack

Quantitative KPIs		Qualitative KPIs	
KPIs	**Achievements**	**KPIs**	**Achievements**
Clash Detections	5 % Cost Reduction	Decision Latency	-
RFI	Reduced	Response Latency	Faster Responses
Change Orders	Reduced	Stakeholder's Involvement	Improved involvement
Schedule Compliance	30 days Behind Schedule	Meeting Effectiveness	Improved effectiveness
Budget Compliance	10% over Budget		
Paper Document Reduction	75% paper Reduction		

5.3 Time/Effort curve

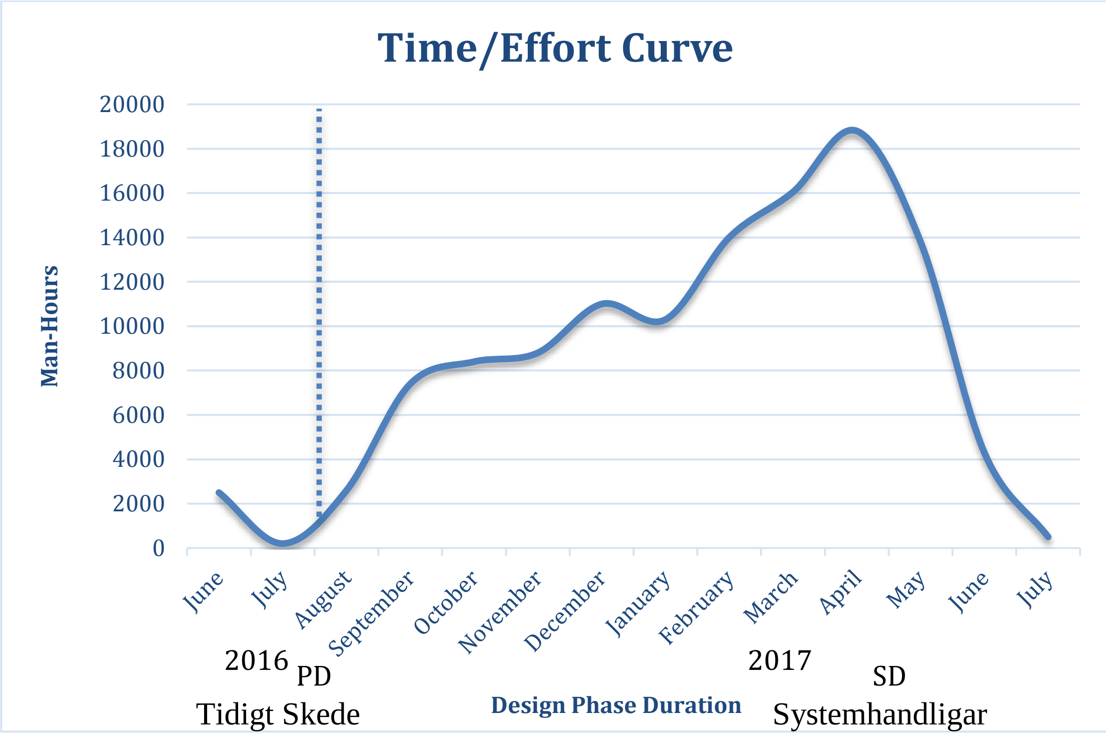

Figure 5.2 Showing the Time/Effort Curve of the Central Station Bid-Pack of the West Link project

Figure 5.2 illustrates the Time/Effort Curve of the Central Station Bid-pack (West Link Project). The Central Station Bid-pack consists of around 150 employees. From June 2016 until August 2016 was the PD phase. Though it is important to note that the PD extended prior to June 2016 but was done by fifteen other consultants according to Katarina (Personal interview, March 31, 2017). Starting from September 2016 and up to June 2017 is the SD.

The drop during the PD in the man-hours is explained by the shift from the previous entities responsible for the PD to NCC and due to the summer vacation. The strong rise from August until October is due to the kick off, it represents the start of the SD. A lot of meetings between NCC and Trafikverket have taken place during this time, causing a sharp rise in the man-hours. It gradually slowed down between October until the beginning of December. This is explained by Trafikverket and NCC as the result of the miss interpretations and communication between the two entities. As the ECI contract is still relatively new, struggles and issues rose as time passed by. They mentioned that it is a learning process and stagnation can occur anytime.
The Month between December and January involved a small peak and then a fall. This is partly because of the recovery from the issues in October and November and the Christmas and New year's Holiday between December and January.

From January 2017 until April 2017 is the time with the highest peak. According to NCC and Trafikverket, there has been a lot of work during that period as they started to get delayed in regards to the estimated schedule. A need to increase the effort was required to catch up. It is also because more and more collaboration has been going on between the two entities and the conceptual drawings has started to take its shape.

The Central Station Time/Effort curve has a strong peak in its Schematic design. This, when compared with the BIM curve of Macleamy (2010) provides a good indication of the current situation, as the Peak that Macleamy (2010) expects to be is within the SD and DD. Though, the situation is not prominent to consider such a conclusion.

Several scenarios can be expected for the future shape of the curve. One of the positive scenarios could be a continuation of an increase in effort during the detailed design following up with a gradual decrease until the end of all phases. This scenario would be the closest to the theoretical one.
One the other hand, a negative scenario could include a steep fall during the DD and another peak later in the CD, such a scenario means that a possibility of double effort exists.

5.4 Surveys

Survey Questions

1. The client has a clear and precise definition of the technical requirements for the digital models
2. The digital formats make it easier for the exchange of information between stakeholders
3. The digital models are used as a communication tool between stakeholders
4. The digital models are used for planning
5. The digital models are used for time and schedule calculation and project development
6. All stakeholders have a common image of what to achieve
7. Change orders are managed in an effective way in the project
8. Cost in project are calculated in high accuracy
9. Administrative Double work are reduced

Scale
0 – Disagree
4 – Totally Agree

Table 5.4 Showing the results of the Survey conducted by Trafikverket

Questions	Participants	Positive View	0	1	2	3	4
1	6	16.7	0.0	50	33.3	16.7	0.0
2	5	60	0.0	20	20	40	20
3	6	83.3	0.0	0.0	16.7	83.3	0.0
4	6	33.3	0.0	0.0	66.7	33.3	0.0
5	6	50	0.0	0.0	50	50	0.0
6	6	16.7	0.0	16.7	66.7	0.0	16.7
7	4	25	0.0	25	50	25	0.0

8	5	0.0	0.0	20	80	0.0	0.0
9	5	40	20	20	20	40	0.0

Through the interpretation and analysis of the survey, a couple of conclusions have been drawn. The questions have been categorized under three main points that summarizes the questions.

<u>Tool for an improved Definition of the Project</u>

First, Question 1 and 6 focuses mainly on the understanding of BIM, it is seen that most the participants do not have a clear definition of BIM. Meaning that there still exists a lack of maturity in the process. This is also supported by the interviewee's opinions in regards to the definition of BIM, see Chapter 5, Section 5.1.1.
An important thing to note is that the West Link project is still considered one of the early projects of Trafikverket where BIM is implemented.

<u>Tool for Communication</u>

Question 2 and 3, circulated around the involvement of stakeholders and the exchange of information between them. The two questions has shown a positive view towards this dimension. It has also been supported by the interviews conducted. Increased stakeholder's involvement is one of the main points the theory has thought BIM can achieve (Eastman et al., 2011).

<u>Tool for cost & time Calculation</u>

Questions 4, 5 and 8 circulated around BIM being a tool in which cost and time can be calculated with a high accuracy. The view towards this dimension is considered a negative one according to the answers of the surveys.
When looking at the KPIs, see Chapter 5, Section 5.2.3, Trafikverket in the Central Station Bid- pack, are not on point when it comes to time and cost. This supports what the KPI analysis has come up to.
This again can be as a result of the variance in competencies between employees, or due the high complexity of the project.

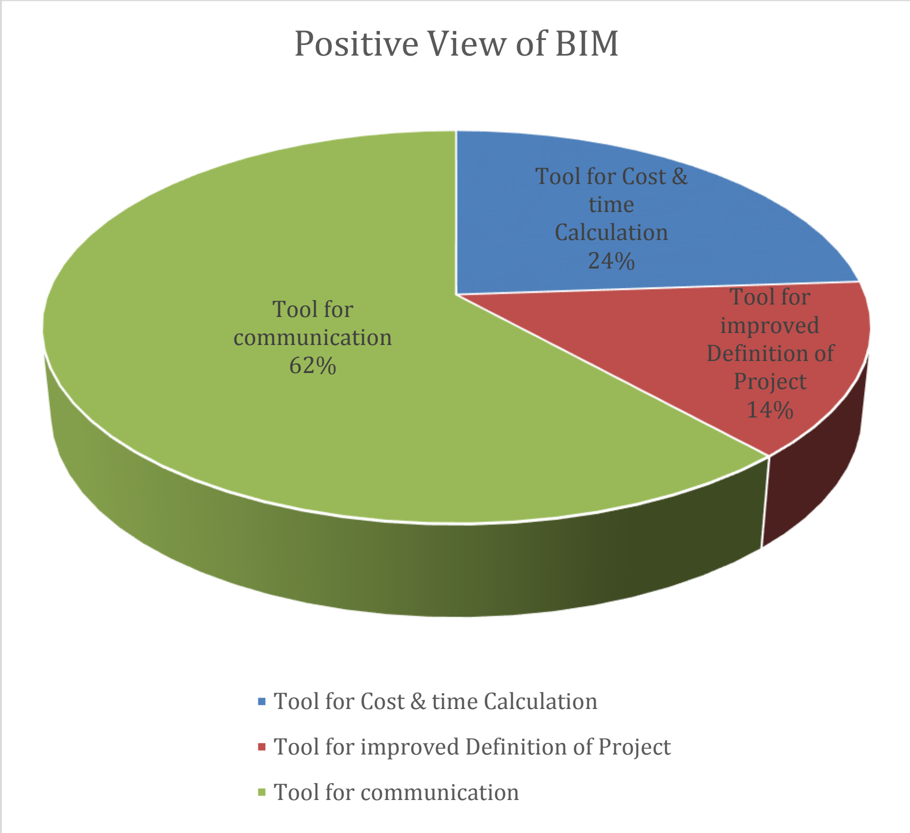

Figure 5.3 Showing a summary of BIM perceived by Employees of West Link project

The summary from Figure 5.3, shows that Trafikverket employees of the West Link project perceive BIM mainly as a communication tool. A tool for cost and time calculation and more insights of the project are the latter advantages.

This conclusion, when compared with the interviews and the KPIs seems matching. Most of the interviewees were positively commenting on BIM in regards to improved communication and collaboration on the West Link project level. This was also supported with the KPIs. On the other hand, on Trafikverket level, the employees interviewed were mainly concerned about the insights and the visual aspects of BIM.

6 Discussion &Conclusion

To understand the topic and the case study of the thesis, a theoretical approach was required.
The theory was collected through scientific journals, books and conference proceedings to understand the scope of the work. A literature review was conducted to get a deeper understanding of what has been found in previous studies. The literature review emphasized on the BIM characteristics, what they were and how are they assessed. A comparison between UK and the Swedish industry in regards to BIM was done later. The study shows the differences, similarities and how the authorities in respective country have handled BIM regarding financial support and requirement Later on, the study focused on the core of the thesis, namely, the Macleamy curve, therefore a deeper insight into Macleamy (2010) and mainly Eastman (et al 2011) was made.

The purpose behind this study was to examine if BIM has the potential to provide an increased productivity during the design phase of a project.
The main method used in examining this potential was the collaboration with Trafikverket, in which one of their ongoing projects, "West Link Project" was used as a case study. Due to the complexity of the project, it was further narrowed down to a single Bid-pack, "Central Station".

The results of the case study were supported by collecting data from Trafikverket's database, interviews, informal meetings and direct observations.
The study also examined several key performance indicators, collaboration between the client and the contractor and how it affects the time/effort curve suggested by Macleamy (2010) during the design phases.

The implementation of BIM brings many advantages to the organization (Azhar, 2011), (Eadie et al., 2013), (Eastman et al., 2011).
Through the research, it has been found that different understandings of BIM within the organization exists, this can create a misleading and scattered approach towards the project.
One major reason is that employees work with BIM in different levels, not all employees have the same competencies and training in using BIM, which affects their maturity levels towards it. This can create a misleading and scattered approach towards the project.

To realize the advantages with BIM, a more engaging environment is needed when it comes to the demands and requirements of the client "Trafikverket".
Trafikverket is a governmental agency, meaning that it is directly affected by the laws and regulations put by the government. If initiatives are not given by the government, it will be a difficult task for Trafikverket to improve its performance. The biggest public client Trafikverket needs to have a more comprehensive strategy, their annual program is to achieve 2-3% of productivity, the steps towards this achievement seems to be implausible. A more detailed and integrated strategy is needed for a precise understanding on how the goals can be reached must be made. This was also mentioned by Katarina Delvret (Personal interview, March 31, 2017) where she stated

that Trafikverket is still struggling to identify an appropriate path towards their goals. This is very crucial, since Trafikvekerket invested in the new pure client role which means that as a client a higher insight in the implementation should be viable.

one of the obstacles according to Josef Habbe (Personal interview, April 19, 2017) is a cultural one, as Swedes are not used to the procedures of measuring and critiquing each other's performance, though in many cases, such an assessment can be necessary for the improvement of the organization. One solution in achieving the productivity growth, is to use UK as a role model and begin a similar implementation program in the organization.
The concept of ECI is a model that was brought from UK into Trafikverket as a way to improve the overall performance (Josef Habbe, Personal interview, April 19, 2017).

Research has shown that BIM involves not only 3D models but also the share of information and active participation early in the process (Eastman et al., 2011). There was an insist in regards of collaboration between stakeholders to utilize the complete potential of BIM.
The “Central Station” Bid-pack with its characteristics, was considered a perfect case to test the collaboration on. With the interviews conducted, it has seen that the collaboration between Trafikverket and NCC is going quite well. The main reason for that was the ECI contract and the Project studio meetings. The study shows that the collaboration strategy (ECI) has suppressed the barriers between client and the contractors, as more exchange of information was occurring between the partners, Trafikverket and NCC are working in the same building, meaning that any clarifications required can be quickly answered. This was confirmed with the interviews that has been conducted.

Through the Time/effort curve, it was seen that the project, despite of the drop at the beginning, records a high number of hours during the SD phase. When compared with the theoretical curve proposed by Macleamy (2010), Trafikverket might seem to be on the right track. As mentioned before, the tasks for which the man hours were recorded, are all the tasks in regards of to the Central Station Bid-pack. It is difficult to say if the increase in man-hours are due to more collaboration and increasing productivity tasks or if they are due to non-increasing productivity tasks.
Another reason why the curve might be limited is due to the difference between the design phases in Sweden and US. Even though there exist many similarities between the phases, some documentations and activities still varies.
The Central Station Bid-pack has only recently completed its SD and are starting with the DD. The amount of information available restricts the possibility to come with a reliable conclusion. It is too early for a precise conclusion to be drawn.

The KPIs approach has come up with some interesting notes. First, if the goals of Trafikverket in regards to BIM, is to gain more insights, reduce paper documents and increase their involvement, then according to what has been found, they managed until now to do that.
But when looking at the other KPIs, such as change orders, schedule compliance, budget compliance and clash detections, the situation is different.

Change orders in the design phase of the project exists, the project is one month delayed and around 10% above budget. As a lot of the data was confidential, only assumptions have been made in regards to these results.
The assumption made might be in compliance with (Poirier et al., 2015), as it was stated in his paper that projects that BIM is being implemented for the first time might witness increase in costs and delays in schedule as the organization still lacks maturity in regards to BIM application (Succar et al., 2012).

6.1 Recommendations and Further research

Several recommendations can be suggested for a possible improvement of the current situation. First it is important for Trafikverket to create a standardized definition of BIM among the whole organization. Also, to develop a standardized procedure in which they assess the productivity of BIM. The agency should be more alert when it comes to measurement of productivity. Implementing BIM, having a pure client role and other methods that in theory can simplify the work for Trafikverket, though without measuring it, realizing the benefits becomes difficult.
Reduce the complications in regards to confidentiality and provide more access to stakeholders directly involved in the project.
It is very important to code the change orders, record the clash detections and record the RFIs. With this kind of information, analysing the productivity can become much easier, differentiating between change orders and RFI related to BIM becomes possible.

For further studies, it is interesting to know how the Time/Effort curve will continue as the DD and CD ends and how the collaboration will be shaped.
Also, it would be of a great interest to compare the Time/Effort curve of the Central Station Bid-pack with the other Bid-packs were no ECI contract is available. This would provide an opportunity for Trafikverket to assess the efficiency of the ECI contract.

It is recommended to analyse the surveys conducted on Trafikverket's level (Organizational level). From the analysis, a comparison can be made with how the objectives of BIM might differ in an organizational and project perspective.

If the study is to continue into the construction phase, perceiving how the collaboration will go on between NCC and Trafikverket and how much of BIM usage is still existing would provide greater and a broader insight in regards to BIM.
The price offered by NCC for the procurement of the Central Station will be an important indication of the collaboration between the two entities.

References

Arditi, D., & Mochtar, K. (2000). Trends in productivity improvement in the US construction industry. *Construction Management and Economics*, *18*(1), 15–27. https://doi.org/10.1080/014461900370915

Barlish, K., & Sullivan, K. (2012). How to measure the benefits of BIM - A case study approach. *Automation in Construction*, *24*, 149–159. https://doi.org/10.1016/j.autcon.2012.02.008

Barnes, Davies, P., & Nigel. (2014). *BIM in principle and in Practice*. ICE Publishing.

Borg, L. (2010). Contract Types in the Swedish Construction Sector: Overview and theoretical analysis. *Conferencia Internacional Da LARES*.

Brunbäck, L. (2014). *The West Link Project Contract works , preparatory works and services* (Vol. 2).

Cheng, J. C. P., Lu, Q., & Deng, Y. (2016). Analytical review and evaluation of civil information modeling. *Automation in Construction*, *67*, 31–47. https://doi.org/10.1016/j.autcon.2016.02.006

Coates, S. P. (2013). *Bim Implementation Strategy Framework for Small Architectural Practices*. The University of Salford.

Council, A. I. A. and A. I. A. C. (2007). Integrated Project Delivery, a Guide.

Eadie, R., Browne, M., Odeyinka, H., McKeown, C., & McNiff, S. (2013). BIM implementation throughout the UK construction project lifecycle: An analysis. *Automation in Construction*, *36*, 145–151. https://doi.org/10.1016/j.autcon.2013.09.001

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*. *Building* (Vol. 2). https://doi.org/10.1002/9780470261309

Elliot, M., Fairweather, I., Olsen, W., & Pampaka, M. (2016). *A dictionary of social research methods*. Oxford University Press.

Fischer, M. (2013). 2nd Annual BIM conference in the Middle East. In *Leasons Learnt from Hundreds of BIM implementations*. Abu Dhabi.

Giel, B. K., & Issa, R. R. A. (2013). Projection-Recognition-Projection Method for Automatic Object Recognition and Registration for Dynamic Heavy Equipment Operations. *Journal of Computing in Civil Engineering*, *28*(5), 1–9. https://doi.org/10.1061/(ASCE)CP

HM Government. (2012). Building Information Modelling. *Industrial Strategy: Governement and Idustry in Partnership*, *Vol.1*, 1–22. https://doi.org/10.1016/j.aei.2007.03.001

Kent, D. C., & Becerik-gerber, B. (2010). and Attitudes toward Integrated Project Delivery. *Journal of Construction Engineering and Management*, *136*(8), 815–825. https://doi.org/10.1061/ASCECO.1943-7862.0000188

Kunz, J., & Fischer, M. (2012). Virtual Design and Construction: Themes, Case Studies and Implementation Suggestions. *CIFE Working Paper*, *97*(Version14), 50. Retrieved from http://www.stanford.edu/group/CIFE/online.publications/WP097.pdf

Latiffi, A. A., Brahim, J., Mohd, S., & Fathi, M. S. (2015). Building Information Modeling (BIM): Exploring Level of Development (LOD) in Construction Projects. *Applied Mechanics and Materials*, *773–774*, 933–937. https://doi.org/10.4028/www.scientific.net/AMM.773-774.933

Lu, W., Fung, A., Peng, Y., Liang, C., & Rowlinson, S. (2015). Demystifying Construction Project Time – Effort Distribution Curves : BIM and Non-BIM Comparison, *31*(6), 1–8. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000356.

MacLeamy, P. (2010). No Title. In *The Future of the Building Industry*. HOK. Retrieved from https://www.youtube.com/playlist?list=PLBtjS8gtZsR4pVFuLIFni2nZr6oAHEhM8

Mårtensson, H. (2015). BIM ökar konkurrenskraften. Retrieved from http://dagensinfrastruktur.se/bim-okar-konkurrenskraften-om-sverige-ar-snabbt-nog/

Ncc, Svenskbygg, & SBUF. (2013). *Slutrapport Fokus I – BIM med BSAB* (Vol. 1).

Nilsson, G. (2013). Bättre informations fl öde i BIM med BSAB-systemet. *Open BIM*.

Park, H.-S., Thomas, S. R., & Tucker, R. L. (2005). Benchmarking of Construction Productivity. *Journal of Construction Engineering and Management*, *131*(7), 772–778. https://doi.org/10.1061/(ASCE)0733-9364(2005)131:7(772)

Poirier, E. A., Staub-French, S., & Forgues, D. (2015). Measuring the impact of BIM on labor productivity in a small specialty contracting enterprise through action-research. *Automation in Construction*, *58*, 74–84. https://doi.org/10.1016/j.autcon.2015.07.002

Riksrevisionen. (2011). Trafikverkens produktivitet.

Smith, P. (2014). BIM & the 5D Project Cost Manager. *Procedia - Social and Behavioral Sciences*, *119*, 475–484. https://doi.org/10.1016/j.sbspro.2014.03.053

Soekiman, A., Pribadi, K. S., Soemardi, B. W., & Wirahadikusumah, R. D. (2008). *Study on Factors Affecting Project Level*.

Song, L., Mohamed, Y., & AbouRizk, S. M. (2009). Early Contractor Involvement in Design and Its Impact on Construction Schedule Performance. *Journal of Management in Engineering*, *25*(1), 12–20. https://doi.org/10.1061/(ASCE)0742-597X(2009)25:1(12)

Succar, B., Sher, W., & Williams, A. (2012). Measuring BIM performance : Five metrics. *Arquitectural Engineering and Design Management*, *8*(2), 120–142. https://doi.org/10.1080/17452007.2012.659506

Svenskbyggtjänst. (2015). BSAB 2.0. Retrieved from https://byggtjanst.se/aktuellt/effektiva-byggaffarer/bsab-2.0/

TrafikVerket. (2015a). The West Link Project (Västlänken).

TrafikVerket. (2015b). Vägen till Trafikverket.

Vogl, B., & Abdel-Wahab, M. (2015). Measuring the Construction Industry's Productivity Performance: Critique of International Productivity Comparisons at Industry Level. *Journal of Construction Engineering and Management*, *141*(4), 4014085. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000944

Yin, R. K. (1994). *Case Study Research : design and methods* (2nd ed.). Thousand oaks, CA: Sage.

Yu, T., Shen, G. Q., Ph, D., Shi, Q., & Ph, D. (2017). Comparing the Performance Quality of Design-Bid-Build and Design-Build Delivery Methods, *143*(4), 1–10. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001262.

Appendix 1 – Interview Questions

1. What is ECI for you
2. How do you see ECI
3. Is the collaboration between Trafikverket and NCC efficient
4. Are there any advantages in using ECI
5. What Limitations do you see in ECI
6. How would the situation differ if a different procurement strategy was chosen
7. Who are the contractors
8. Who are the consultants
9. How does the organizational chart look like
10. What is BIM to you?
11. How Does Trafikverket Measure BIM performance
12. Do you see BIM as an important strategy for improving your Productivity
13. What is it you want to achieve with the implementation of BIM
14. What are the competency levels in your organization regarding BIM
15. Has BIM helped in clash detections, reducing costs and improving cost accuracy
16. Do you have any standards to measure your productivity
17. Has BIM contributed in the involvement of stakeholders

Appendix 2 – Survey Questions

1. The Client has a clear and precise definition of the technical requirements for the digital models
2. The digital formats makes it easier for the exchange of information between stakeholders
3. The digital models are used as a communication tool between stakeholders
4. The digital models are used for planning
5. The digital models are used for time and schedule calculation and project development
6. All stakeholders have a common image of what to achieve
7. Change orders are managed in an effective way in the project
8. Cost in project are calculated with high accuracy
9. All administrative double work is reduced.