BIM - the Next Step in the Construction of Civil Structures

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Preface

This master thesis is the final step in the authors’ education at the Royal Institute of Technology, where they have been studying at the department of Civil and Architectural Engineering for the last four and a half years. The thesis is written for the division of Structural Engineering and Bridges and Skanska Sweden AB. The thesis comprises of 30 credits for each of the authors.

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Stockholm, Sweden, Tuesday, March 16, 2010

Erik Dahlqvist & Andreas Winberg
Abstract

Productivity in the construction industry has been stagnant during the late twentieth century. One reason for this is considered to be an inefficient construction process, ‘Building Information Modeling’ BIM is considered by some to be the tool that is going to transform the construction process. The concept of BIM is not new, almost 40 years ago the foundation for what we today call BIM was laid. However, it is only recently that the work with the BIM has made an impact in the building and construction industry, the impact has mainly been in building projects and therein during the design phase. Since the focus so far mostly has been on the design phase and the building industry, the authors thought that it would be interesting to explore how BIM can be used in the construction phase in civil construction projects.

The purpose of the thesis is to clarify how BIM is used in the construction phase of civil construction projects within Skanska Sweden AB, which is in an early phase, and Skanska USA Inc., which have reached further in the implementation work. The authors’ aims to explain how the implementation of BIM has been conducted and to what extent and after this analyze what has gone well and what has gone less well. This work is done in order to be able to give suggestions for what Skanska Sweden ought to consider during the continued implementation of BIM.

To achieve these aims the authors had to carry out a literature review regarding the subject area. This proved easier said than done since there are many different opinions about what BIM more precisely entails, but literature describing the subject from a broad perspective is sparse. After the literature review was conducted the authors carried out 19 interviews, 11 in Sweden and 8 in the U.S., all in all the authors visited 6 projects. After this a survey was executed in which 6 people participated.

The results from the study show that the knowledge and expectations of BIM within Skanska Sweden differ considerably. Furthermore, Skanska USA Inc. has, just as expected, made more progress in the implementation of BIM in civil projects; this has possibly led to the understanding of the subject as well as the expectations of BIM more dispersed within the organization. The conclusions from this study show that the expectations of BIM in Sweden are largely met by the implementation work carried out so far in the U.S. The primary lessons derived from the implementation of BIM within Skanska USA Civil are; start working with a
model in which the employees feel comfortable, make sure there is enough resources to keep the model updated and remember that the implementation process is at an early stage, which ought to lead to an iterative approach to the work with the model.
Sammanfattning

Produktivitetsutvecklingen i byggbranschen har under den senare delen av nittonhundratalet varit stillstående. En anledning till detta anses vara en allmänt ineffektiv byggprocess, det som skall råda bot på detta är enligt vissa ‘Building Information Modeling’ BIM. Konceptet är inte nytt, för nästan 40 år sedan las grunden till det vi idag kallar BIM. Dock så är det först på senare år som arbetssättet börjat få fäste inom bygg- och anläggningsbranschen, främst på hussidan och där i inom projekteringen. I och med att fokus legat på projektering och på hussidan tyckte författarna att det vore intressant att undersöka hur BIM skulle kunna användas inom produktionen på anläggningsprojekt.

Målet med arbetet är att klargöra hur BIM används i produktionsfasen på anläggningsprojekt inom Skanska Sverige AB vilka befinner sig i startgroparna och Skanska USA Inc. vilka har kommit längre i implementeringen. Författarna vill förklara hur implementeringen av BIM utförts och i vilken utsträckning, och från detta analysera vad som har gått bra respektive mindre bra i det arbetet för att på så sätt kunna ge förslag till vad Skanska Sverige bör tänka på vid den fortsatta implementeringen av BIM.

För att uppnå målen så var författarna tvungna att läsa in sig på ämnesområdet BIM, vilket visade sig vara lättare sagt än gjort då det finns många olika uppfattningar om vad BIM mer exakt innefattar samt att det finns väldigt lite litteratur som beskriver begreppet och konceptet på en övergripande nivå. När dessa litteraturstudier var utförda så genomfördes 19 intervjuer, 11 i Sverige och 8 i USA, totalt så besökte författarna 6 projekt. Därefter utfördes även en enkätundersökning vilken besvarades av 6 personer.

Resultatet från arbetet visar att kunskapen liksom förväntningarna på BIM från Skanska Sverige skiljer sig kraftigt. Vidare framkommer, precis som förväntat, att Skanska USA Inc. kommit längre i implementeringen av BIM vad gäller anläggningsprojekt, vilket möjligtvis gjort att kunskapen i ämnet liksom förväntningarna på BIM är än mer spridda inom organisationen. Slutsatserna i arbetet gör gällande att de svenska förväntningarna som finns på BIM i produktionen till stor del uppfylls av den implementering som än så länge gjorts i USA. De huvudsakliga lärdomar som harrör från Skanska USA:s implementering av BIM är; starta implementeringen med en modell i vilken de anställda känner sig trygga, lägg resurser på att hålla modellen uppdaterad samt erinra sig att implementeringsprocessen är i ett tidigt skede vilket bör leda till ett iterativt angreppssätt till arbetet med modellen.
Glossary

**English to Swedish**

**Abutment** – Landfäste
**Acceptance test** - Mottagningskontroll
**As-built document** - Relationshandling
**Assistant Project Manager** - Biträdsande projektcchef

**Block Manager** – Blockchef

**CAD Engineer** - CAD-projektör
**Call** – Avrop

**Changes and additional work, CAW** - Ändrings- och tilläggsarbeten, ÄTA
**Contractor** – Entreprenör
**Construction barracks** - Byggbod
**Construction meeting** – Byggmöte
**Control of construction phase** - Produktionsstyrning
**Construction phase** – Produktionsskede
**Control Plans** – Kontrollplaner

**Construction phase time plan** - Produktionstidplan
**Construction project management** - Byggledning
**Cooridination meeting** - Koordineringsmöte/samordningsmöte

**Decision time plan** – Beskedstidplan

**Declaring Documents** - Redovisande document
**Design and build** – Totalentreprenad

**Desing-bid-build** – Generalentreprenad

**Design documents** – Bygghandelgar

**Design phase** - Projektering
**Design Phase Manager** - Projekteringschef

**Deviation report** – Avvikelserapport

**Document delivery plan** - Handlingsleveransplan

**External review** - Extern remiss

**Facility management** – Förvaltning

**Financial management** - Ekonomisk styrning

**Foreman** - Arbetsledare

**General agreement** – Ramavtal

**Goods reception** - Godsmottagning

**Governing Documents** - Styrande document

**Governing planning tool** - Styrande planeringsverktyg

**In-house review** - Internremiss

**Inquiry documents** – Förfrågningsunderlag

**Investigation** - Utredningar/program före projektering

**Laydown area** – Upplagsplats

**Loom** - Ledningsdragning

**Machine-guidance** - Maskinstyrning

**Machine plan** – Maskinplan

**Management tools** - Styverktyg
Manpower diagram – Arbetskraftsdiagram
Material Delivery Plan – Materialleveransplan
Materials Management (MM) - Materialadministration (MA)

Non-manual worker plan - Tjänstemannanplan
Owner – Beställare
Pipe trench - Rörgrav
Plan of construction site disposition, PSD - Arbetsplatsdispositionsplan, APD-plan
Plan of mass disposition – Massdispositionsplan
Plan of traffic accommodation - Trafikanordningsplan, TA-plan
Plan for the working environment, PWE – Arbetsmiljöplan
Planning meeting – Planeringsmöte
Procurement - Upphandling
Project Engineer - Projektingenjör
Project management meeting - Projektledningsmöte
Project plan – Projektplan
Project time plan – Projekttidplan
Projection time plan - Projekteringstidplan
Purchase Manager - inköpare
Purchase plan – Inköpsplan
Quantity take-off - Mängdning
Reception control – Mottagningskontroll
Resolve on site, ROS - Lösas på plats, LPP
Revetment - Stödmur till ett landfäste
Revised drawing - Reviderad ritning
Risk meeting – Riskmöte
Skilled Worker – Yrkesarbetare
Stakeholder - Intressent
Structure Plan - Strukturplan
Subcontractor – Underentreprenör
Survey block - Mätblock
Survey Protocols – Besiktningsprotokoll
Surveyor's Assistant – Utsättare/mättekniker
Surveyor's Manager – Mätchef
Telecommunication drawings - Teleritningar
Tender – Anbud
Ties - Sliper
Time plan – Tidplan
Time plan meetings – Tidplanemöten
Work Crew - Arbetslag
Work Force Diagram - Arbetskraftsdiagram
Work preparation – Arbetsberedning
Work orders - Arbetsordningar
Dictionary

3D - Refers to the three dimensions length, height and width which together shape a geometrical model of space.

4-D modelling - Time analysis is added to the 3D-model

5-D modelling - Cost estimates are added to the 3D-model

nD-models - Concept of modelling where there is no limitation on dimensions; the models can be used for business intelligence, lean construction principles, green policies and whole lifecycle costing etc.

AECO - Acronym for Architecture, Engineering, Construction and Operations industry

AIA - the American Institute of Architects

BIM - building information modeling, refers to the activity of modeling, when referring to a specific building information model the term ‘BIM model’ is used.

CAD - Computer Aided Design

CPM - Construction Project Management

FEA - Finite Element Analysis

General Contractor (GC) - Responsible for selecting subcontractors, planning and supervising the construction, coordinating the project team.

HVAC - Heating, Ventilating, and Air Conditioning

Informer - The person who is interviewed

IPD - Integrated Project Delivery

MEP - Acronym for mechanical, electrical and plumbing engineering

NIBS - National Institute for Building Standards

NFL – National Football League

ROI - Return on investment

SEK – Swedish kronor

USD – United States Dollar

VDC - Virtual Design and Construction
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1. Introduction

1.1 Background

In 1974 Chuck Eastman, now professor at Georgia Institute of Technology, and five other authors presented a paper. The paper described problems with the principal means of communications in the building process, those means were of course drawings, including notes and written specifications. Some of the problems they pointed out were:

- 2D drawings are inherently redundant, because to describe a three dimensional space with two dimensional drawings you need at least two drawings, thus depicting one dimension twice. 2D drawings are also redundant in the aspect that many objects are presented on several different drawings but in different scale. All this means that design changes leads to changes in a whole set of drawings.

- Large efforts are needed to keep information up-to-date. But even with a large effort there is a great risk that information somewhere is obsolete or non-consistent. This might result in designers making decision on faulty information.

- Information needed for analysis of the construction must be manually taken from the drawings. This is labor intensive.

Their solution to this problem was to create a computer system that could store and manipulate design information at great detail allowing design, constructional, and operational analysis. This computer system was called Building Description System, BDS. (Eastman et al 1974).

Today, the problems identified by Eastman et al more than 35 years ago still exist (based on our interviews in Sweden), maybe to a lesser degree but they are still very much a part of the building process; it is fragmented and communication is mainly done by paper - and errors in these documents often create delays and unanticipated field cost (Eastman et al). And even more and today’s solutions to these problems resembles the solutions presented by Eastman et al, regardless if it is presented as Virtual Design and Construction (VDC), Integrated Project Delivery (IPD), or Building Information Modeling (BIM). However, over the past years BIM has become the acronym of choice for many institutions (GSA, AIA, NIBS, (Bell et al 2007)), as well as for the major producers of modeling software (Autodesk, Tekla, Bentley).
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Even if the concept, or a concept similar to BIM, was developed 35 years ago it never really took off in the construction industry. Instead of embracing computer modeling in similar ways as the aeronautical industry – which used it for design, tests and optimizations, the construction industry opted to more or less just digitize 2D drawings. However this is about to change. As of late some major institutions and big owners, e.g. the GSA in the USA and Senate Properties in Finland, have started to stipulate the use of BIM when they procure contractors and designers (Bell et al 2007). But this mostly applies to the building part of the construction industry and not to the civil part of the industry; this is however also about to change e.g. Bentley software has BIM software designed for bridges which has had a good market penetration in the USA (Drogemuller 2009).

It is said that BIM will have a major impact in the construction industry, and many of the problems facing the industry will be solved with the help of BIM, among others it is said that:

- With BIM you will be able to generate drawings of any set of objects at any time in the project straight from the model thus hugely reducing time spent on generating drawings by hand. You will be able to do cost estimates and quantity take offs quickly and easily.
- The model will facilitate the work of detecting clashes before moving out into the construction phase.
- Proposed design changes will in the model show directly and automatically the impact of the change on other parts of the structure.
- Lean production techniques will be more easily implemented since they require careful coordination which BIM facilitates.

But when will these pros show within civil construction industry? And to which degree does one need to implement BIM to see any of these advantages? The questions regarding BIM and its uses are of course many, and in this thesis we will try to answer a few of them.
1.2 Problem Description

The construction industry has problems. As mentioned earlier the work process with 2D drawings is not efficient and prone to errors. Further we can consider figure 1.1. What the graph shows is that the construction industry requires a great deal more field work hours per dollar of contract than the non-farm industry, i.e. it shows clearly how the construction industry have fallen behind in terms of labor productivity – although the graph shows the state in the USA, Märten Lindström corroborates that the situation in Sweden looks the same at least going back 20 years in time (Teicholz 2004).


Figure 1.1 Graph showing the development of labor productivity during the years between 1964 and 2003 in the construction industry and the non-farm industry. [http://www.aecbytes.com/viewpoint/2004/issue_4.html](http://www.aecbytes.com/viewpoint/2004/issue_4.html)

Some of the causes to this situation are according to Paul Teicholz (professor of Civil and Environmental Engineering at Stanford University):

- Split responsibility in design and construction projects due to the design-bid-build business model. Potential gains from investing in productivity enhancing methods are not explored since stakeholders feel that it is not worth the risk. The owners seldom have the financial freedom to assume the risk of new methods.
1 INTRODUCTION

- Most of the IT applications in the construction industry are stand-alone, i.e. they do not permit collaboration – different designers use different CAD-software, cost control is independent of changes to specs and drawings. Although computers generate a lot of data, the data itself must be reviewed manually.

- The building industry basically consists of a large number of small businesses – these are often not in a position to provide leadership in the adoption of new technology.

Teicholz concludes that there is no one answer or fix for the problem, but that the most important step in dealing with these problems is the introduction of object-based 3D CAD (BIM). This will help design, collaboration, bidding, planning and construction.

1.3 Definition of BIM

This paragraph explains the term BIM as we use it in this paper, a more lengthy account on how we define BIM in this master thesis can be found in chapter 2.2.

Building Information Modeling is not defined in Sweden by any government body or branch at the moment; hence an obvious definition of the term for this paper is not available. Instead we have opted to use the definition that the General Service Administration (GSA) has issued in the USA.

The GSA writes (3D-4D BIM Overview 2007) "Building Information Modeling is the development and use of a multi-faceted computer software data model to not only document a building design, but to simulate the construction and operation of a new capital facility or a recapitalized (modernized) facility. The resulting Building Information Model is a data-rich, object-based, intelligent and parametric digital representation of the facility, from which views appropriate to various users’ needs can be extracted and analyzed to generate feedback and improvement of the facility design."

In this thesis when BIM is mentioned it refers to the activity (building information modeling), when referring to a building information model the term BIM model is used.
1.4 Purpose and Aim of the Study

1.4.1 Purpose

With this thesis we try to clarify the position of BIM in the construction phase of civil engineering within Skanska Sweden as well as Skanska’s subsidiary in the US. I.e. at what maturity state the BIM-implementation at Skanska has reached.

1.4.2 Aim

One of the aims with this thesis is to determine the potential of BIM in the construction phase. Other aims with this thesis are:

- Explain how the implementation of BIM has been carried out and to what extent.
- Clarify what lessons can be learned from the implementation process so far.
- Account for how Skanska Sweden should proceed in its implementation of BIM in the construction phase.

1.5 Limits of the Study

This thesis is the final part of the authors’ education at the Royal Institute of Technology and the Department of Civil and Architectural Engineering in Stockholm and comprises 30 credits for each of the authors. The thesis includes a literature review, compilation of interviews, compilation of survey, analysis, conclusion, writing of a report, and a presentation of the study. The limitations in the thesis have been set with consultation from our tutor with respect to the magnitude of course and of course spring from our own interest.

We have chosen to limit our study to the construction phase of civil structures (with the exception of the project ‘Bromma Center’) in Skanska Sweden and Skanska USA. The reason we choose the USA was because much of the literature read for this thesis is American and that American institutions (GSA, US Coast Guard) are among the first in the world to demand BIM when procuring, this made the impression that the USA was a forerunner in the work with BIM. We also choose to work in the USA since we knew the language and culture which would ease the interview process. In Sweden the projects visited were located in the Stockholm region; however interviews were also performed with informants from Gothenburg, and questionnaires were also sent out to informants in Gothenburg. In the US the
study was limited to the area around New York City; where we were able to get in contact with two interesting projects there. Further we choose to study the work with logistics and deviations handling more in-depth. The projects we have studied are (all projects are Skanska-projects):

- NL 11 – Infrastructure project in Stockholm (tunnel)
- NL 52 – Infrastructure project in Stockholm (tunnel, bridge, slip roads)
- Lindhagensplan – Infrastructure project in Stockholm (tunnel/over-decking)
- Bromma Center – Re-building project (rebuilding of a hangar into a shopping mall)
- Croton Filtration Plant – Civil structure in New York City (Water treatment facility)
- New Meadowlands Stadium – Stadium in New Jersey (stadium for NFL-teams Giants and Jets)

The study is limited to the *BIM Field* ‘process’ and the *sub-field* ‘contractors’, and the *BIM Lenses* we have used are: construction phase, logistics and deviations.

The study is written for Skanska and it will be kept as an internal document within Skanska for one year before being published online at the Royal Institute of Technology’s website. The study is aimed to people interested in how the work with BIM in the construction phase looks like at large civil projects.
2. Theory

In this chapter we present the definition of BIM that is used throughout the thesis. Also there is a brief examination as to how the building process and more specifically the construction phase of the building process, looks like. The chapter is finished off with a relatively extensive study of BIM in general. The BIM chapter is almost in its entirety based on the BIM Handbook by Eastman, Teicholz, Sacks, and Liston, this is in itself may be seen as a result. The fact that the authors have struggled to find decent literature that explain BIM on a more basic level and with a broad perspective will be addressed later in the thesis.

2.1 Description of the Construction Process in Sweden pre-BIM

In this chapter we will briefly review the building process in Sweden. Then we get more into detail on how the construction phase looks like. Then we will move on and describe how the logistics look like at the construction site, and how deviations are handled. This is done to create a framework to which one can refer when reading about BIM in the building process in general and construction phase particularly. The chapter is based on Skanska Documents from ‘Forum Sverige Väg och Anläggning’ and the book ‘Byggprocessen’ by Uno Nordstrand.

2.1.1 Construction Process

The construction process can take many forms, depending on what is to be built, who will own the building or structure, manage it, and so on. But generally speaking, the construction process can be said to look something like this: Someone needs a new or altered building and they will have this built - this person, company or organization is called owner. The owner initiates the project, which has as a goal to produce a structure that meets the requirements of the owner. In order to ensure that the requirements are met, documents that describe the structure in detail (dimensions and installations, materials, etc.) are needed. These documents are developed during the Design Phase. The Design Phase is often handled by outside consultants, including architects. This is followed by the Construction Phase, i.e. when the structure is built. This work is carried out by the Contractor, which has been chosen by the Owner during the Procurement Phase. When the structure is completed, it is handled over to the Owner who then starts using it and manages it – i.e. Facility Management (Nordstrand
2 Theory

2000). Below are simple diagrams of the two most common business models’ in the construction industry; Bid-Build and Design-Bid-Build.

Figure 2.1 Showing the basic structure of building process in a Bid-Build contract, the horizontal axis depicts time.

Figure 2.2 Showing the basic structure of building process in a Design-Bid-Build contract, the horizontal axis depicts time.

2.1.2 Construction Phase

2.1.2.1 Construction Phase Preparation

Prior to the construction phase of a building starts, a detailed project plan needs to be created. This enables the project to be carried out in a proper manner with regard to the owner’s restrictions on time, economic conditions, and etcetera. Planning is also the basis for controlling the construction project (Nordstrand 2000). The project plan is often exhaustive, the part that covers the construction phase preparations usually include, among others:

- Risk Management
- Time planning, resource planning and work planning
- Purchases
- IT Communication and IT
In addition to this, new organizations are often created to run and manage the project. The overall responsibility lies with the Production Manager, the Production Manager sometimes have other subordinates on a managing level, e.g. Block Managers, Foremen, and Purchase Managers (Nordstrand 2000).

There is no general rule for which plans that need to be established before the start of the construction phase - the need for plans is of course dependant on the size and complexity of the project. The most common plans that are produced to the start of the construction phase are (Nordstrand 2000, Forum Sweden):

- **Plan of Construction Site Disposition (PSD)**, the plan aims to show how the workplace is to be disposed, so that it allows a smooth material flow. The plan shows laydown areas, temporary roads, workspaces, offices, construction barracks and storage containers.

- **Structure plan**, reports the method with which you carry out the construction phase.

- **Construction Phase Time Plan**, the contractor's construction phase time plan includes all activities, including subcontractor activities for the whole construction phase. For larger projects separate schedules can be set up for the different work blocks.

- **Purchase Plan**, the purchase plan is related to the construction phase time plan. It is the plan that describes all purchases and it also shows the dates by which suppliers are to deliver their products, who are responsible, etcetera.

- **Machine Plan**, this plan contain information about temporary equipments e.g. machines and cranes that will be used in a certain time of the construction phase. The machine plan is based on a time plan or the budget.

- **Document delivery plan**, contain explicit information on when the different documents ought to be delivered. This plan is to be synchronized with the construction phase time plan.

- **Non-manual worker plan**, this plan contains information of how many non-manual workers that is needed during the whole project. The base for the non-manual worker plan is derived from different parts of the project plan.
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These plans are later used in the controlling of the construction phase. When all the plans are drawn up and permission obtained, the work to establish resources (machines, subcontractors, personnel, etc.) can begin, after that the construction phase can begin.

2.1.2.2 Controlling the Construction Phase

The plans produced during the construction phase preparation should show the best way to construct; therefore, the Production Manager must do the utmost to ensure that the construction phase follows those plans (Nordstrand 2000). However, there occur deviations from these plans, and in order to address this there is a need for management tools. Below is a list of a couple of different management tools:

- **Work Preparation**, some of the activities performed during the construction phase is complex or hazardous. In order to complete these activities without interruption, delay or a work related injury, the activities are reviewed and prepared extra careful. To these activities a work preparation is performed, the preparation will detail how the activity is best performed.

- **Checking and updating the construction phase time plan**, a comparison between planned and actual progress is performed. Further analysis of deviations from the plan can result in re-planning, redeployment of staff, discussion with supplier, and etcetera.

- **Financial Management**, a comparison between projected and actual costs is carried out. The quantities are checked as well as that the number of work hours follows the plan. If there are deviations certain measures can be taken to resolve the situation.

- **Updating the machine plan, workforce diagrams and the non-manual worker plan**, these are checked regularly against the original plans and are revised if necessary in connection with revisions to the construction phase time plan.

In addition to these management tools there are a number of meetings held with the aim to manage, coordinate and evaluate current construction. That is to say, the meetings are for decision making, information, reconciliation and experience feedback. A few examples of the meetings held are listed below:

- **Weekly Planning Meetings**, every week a thorough review of the next 2-4 weeks ahead is done, this forms the basis for the daily planning.
2.1 DESCRIPTION OF THE CONSTRUCTION PROCESS IN SWEDEN

• Planning Meetings, during these meetings, which occur once a week, the rolling weekly plans are determined, these meetings are led by the Production Manager and among the other participants are Foremen and Planners. Coordination meetings are also held in order to coordinate the efforts between the contractor and subcontractors.

• Construction Meetings, these meetings are held regularly during the construction phase, and they include the client and contractors. During the meetings decisions are made and there are follow-ups one the schedule, the economy, the quality, the environment, and etcetera.

Together, these meetings and management tool constitutes the primary way to control the construction phase.

2.1.3 Logistics

The construction of houses can be said to be characterized by the need for many parts from many different suppliers, and the parts need to come at the right time because there may not be ample storage space on the construction site. When it comes to the construction of civil structures, it may perhaps be a fewer number of parts, but the parts themselves may still represent logistical problems due to their sheer size. Thus it be stated that logistics is an important area in the construction phase.

The part of the construction process dealing with logistics is known as materials management (MM). They take care of the planning, management and control of the logistics process. The process itself can be divided into three parts: purchasing/procurement, delivery and payment (Nordstrand 2000).

To control the flow of material to the construction site, a material delivery plan is prepared. This is based on the construction phase time plan, and it stipulates what type of material should arrive, and when. The PSD-plan is often used in conjunction with the material delivery schedule to manage the material flow at the workplace, that is, how, were and for how long material is stored.
2 Theory

The process from order to storage can be said to be as follows:

- **The call**, based on the purchasing and materials delivery plan. It is the Project Manager who designates who has the power to call of goods and services.

- **Acceptance test**, aims to ensure that shipments comply with specified requirements.

- **Goods reception**, check that the delivery matches the delivery note, and look for any damage to packages.

- **Storage**, received and accepted item is to be kept as specified, so that their properties do not deteriorate.

2.1.4 Deviations Handling

Deviations handling regards treatment of something (also self performed work) that do not meet specified requirements, which affect the quality of work practices, products or external environment. Many companies demand that every employee and subcontractor report any deviation and disorder in any stage of the construction phase, or a completed work. The report is then handed over to the person responsible for the project. Deviations and disturbances are handled systematically and described in a deviation report. Further, the report lists the cause of the deviation, and what should be done to correct the deviation and prevent recurrence. (Forum Sverige) Even minor errors and scuffs, unclear instructions, delivery delays or communication problems, which do not affect the quality of the finished product, are recorded continuously, for example in a diary, and thereafter treated appropriately at a meeting (Forum Sweden).

**Deviation Report**

It is often the Project Manager’s responsibility to inform the employees about a deviation, if corrective measures have been taken, and to ensure that they have had the intended effect. In the case of deviations that a general agreement supplier causes, the purchasing department sometimes needs to be informed. Deviation reports are then compiled for the whole project. Deviations can also be used as the basis for as-built documents. (Forum Sweden)
2.2 Working Definition of BIM in the Master Thesis

This paragraph explains the term BIM as we use it in this paper.

Building Information Modeling is not defined in Sweden by any government body or branch at the moment; hence an obvious definition of the term for this paper is not available. Instead we have opted to use the definition that the General Service Administration (GSA) has issued in the USA.

The GSA writes (3D-4D BIM Overview 2007) "Building Information Modeling is the development and use of a multi-faceted computer software data model to not only document a building design, but to simulate the construction and operation of a new capital facility or a recapitalized (modernized) facility. The resulting Building Information Model is a data-rich, object-based, intelligent and parametric digital representation of the facility, from which views appropriate to various users' needs can be extracted and analyzed to generate feedback and improvement of the facility design."

BIM can be further delineated into a BIM framework. This framework consists of three dimensions; fields, stages, and lenses (Succar 2009):
2 Theory

BIM Fields: defines different industry stakeholders and their deliverables. These fields are:

- **Technology** - consists of software companies such as Autodesk as well as hardware companies.

- **Process** - consists of the builders, designers and those who use, manage and maintain the buildings.

- **Policy** - consists of regulatory bodies, educational institutions, research centers etc.

Figure 2.3 Venn diagram showing the different BIM Fields and where they overlap. (Succar 2008)
2.2 Working Definition of BIM in the Master Thesis

**BIM Stages:** The stages aim to identify the different degrees of maturity of BIM projects. There are five stages:

1. *Pre-BIM:* 2D-drawings explain a 3D* world, i.e. all cross-sections are not provided. Quantities and cost estimates are not based on a 3D-visualization. Collaboration between stakeholders is not prioritized; work flow is linear and asynchronous.

2. *BIM Stage 1:* Object based modeling: Software that enables 3D modeling such as Revit, Tekla or ArchiCAD is being used. The models are not interdisciplinary and data flow is one directional.

3. *BIM Stage 2:* Players are collaborating in this stage by exchanging models or part of models. E.g. machine-guidance. The exchange can occur between designers as well as between designers and architects. 4D and 5D modeling is made possible. With this change in the building process a change in contracts between players are often necessary.

4. *BIM Stage 3:* Network-based Integration: In this stage the models are created, shared and maintained by all the players in the building process. The models become interdisciplinary nD models.

5. *Integrated Project Delivery (IPD):* This is the goal of BIM implementation - to combine domain technologies, processes and policies into one organization.

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**BIM Lenses:** The lenses are a tool to outline the BIM-domain, they are distinctive layers of analysis used to focus research on a specific part of the AECO industry. By using the lenses one is able to clarify the limits of a study concerning BIM, e.g. if a researcher studies the data flows and data processing in a project he or she can be said to use a 'data management' lens. An analogy can be made with infrared light to further illustrate the BIM lenses: When filming one can use an infrared filter to highlight heat sources in the image; BIM lenses work the same way, they highlight the area one wishes to study. There are no predefined lenses but the...
lenses can be disciplinary, as in the previous example where the lens concerned 'data management' (Succar 2009).

Seen from Succars framework this thesis falls into the 'process' field and with regards to it being a master thesis it also falls into the policy field and further BIM in the construction phase can vary a great deal depending on what maturity stage the project is in.

2.3 A Brief History of the Term BIM

This paragraph briefly covers the history of the term building information model, BIM. The paragraph is based on the foreword, written by Jerry Laiserin, to the BIM-Handbook.

The term BIM was first used in a paper in 'Automation in Construction' in December of 1992, however the first time a concept that can be labeled BIM was mentioned was in the journal 'AIA Journal' as far back as in 1975. In the journal Chuck Eastman (now professor at Georgia Institute of Technology) introduces something called 'Building Description System' which deals with much of the same BIM-ideas as we deal with today. During the following years the term "Building Product Models" was used in the US to describe the concept of BIM, in Europe however (especially in Finland) the term "Product Information Model" was used and when the European and US nomenclature amalgated the term "Building Information Models" came to life.

2.4 BIM Technology

This chapter will go through the technological development leading to BIM and it will explain the differences between ordinary CAD systems and BIM design applications and the abilities of BIM. This chapter is based on the second chapter in the BIM Handbook.

2.4.1 Development of BIM Tools

In the beginning of the 1970s three separate research teams created systems that could form and edit arbitrary 3D shapes. Among these systems there were two different approaches to describe 3D shapes:

- The first one used Boolean operations (union, intersection and subtraction) to define shapes. Together different shapes could be created that enclosed a volume. This approach is known as The Boundary Representation approach, B-rep.
2.4 BIM TECHNOLOGY

- The second approach used a tree of operations to define the shape of the desired 3D object, this process is called Constructive Solid Geometry or CSG. In the beginning there were several different types of operations or methods used to render the final shape, one method used to render different shapes was the use of Boolean operations and thus the two approaches concatenated. An example of a CSG-tree using Boolean operations is shown in figure 2.5.

![Figure 2.5 CSG-tree with use of Boolean operations, start from bottom.](http://www.generativeart.com/on/cic/papersGA2003/a11_file/image006.jpg (2009-11-24))

These new methods of displaying objects in 3D found its way into construction industry and other industries as well e.g. mechanical and aerospace, in the late 1970s and beginning of the 1980s via CAD systems such as RUCAPS (later Sonata), TriCad, Calma etcetera. However these CAD systems were often very expensive and required a great deal of computing power, but even with a high price tag the manufacturing and aerospace industry saw potential benefits that would come with these kinds of systems; benefits such as integrated analysis capabilities, reduction of errors and greater factory automation. Hence the aerospace and manufacturing industry started to work with software developers to develop the systems further and overcome the technological problems in the systems. However the construction industry opted for another kind of system; instead they started working with architectural drawing editors (e.g. AutoCAD and Microstation) who then worked with digitalizing 2D drawings, and that cooperation has continued since. The BIM tools we have today, such as Autodesk Revit, Tekla Structures and ArchiCAD, are not descendants of the 2D drawing programs; instead they are based on object-based parametric modeling systems developed for mechanical systems design.
2.4.2 Object-Based Parametric Modeling

In regular CAD systems objects are described by fixed geometries and properties, in BIM and other types of object-based parametric modeling objects geometry and properties are instead defined by rules and parameters. By defining different rules and parameters you can control how objects act and interact depending on the context; the object submits to a user-defined hierarchy. In object-based parametric modeling instead of designing an instance of a building element like a tie on a railway track or retaining wall on an abutment you define a model family or element class. These families or classes are basically a set of rules and relationships, objects are then defined by parameters such as length, height and angles, the parameters are constricted by the family rules, example of rules can be that the object has to be attached to, parallel to and distanced from another object. This means that each object in a class or family differs based on their parameters and context. But rules and regulation can also be setup as requirements on the design, meaning that the changes a designer makes to an object are continually checked against the rules; if there is a departure from the rules the designer will be alerted of this. If we were to make a model family for railway ties the rules, regulations and parameters could look something like this:

- **Rules and regulation**: Ties are attached to the rail via a bracket, each tie has two brackets from a predefined list of bracket types, bracket position on tie must conform to the following regulation X, ties are constricted to a c-c distance of \( Y \) mm, ties must have a minimum of \( Z \) mm to bedrock, ties have to be of concrete from one of the following classes A, B, or C.

- **Parameters**: height, length, width, bracket type, bracket position, concrete type.

2.4.3 Parametric Modeling of Civil Structures

To work with object-based parametric modeling is what one does when working with a BIM model. That is to say that BIM tools are object-based parametric models with a set of object families. The set of object families in a BIM model comes from either the software developer, an independent firm who develops object families or the user of the BIM model that have created their own object family. The software that exist today often comes with an large array of predefined object families to use, for example in Autodesk Revit Structure the following parametric structural components are included: walls, joist systems, beams, trusses, open web

2.4.4 Abilities of BIM and Parametric Modeling

With BIM the modeling procedure goes from being a geometric design tool and becomes a multi-layered, data rich and intelligent representation of a structure, and with this comes a great deal of abilities. Here is a selection of these abilities:

- **Topological structures**: With these intelligent models the user can define connections between objects such as walls and windows and between pipes. Connections need to carry three types of information: what can be connected, what are the connection made of (bolts, butt weld etcetera) and what connection is suitable with regards to the surrounding environment? So if a user can deliver the necessary information to a BIM model it should be able to automate some low level design.

- **Property and attribute handling**: To properly analyze a part of a structure you need information about the part, i.e. the part needs properties in the model. These properties can be: material specifications, how to assemble, casting order and environmental impact. In a BIM model these attributes can be managed and thereby the users of BIM have the ability to analyze parts of construction.

- **Drawing Generation**: From the BIM model the user can extract a 2D drawing from a vertical or horizontal section at whatever detail level the BIM model will allow. If a designer changes a object instance this change will be automatically updated in the rest of the model making every drawing consistent given that they are taken from the same version of the BIM model
2 Theory

2.4.5 Development of a BIM model

It is a complex and multifaceted task to develop a BIM model. There are different ways to proceed in the process to compile a model depending on the shaping of the contract.

- **Design-Bid-Build** (DBB), this type of contract doesn't give the contractor an opportunity to contribute in the design process.

- **Design-Build** (DB), this type of contract gives the contractor opportunity to contribute in the design process. The knowledge and experience from construction sites that the contractor has differentiates him or her compared to the owner and designer. This knowledge and experience will add quality to the design process and thereby help the owner and designer to make better decisions about the design of the construction. This in turn will influence the project’s cost and construction time.

Even though some of the benefits with BIM fades in a DBB contract there still is significant benefits by using BIM models during the construction.

Many architects use some kind of 3D-model or at least 2,5D-model when they style the construction; even many designers use a model in the design progress. If the constructor uses this model in the construction phase he or she must be able modify the model and thereby add specific details regarding components and such things.

From a cost estimation point of view the use of BIM models early on can be of great help. This is because BIM tools in contrast to regular 'early design packages' have the ability to deliver areas, volumes and also types of space. With these data a rough cost estimate can be generated quickly. And as the design process continues more detailed data on the structure will be at hand directly from the model for the estimator to use. Although these models provide quantities they cannot yet analyze and estimate cost that arise from such things as difficult access conditions and complex assembly, so the models are in no way a replacement of estimators.

The different benefits that come from using BIM in the construction phase will be discussed in the following chapters.
2.5 The Use of BIM from Different Perspectives

This chapter mainly concerns the benefits that come with using BIM, both in the design and the construction phase. Even though the industry has not yet reached the stage of fully Integrated Project Delivery, the authors still want to illuminate the most significant benefits that BIM offers. The authors will use Eastman et. al. knowledge that is presented in the BIM Handbook as a basis for this chapter.

2.5.1 Owners

This part is based on chapter four in the BIM Handbook.

The main focus from the owner during a project regards the time and costs. It is rare that projects in the civil construction industry holds the time plan and doesn't have increased costs. By using BIM the owners will be able to:

- **Analyze and compare different designs and materials**, for use in construction. This will make it possible to optimize the construction in advance with regards to both time and cost.

- **Automatically extract reliable and accurate information**, from the BIM model regarding the quantity of different building materials. This will make it easier for the owners to see the impact of their changes, which can be made in an early stage and thereby, have a great influence of the total cost of the construction.

- **Shorten the construction time**, by coordinating the different tasks in advance so that there would be a minimum of clashes during construction. It would also be possible to shorten the construction time by using prefabricated parts in a larger scale; prefabrication may be used due to better accuracy in the BIM model compared to the pre-BIM documentation.

- **Control the time plan**, during the whole construction phase and study the impact on the time plan from a specific deviation. It is also possible to simulate different solutions for a deviation and thereby try to optimize the solution with regards to time and cost.
2 Theory

- *Use the BIM model*, during the maintenance of the construction. It is also possible to connect a maintenance plan to the BIM model. By using the BIM model during a renovation the owner will be able to clarify and compare the impacts of different modifications on the construction.

2.5.2 Designers

*This part is based on chapter five in the BIM Handbook.*

The direct economic effect for design firms to use BIM is quite difficult to quantify. However, the implementation of BIM in the design phase will increase the quality of the design documents. It is easier for the designer to make quality controls and make sure that there are no clashes in the design between different trades. The designer will also be able to analyze and simulate the construction in a way that was not possible in the pre-BIM stage.

The model that the designer creates will be of great interest for the owner, as discussed in 2.5.1 Owners, and thereby be an asset for the design firm. The owner will not be able to analyze and simulate different modifications of the construction alone; this will open up a new way to work for the designing firms. By using the BIM model that was created during the procurement of the construction the designing firm will be able to optimize the maintenance of the construction.

2.5.3 Contractors

*This part is based on chapter six in the BIM Handbook.*

During a pre-BIM construction the contractor will deal with a lot of different problems. Some of them are rather small and some are more comprehensive. By using BIM the contractors will be able to:

- *Acquire detailed information from the BIM model*, regarding the construction. This will be visualized by a 3D model over the construction. The model should contain all components of the construction and the contractor should be able to get quantities and information of the components from the model.

- *Acquire information of temporary components*, e.g. formwork or special equipment that will be used during critical sequences in the construction.
2.5 The Use of BIM from Different Perspectives

- **Acquire specific data about all the different construction components**, in the model there should be links to textual specifications regarding the components that the constructor must purchase or construct.

- **Check the analysis data that has been made for the structure by the designer**, such as structural loads, connection reactions, maximum expected moments, shear forces and so on.

- **Evaluate the design and construction status**, the contractors should be able to give input to the model about the construction progress. Thereafter the contractor will be able to compare the construction progress with the time plan; the contractor will also be able to compare the construction with the design and the procurement.

### 2.5.4 Subcontractors and Fabricators

This part is based on chapter seven in the BIM Handbook.

When using BIM, as discussed in 2.5.2 Designers, the designers will increase the quality of the design documents. This will enable more prefabrication off-site because the BIM model contains all the important details of every component in the construction. There are three different kinds of prefabricated building components:

- **Made-to-stock**, e.g. reinforcement bars, standardized pipes of different types and other building components that has its own standard.

- **Made-to-order**, e.g. ventilating fans and other building components that is made for a broad market segment.

- **Engineered-to-order**, e.g. pre-cast concrete pieces and other building components that is specially made by a subcontractor to fulfill a specific function.

The first two kinds of prefabrications will not be effected by BIM in the same extent that the third; Engineered-to-order (ETO). The subcontractors and fabricators that provide ETO components will have an incentive to begin their work with BIM; by working with BIM they can expand their business.
2.6 The Use of BIM in the Construction Phase

BIM is a very wide field and as a concept sometimes fuzzy. In chapter 2.2 the phrase BIM was defined, however that does not say all that much as to what BIM means in the phase that is studied in this thesis; the construction phase. This part is based on chapter six in the BIM Handbook.

On a work site of a project that has reached IPD-state the BIM model will contain all the information necessary for the construction. However not many sites - if any - has reached this state. Instead projects will often only have reached the lower BIM-stages; in these cases BIM in construction phase can mean that information regarding site logistics is at hand through a BIM model or perhaps that a BIM provides documentation on how to perform complex tasks. But BIM can also be used to analyze more complex processes that can have an impact on the future of the construction, for example: through a BIM model you might notice that a given casting order doesn't work since it will hinder transportation of goods to a certain place on the work site, a BIM model can then give the ability to re-analyze the situation and provide a new casting order. Thus BIM in the construction phase refers to a process in the phase that is facilitated by a BIM - regardless of the BIM-stage of the project. Nevertheless BIM will be discussed from a wide angle and the benefits of using BIM will be pointed out.

2.6.1 Planning Phase

An important part in the project planning phase is the coordination between the different stakeholders; owners, architects, designers, constructors and subcontractors. The aim with this coordination is to build a group that shall work with the manufacturing of the BIM model. The group ought to consist of people with expertise in different areas of the project phases and thereby maximize the level of knowledge in the group. It is of great importance that contractors and in some cases even subcontractors participate in this group since they possess knowledge of the construction phase. This knowledge enables the owners to make better decisions which may influence the projects duration and thereby the project cost.

One way to develop BIM models is to work in so-called bee-hives. By gathering the knowledge that the group possesses in one room, the colleagues will have much shorter ways of decisions and be able to discuss their problems in an inspiring environment. Today there are many meetings that bring up problems which the liable part brings back to their office.
where they solve the problem. The solution will be presented on the next coming meeting; the difficulty in this working process is that one stakeholder ought to consider how the solution will influence the other stakeholders. Another way to collaborate is to centralize the work with the model by having meetings where you instead of just bringing up problems try to solve them directly. This meeting ought to consist of members from all the different stakeholders. The benefit of using this kind of meetings is that the solution will be built on the knowledge of the whole group and every aspect will be considered. In addition to this there will be fewer misunderstandings due to communication problems which in turn will lead to less overwork.

2.6.2 Construction Phase

There are many parts in the construction phase where BIM can be utilized. As the use of BIM technology increases, even though the implementation is in an early phase, the contractor will find new ways of using the technology in the construction phase.

The primary information that the contractor wants from the BIM model is:

- *Detailed information of the construction*, this information is visualized by a 3D-model which contains all the constructions components. It should also be possible to extract quantity and components from the model.

- *Temporary components and equipments*, the model ought to contain information about temporary components and or equipments that shall be used during the different parts of the construction.

- *Specification information for each construction component*, there ought to be links in the model that connect every construction component with a textual specification. In the specification there will be information on when the component shall be bought or constructed.

- *Design and construction status*, the contractor ought to be able to add data to the model. This in turn will lead to that he or she can be able to see the construction progress and check the construction progress relative to the construction phase time plan.
2 THEORY

2.6.3 Deviations

In this thesis deviations in the construction phase refers to a situation where there is an inconsistency with design documents and the conditions on site, e.g. clashes between different parts of the construction. Deviations can also refer to a situation where there exists different version of drawings on site, which can lead to construction being done with a faulty or old version of a drawing and thereby certain parts of the construction would be incorrectly built.

In the construction phase, deviations can be a very costly and time consuming matter. For example when working with precast constructions in pre-BIM stages errors regarding inconsistencies in the drawing set have been shown to cost approximately one percent of the total build cost.

Clash control is something that easily can be done with a BIM model. With BIM both hard and soft clashes can be detected. A hard clash is when parts of the construction occupy the same space and a soft clash is when parts of a construction are situated to close to one another with respect to safety, access and insulation for example. BIM tools can detect both clashes based on geometry but as well clashes based on user defined rules such as when and where different trades work. But for this clash control to work satisfyingly the BIM model needs to be sufficiently detailed. If the model is not detailed enough clashes can be missed and thus inflict higher cost on the project as well as possible delays. To make sure that the model carries enough detail it is advised that the contractor gets involved in the design process as early as possible, to give his or her input as to what details are necessary. It is also advised that different subcontractors also take part in the model development and that development of the model moves out to the construction site when possible.

There are two main ways to perform a clash control with a BIM model:

- **Clash control with BIM tools**: all the major developers of BIM software delivers tools with their programs that enables clash control. But often a contractor needs to merge several different models and this can create problems since different programs sometimes speak different languages.

- **BIM integration tools**: this other approach uses software that allows for import of different types of BIM models into one program and performs a clash control. This
however means that clashes detected cannot be transferred to the original model at once since the merged model is not connected with the original model.

The process of updating the model requires great care from the managers; if the updates are not communicated properly there may be delays due to uncertainty on the construction site. Hence a well functioning file system is needed.

Even though a BIM model contains the entire structures in the form of different objects with dimensions, position, properties and specifications there is still a need for drawings since this is the primary information carrier to the people who assemble the parts. Drawings can be generated using a BIM tool; arbitrary sections of the 3D model can be transformed to 2D drawings. How these drawing are produced in the BIM model can be said to depend on how advanced the BIM models are, i.e. how much details they contain. In basic BIM models drawing generation take the following form:

- A section is chosen to be a 2D drawing
- A designer needs to fill out the information lacking from the BIM model, for example line weights, dimensions and annotations.

And then the drawing is done, the details that the designer fills out is however associative; meaning that they stay with the model as long as the section remains and that nobody else changes the information the designer filled out. BIM models that have a higher degree of details are able to fill out these details automatically, for example line weights, dimensions and annotations. All this information is stored in the BIM model as properties to objects. However not all BIM systems allow for a bi-directional flow of information, i.e. if there is a change in the model the drawings are not automatically updated, they have to be regenerated. This automation means that the time needed to create a drawing is greatly reduced. This is a very important feature of BIM: If there occurs a problem that needs to be solved by a designer, time spent on making drawings is greatly reduced since the designer will just make the necessary changes to the model and then the people at the work site generate a drawing from the model.

Drawings generated from BIM models has a common heritage, this means that as longs as drawings comes from the same BIM model; they are consistent. This means that all parts of the project with access to the model have the same set of drawings. This compared to pre-
2 Theory

BIM stage when all drawings have to be manually updated when a change occurs - this can off course lead to problems due to the human factor.

2.6.4 4D-Modeling in the Construction Phase

It is the planners work to produce a construction phase time plan where all the different activities are presented. An activity is a work task that will be executed on a certain place at a certain time. Different activities have different demands regarding, e.g. material, temporary resources or different preparation work.

Traditionally the construction phase time plan has been visualized by a Gantt chart which has linked the different activities to each other. In a big project there are thousands of different activities that are linked to each other in different ways. As the number of activities increase the understanding of the construction phase time plan will decrease. This in turn can lead difficulties to see which impact a certain work task has on the project.

When using BIM it is feasible to connect the construction phase time plan to the model. The different construction components will have different internal hierarchy. I.e. you cannot perform a certain activity before others, e.g. you cannot cast concrete before excavating, building formwork and installed the reinforcement.

The information in the 4-D model can be visualized in a simple and intuitive way. This in turn will increase the understanding of the construction phase time plan and which impacts a deviation from the time plan will cause on the project. The 4-D model also has benefits when it comes to:

- **Communication**, the planer can with the assistance of the model visualize different phases in the construction. This can be communicated to the construction site work crews but also to other stakeholders in the project. It will also be possible to use the model to visualize how a complex activity ought to be executed.

- **Multiple stakeholders**, the model can be used to facilitate the communication between the project team and laypersons. E.g. which impact the construction will have on the access to different important institutions.
2.6 The Use of BIM in the Construction Phase

- **Site logistics**, the 4-D model can be used to include temporary construction components. E.g. lay-down areas, accommodation roads or places were to store large equipments as a screen.

- **Trade coordination**, a 4-D model may comprehend information about expected time and space flow of trades on the construction site. This in turn enables planers to see potential bottlenecks.

- **Analyze the working progress**, by using an up-dated 4-D model the planer can easily check whether the project is running on schedule or not.

There is specific demand on a 4-D BIM model that is going to be used in the construction phase. E.g. if a concrete slab is going to be poured in three stages the whole slab must be divided into three sections. This is due to the simulation of the working process. A 4-D BIM model ought to contain information on temporary structures, e.g. excavation areas, formworks, scaffolding and lay-down areas. This information is important when it comes to organize the work and make sure that there are no conflicts between different activities on the construction site.

A BIM model can be directly linked to an estimation program, i.e. an aid program for the BIM modeling program that is specified on estimation tasks. By using this kind of program the planers will be able to associate the constructions components and its assemblage with the resources that is needed for constructing, e.g. a cast of a certain concrete slab demands three skilled workers, a concrete truck with its accommodation road, eight square meters of formwork, quality check on concrete etcetera. By using this tool the planer will be able to compare different construction set-ups. This in turn opens up the possibility to optimize the production phase, e.g. through assemble sufficient size of a work crew, co-operating material flow or planning the work so the heavy machinery, such as wheel loaders, will be utilized as much as possible.
2 Theory

2.6.5 Prefabrication

To construct prefabricated construction components there are specific demands on the design documents, as well as it requires comprehensive planning and coordination between the different stakeholders. Some of the advantages of using prefabricated construction components are:

- **Reduce risk**, prefabrication is to prefer with regards to the large risk of shortcomings in an onsite fabrication relative to prefabrication.

- **Time optimization**, the construction components may be fabricated in advance and be delivered to the construction site just in time for the installation of the prefabricated component.

Furthermore an error in an offsite fabrication, compared to an onsite fabrication, will have smaller impact on the construction time which is correlated to the construction cost. When using a BIM model in the design phase the accuracy in the design documents will increase, this in turn will lead to:

- **Increased participation**, the experience and knowledge from the fabricators can be used in an early phase to verify and validate the model. Particularly when it comes to specific construction components that may be prefabricated.

- **Enable prefabrication in larger extent**, since an accurate model does not omit any sections, the constructor knows how every construction components shall be constructed.

2.6.6 Additional Dimensions

Presently there exist many tools used to control the different processes involved in a construction project. These processes can be such processes as accounting, procurement, payroll, safety etcetera. The tools that help manage these processes often rely on data in the form of information about certain objects in a building or structure, this information is in pre-BIM stages plugged in manually and this work is time consuming. In a BIM-model one is able to extract the information needed for such processes as mentioned above, hence if you connect the BIM model to a desired tool, e.g. a procurement system, the manual input of data
2.6 The Use of BIM in the Construction Phase

is redundant. Below follows a list of examples of how BIM can be used to support different processes in the building process.

- **Project status**: In a BIM model the status of a project can be visualized. This can be done by coloring objects after what status there in (in design, delivered, being (pre-) fabricated, being constructed, and installed). This enables the project management to quickly form an opinion on how the build is going and also gives an opportunity to spot potential bottlenecks.

- **Procurement**: A BIM model contains, depending on BIM stage, a certain amount of information about the objects that constitute a structure or a building; this means that procurement tools can be connected to the model since the model identifies which parts are necessary. There are systems today that can give quotes in real time including delivery to the site.

- **Procurement Tracking**: In the pre-BIM stage it was very hard to relate the procurement process to the planning since the construction phase time planning often is very vast this in turn makes it hard to assess. In a BIM model were the time plan is connected to the model, planners and constructors can easily investigate the procurement status of a certain object. This opportunity provides an important tool for discovering potential delays due to the procurement process, e.g. if a object which has a long lead time is going to be installed in a couple of months and the object is not ordered this will show, perhaps via color, when an inquiry is done - crosschecking time plan with object status.

- **Risk Management**: By visualizing the site in 4D potential site-hazards may be detected before the construction site work crew is on site - this enables better planning of work as well as a safer site.
2 THEORY

2.7 Summary of Case Studies

In this chapter the authors review some case studies from the literature. The cases discuss different projects where BIM has been used during the construction phase. This chapter is written as means to try to explain and clarify how the BIM theory is used in the real world.

2.7.1 San Francisco-Oakland Bay Bridge

Source: BIM and Construction Management: Proven Tools, Methods, and Workflows. By Brad Hardin

Project Description

After the Loma Prieta earthquake of 1989 the California Department of Transportation decided that the east span of the Bay Bridge was too be replaced and the west span seismically retrofitted. The project can boast the longest self-anchored suspension span in the world, a price tag of USD 6.3 billion and a daily traffic load of 300 000 vehicles.

Figure 2.6 Part of San Francisco – Oakland Bay Bridge during the construction phase,
2.7 SUMMARY OF CASE STUDIES

How They Used BIM in the Construction Phase

A 4D model was created and has throughout the project been updated and contains over 3000 construction activities both performed by the contractor as well as by different subcontractors. The model contains among other things fabrication and delivery of deck and tower sections, critical stages in the build, staging of temporary structures and equipment moves. The model can be used to simulate the work of several activities simultaneously.

Conclusions from the Case Study

Since the model came into the project in an early stage and was accepted among the stakeholders there has been a continuous work on the model; the model took form by an iterative process. Via simulations where different activities ran simultaneously errors in the planning were detected; some work activities that occupied the same space and time were detected and could be re-planned. The case concludes that using BIM in the construction phase has many advantages, some that occurred in this project were:

- Designers and contractors could more easily be informed about planned construction processes.
- Communication between constructor and owner is facilitated by the model, e.g. visualizations of when and how the bridge had to closed for certain activities.
- Increases collaboration between stakeholders in the project.
- Enables accurate and easily understandable visualization of the projects progress for public.
2 THEORY

2.7.2 Flint, MI - General Motors Production Plant


Project Description

Flint Engine South Plant that enclose 68 000 square meters was built in 2000; this building was complimented in 2006 by a 40 000 square meter large building. The total cost of the building is estimated to USD 202 million. The special thing about this project is that GM set up hard criteria’s for the project when it comes to design and construction time. To manage this criteria’s GM decided to use BIM during the whole project, they had also special demands on their cooperators. The cooperators ought to use BIM in their part of the work and it was a qualification if they had used BIM in a previous project. If a cooperator without experience in BIM was hired GM acted like consultants towards that operator when it comes to produce information to the BIM model.

Figure 2.7 A view of the Flint Engine South Plant,
www.corenetglobal.org/files/learning/awards/edla/ppt/Michigan_EDC.ppt
How They Used BIM in the Construction Phase

In the Flint project they used a 3D-BIM model and a digital information flow instead of 2D CAD drawings and paper-based flow, this lead to dramatically reduced feedback times. The BIM model was also used in the procurement, e.g. instead of sending the fabricators 2D CAD drawings they handled them the model. This in turn resulted in reduced transformation cost and shorter delivery time since the BIM model did not require any modification.

The Flint project used BIM for:

- 3D-BIM collaboration
- Clash detection
- As-built documents
- Just-In-Time delivery
- Prefabrication

Conclusions from the Case Study

During the construction phase the BIM model lead to an extraordinary high degree of prefabricated construction components along with preassembly of components. This was enabled thanks to continuous work with the detailed BIM model, which resulted in a construction site without field changes. Besides the advantage from the minimization of field changes the BIM model helped to keep the movement of people and materials to a minimum on the construction site which in turn leads to increased safety on the site. The construction site was also very well-organized during construction thanks to the BIM model. One reason for the well-organized construction site was that they used the BIM model to get Just-In-Time deliveries and thereby minimize the store-keeping on the site.

Since all stakeholder used a fully-coordinated BIM model clashes was discovered early in the project. The information between different stakeholders was enhanced by the digital information flow, this in turn lead to a good atmosphere and facilitated the interaction and collaboration between the cooperators. The collaboration between the cooperators leads to a great amount of real-time, well thought-out and accurate decisions. The Just-In-Time deliveries accompanied by a well organized construction site lead to a remarkably low waste of material on site.
2 Theory

2.7.3 Mountain View, CA - Camino Medical Group Office Building Complex


**Project Description**

The building with an adjacent parking garage is located in Mountain View just outside San Francisco in California USA. The medical center is to be used for short term care and surgery. The build comprises about 23,000 square meters of office, 6,000 square meters of medical facilities such as laboratories and operating rooms and close to 40,000 square meters of garage in 3 levels. Architects started drawing on this project in October 2003 and the project was finished in April of 2007, the project cost was USD 94.5 million. The owners, Camino Medical Group, were the ones who wanted the project to be executed with BIM

![Image of Camino Medical Group Office Building Complex](http://omswiki.pbworks.com/f/DPR_Camino+Case+Study.pdf)
How They Used BIM in the Construction Phase

The general contractor (GC) who was hired for this project was responsible for the BIM-model, selection of subcontractors, coordination of detail design and construction, getting necessary permits, and making sure that goals pertaining to time, cost and safety were met.

These goals were going to be met by the use of lean construction techniques such as: early involvement of subcontractors in the design process, extensive use of prefabrication and preassembled parts, and the use of a 3D model for clash detection, planning and correction. When the subcontractors were chosen, the GC demanded ability to design in 3D, but in some cases such subcontractors could not be found and in those cases their 2D drawings had to be converted to 3D by an external consultant.

Work on the 3D-model was made continually through-out the build, the model itself was located on servers in a trailer at the work site. Each week the GC held a meeting with the architects and subcontractors were they went over the work that had been performed as well as analyzing the work to come as to avoid hard clashes. Apart from this the trailer was also used by detailers that the subcontractor had hired.

In this project the design phase overlapped the construction phase. For this process to run smoothly the subcontractors were allowed to start designing their part of the construction before architects and engineers were done with their design. The planning of this overlap was deemed to be very important; if the subcontractors were brought in to early in the design phase they risked having to re-design certain parts if the owner had a change of heart, on the other hand if they were brought in to late it could mean delays in the construction. The schedule that was made for this purpose showed all stages of the construction and what design documents were necessary for the stages. This schedule was linked to another schedule that was used to order material and prefabricated parts. This enabled the work process to run more smoothly especially with regards to the just-in-time deliveries.

Cooperation between subcontractors was facilitated by setting standards for them to work after. The GC for example dictated that the subcontractors used the same scales, had a common point of reference that was set by the architects and that they used file formats compatible with the software used to compile the 3D-model.
Conclusions from the Case Study

By working with BIM the GC and subcontractors anticipated that they were going to be able to more efficiently construct the building and also that they more easily could see how material and prefabricated parts was to be assembled. The benefits that were realized were the following:

- Ability to more easily plan the logistic and assembly of prefabricated parts.
- Better cooperation and coordination between subcontractors.
- Construction components have a better fit and needs less modification on the construction site. In all there were only five field changes made on site for the MEP trades.
- Only 41 of 25,000 work hours were rework.
- Just-In-Time deliveries meant less cluttered lay down areas which in turn meant that less work hours spent on moving material on site.
- The tendency that subcontractors want to be first on site, because they don't want their work to clash with the work of preceding trades, was eliminated.
- Smaller workgroups were required due to the high degree of off-site fabrication.
- A safer job site, which in turn rendered fewer work hours on the construction site and less improvisation and better planning.

The design and construction teams said to have learned the following lessons:

- Start planning with a 3D model when 50% of the design development is finished, start the detailing when 95% of design development is finished.
- Make sure that everybody works in 3D, this to ensure that the compiled model will be as accurate as possible. It is very hard to get a correct model when converting 2D drawings into a 3D-model. Of the problems that arose during construction they were most often due to inconsistencies that occurred when converting 2D drawings to the 3D-model.
• Conduct meetings once a week where you deal with design, coordination and construction, and fuse the schedules of these parts together based on the date of installation of specific building components and make sure that there are people in the construction that are responsible for the installation of each part, and that these responsible people are present at the meeting.

The use of a 3D-model connected to lean construction techniques proved to be both profitable and time-saving. Apart from this, labor efficiency increased with 15 to 30% compared to industry average and prefabricated and preassembled parts were used to a higher degree and the parts had higher accuracy.
3 Method

In this chapter we present the method used to realize this thesis. The chapter consists of a discussion on the different methods that can be used to collect information during interviews, there is also discussions regarding data gathering via observations, questionnaires and literature reviews. Also found in this chapter is a brief assessment of the reliability and validity of the thesis.

3.1 Execution

To achieve the aims and fulfill the purpose stated in chapter 1.5 close to twenty qualitative interviews were performed in both Sweden and the US, a questionnaire was also developed and sent out to nine respondents, and a literature review was carried out as a means to get acquainted with the subject. This modus operandi results in qualitative data. The reason this methodology was chosen is because the authors wanted personal opinions and experiences. The informants were chosen from different levels of the organization, e.g. Skilled Workers, Foremen, Block Manager, Production Managers and Project Managers. More or less all of the informants worked in the construction phase or had experience of work therein.

After the interviews were performed and the questionnaires were filled out a qualitative analysis on the data was carried out.

3.2 Literature Review

Literature reviews are a matter of great importance in scientific reports. With a well conducted literature review a scientist can avoid the risk of just repeating known facts and instead continue to building on the current knowledge (Höst et al 2006).

By declaring the sources in a clear manner the researcher makes the process of scrutinizing the work more easy, as well as to make it easier to find sources for people wanting to learn more about the subject (Höst et al).

In this thesis literature has been used as means to learn more about; the subject of BIM, methodology about interviewing, pre-BIM work process, and how to structure the thesis.
The literature review made with thesis is based on:

**Specialist literature:** The literature consists of literature on methodology from the Royal Institute of Technology's library at campus Valhallavägen, and the Stockholm City Library. Literature about BIM was bought online after recommendation from professor Renate Fruchter of Stanford University. We also used literature on how to structure the thesis.

**Research Reports:** Research reports on the subject were read to gather information.

**Seminars:** A seminar on 'Planning of Concrete Structures and Constructing with BIM', the seminar featured 5 lectures discussing how BIM have and will change the AEC-industry. The seminar was held at Älvsjömässan during the fair 'Betongfeber'.

**Master theses:** Old master theses were studied to get an idea on how this thesis should be structured.

**Undisclosed company information:** Use of 'Forum Sverige' the internal network of the Skanska Company to gather information about the work process during construction.

**Articles and Papers:** Articles from magazines such as 'IT in Construction', 'Automation in Construction', 'Queensland Roads', and 'Byggindustrin' were used to gather knowledge. Some articles were found while searching different databases containing scientifically papers, e.g. Scopus.

**WebPages:** We used the Google search engine to find several of the pictures used in this thesis.
3 Method

3.2.1 To Rate the Sources

Sources differ in credibility. Some sources have gone through scrutiny by experts in the field, and can thereby be said to have high credibility, other sources might just be plain lies and as such they hold low credibility - if any. When choosing sources the authors have asked five questions about every source to try to determine the credibility of the sources (Höst et al 2006):

- Has the material undergone scrutiny? And if so, by whom?
- Who ensures the credibility?
- Is the research methodology credible?
- Are the results produced in a context that is relevant to the aims of the study that is being written?
- Has the results been confirmed or led to recognition from pundits and has the results been referred to in other credible contexts?

In this thesis much of the material in the literature review lives up to most of these questions:

- The specialist literature, apart from literature on methodology, fulfills all of the questions in satisfactory manner.
- Research reports and articles used in the thesis also fulfill most of the questions. E.g. the articles/papers from scientific papers have been cited many times in other articles/papers.
- We feel confident that all information gathered in the literature review has been presented in a, to us, relevant context.
3.3 Interviewing

An interview is a structured hearing of a person regarding a specific subject (Höst et. al. 2006 (s. 89)). An interview may be conducted in several different ways. It can be structured, as it is with a questionnaire - fixed questions with answers bound by options given by the interviewer. On the other hand it can be open with only open questions within chosen subjects. The data collected can be qualitative or quantitative, the processes by which these data are gathered is however similar in that they both emanate from certain prerequisites and choices made by the person who conducts the interviews (Magne Holme et. al 1997 (s. 151)). There is no method better than the other; instead choosing method depends on which method will present the best result with respect to the time and resources that are available and which results the study aim to achieve (Patel & Davidson 2003).

With our thesis purpose in mind we identified three main reasons of our interviews.

- To get a deeper knowledge about BIM and how its implemented
- To get a clear view about the status of BIM in the construction phase of projects
- To get an understanding of the work process at regular sites

With the data collected from the interviews we aim to fulfill the purpose and aim of the thesis.

3.3.1 Quantitative Interviewing

The characteristic feature with quantitative interviews is that it results in a number or another measurable parameter. The outcome from a quantitative interview is only valid if there are many participants in the study; otherwise the result is seldom statistically relevant (Höst et. al.).

The choice of participants in a quantitative interview is made by a random selection out of the studied population. The aim is to get an overall picture of the studied subject in the population by analyzing quantitative data; that is data that can be represented in numbers and values. The techniques by which one could analyze quantitative data are numerous, but there are two principal ways: First you can explore the data to get a deeper understanding and secondly you can use it to show connections and to test hypotheses (Höst et. al. 2006). To get statistically
significant results about a population it is important to have a good selection; both in numbers of participants as well as how the participants are chosen (Höst et. al.).

The results from the quantitative interview are influenced by the scientists prejudice, education and past experience. Depending on how you are trained to solve problems you will be able to see things in different perspectives. Likewise your background can influence your point of view when it comes to see and analyze what the problem is in a specific situation (Holme et. al. 1996).

A quantitative interview is controlled by the interviewer and leaves small opportunity for the informer to contribute with his or her own experiences. Therefore the preparation made by the interviewer regarding the questionnaire is very important. The lack of interaction between interviewer and informer is often a problem since it leaves no room to elaborate on certain answers or to clarify a question if necessary. This can be avoided if the survey is done face to face (Höst et. al. 2006).

3.3.2 Qualitative Interviewing

The characteristic feature with qualitative interviews is that they are trying to measure soft parameters, e.g. the informer’s point of view on a certain subject. The interview is not controlled by the interviewer in the same extent as with a quantitative interview. There is no questionnaire in a qualitative research; instead there is an interview manual. The aim with an interview manual is that the interviewer will have some guidelines during the interview. This makes the dialogue relatively open but at the same times leads the discussion in the way the interviewer wants (Holme et. al. 1996).

The aim with a qualitative interview is not to find some kind of mean value in the studied subject; its purpose is rather to accent the extraordinary. This is why the selection of participants is made by developing certain criteria and from there find the specific persons. The person who compiles the criteria needs to have large experience in the required subject and insight in the working group in order to find the most suitable interview group (Holme et. al. 1996).
There are two different types of interviews (Holme et. al. 1996):

- **Respondents interview** - an interview with a person who is personally involved in the studied subject

- **Informant interview** - an interview with a person who is not personally involved in the studied subject but have influence and great knowledge in the issue.

A qualitative interview can be carried out in two different ways. It can be an open mode interview or a semi-structured interview. An open mode interview is regulated by a interview guide where different extents of the interview is defined. In a open mode interview the informer has a great influence, his or hers willingness to talk about different areas will have a significant effect on the outcome of the interview (Höst et. al. 2006). One shall be aware of the informers willingness to talk of a specific area can depend on the unwillingness to talk about another area. A good thing is to make critical ranges which will make sure that all the different areas will be dealt with during each interview. To secure the quality of an open mode interview a recorder should be used, this makes it possible to go back and actually listen to what the informer said about a specific subject.

A semi-structured interview is and open mode interview mixed with predetermined questions that have fixed answering alternatives. An important thing is to phrase the questions in the same way during all the interviews and to use the same order of question; the setup of the question can influence the informer in different ways.

A benefit in quantitative interviewing is that the interview in many ways resembles an ordinary conversation. This results in good quotes but also gives the interviewer ability to read between the lines and get an implied message, if there is one. A prerequisite to get good quotes is to use a recorder (Holme et. al. 1996). There are many things to consider during a qualitative interview, here below are some of the more important ones listed:

- Don't influence the informer opinion in the studied subject.

- Try to hold the interview as open as possible, this to try and make the informer share his or hers personal experience in the subject

- Be a good listener to gain the informers trust
3 Method

3.3.3 Method Choice

One aim with the interviews is to get a impression of where Skanska is in their work of implementing BIM in the construction phase. We want to compare the differences in the construction process for projects BIM (i.e. any of the BIM-stages 1-3 and the IPD-stage) and projects that do not use BIM. Therefore the authors have chosen to interview two main groups, one with a large experience in constructing with 2D-drawings and one group that have experience of BIM in the construction phase – the latter group is the American group since such a group was not to be found in Sweden. The result of the comparison between these two groups will give us an opportunity to analyze pros and cons with BIM today compared to building with 2D-drawings. As well as information on how BIM has been implemented in the construction phase in civil projects and what can be learnt from that process. This should give the authors enough information to be able to draw some conclusions as to how the implementation work ought to be carried out in Sweden.

The respondent consists of Foremen, Skilled Workers, Project Managers, Production Managers, Coordination Managers, Surveyors, Block Managers, Scheduling Engineers, VDC Model Managers, Senior Consultants, and MEP Managers. Since there are no workers with experience of BIM in the construction phase at Skanska Sweden Civil, this group consists of employees in Skanska USA. A random selection of participants in this group for the interviews is not feasible since the number of people with BIM experience in the construction phase within Skanska USA Civil is not large, and our limited budget also restricts how much travelling we can do to find good informants. Instead the selection is to be made by scouting co-workers at Skanska USA Civil with the greatest experience in BIM in construction phase in the Northeast business region.

Seeing that our BIM-group is small and that the type of data we want to collect is mainly general information and personal experience from the workers, we find the best way to collect the information is during an open mode qualitative interview. The reason that we choose an open mode interview instead of a semi-structured interview is that we want the informer to use his or hers own words to express their thoughts, without the generalization that comes with questions with fixed answering alternatives.
The group of informants in Sweden is chosen with regards to their experience from the construction phase in civil projects, it is also considered as an advantage if the informants have previous experience of being interviewed. Since the aim with these interviews are to get a picture as to how the construction phase looks like in Skanska Sweden and how the informants feel about it, an open mode qualitative interview is the most suitable choice.

The authors will also conduct interviews in Sweden with informants that are considered experts in the BIM-field. These informants are chosen after consultation with the tutor and examiner of this thesis. These interviews will be used as a means to gather information about the future of BIM and technology related to BIM, this purposed is best served if the interviews are of an open mode qualitative type, since this will enable the informants to elaborate on bits and pieces they feel are relevant.

### 3.3.4 Method of Analysis

There are numerous ways of analyzing interview data depending on the type of interview, what you are studying etcetera. With respect to the aim of this thesis we have overlooked the different types of analyses that concerns linguistics. Also overlooked is so called bricolage since this technique - which is best described as a technique were one moves freely between different analytical techniques and concepts, seems inappropriate for novice interviewers (Kvale et. al. 2009). Instead the analytical technique found most appropriate with regards to time, knowledge and resources was coding.

#### 3.3.4.1 Coding and Textual Analysis

Coding is a process by which qualitative data can be analyzed. It is a process where text segments get connected to certain key words or phrases - codes; this is done so that the text segments are easier to identify (Kvale et. al. 2009). There are two types of coding; data-driven coding and concept-driven coding. By data-driven coding the codes are developed gradually as the material is studied, with concept-driven coding the researcher defines the codes beforehand based on existing knowledge or a small part of the gathered material (Kvale et. al. 2009).
3 Method

This type of analysis is also referred to as textual analysis, which can be divided into two different parts (Holme et. al. 1997):

- **Totality analysis**, by looking at all of the collected material including the information from the interviews the researcher can then chose different subjects which will be investigated. The analysis only consider the chosen subjects, other aspects will not be covered by the analysis.

- **Sector analysis**, the printouts from the interview includes statements about different phenomenon’s that are more or less connected to the studied subject. These statements can be categorized or written down in a tabular form. The different statements will be connected to each other during the analysis and render an opinion in the studied subject. The different categories can be compiled beforehand.

**Totality Analysis**

A totality analysis can be divided in three parts

- **Selection of subject(s)**, this part can be more or less systematic. By reading over the collected material the researcher might get a view of which the most important parts of the investigation are. This is a subjective point of view and must be compared with empirical material to be validated.

- **Question formulations**, concretize the selection of subject. Find some questions that capture the subject.

- **Systematic analysis**, return and analyze the parts in the collected material that is essential for the analysis. Read over the interviews and make notes where the selected subject figures and write down important details.

**Sector Analysis**

Sector analyses require that the collected material can be divided into different categories or be written in tabular form. The units in the analysis are words and phrases that will be categorized in the different categories.

There are however some problems when it comes to analyzing the categorized material; what does the word selection mean or what does the informer mean by using the same word many
times? These questions are taken into consideration by the fact that the authors will check whether the studied text segments are in their right context or not. This is done by getting feedback from the informant; if the informant disagrees with the interpretation of their answers they can clarify them (Höst et. al. 2006).

3.3.4.2 Choice of Method of Analysis

In this thesis the choice of method of analysis is a 'sector analysis' or 'concept-driven coding'. This choice was made because:

- the aim of the study defines specific questions to be answered, this enables the formulation of specific categories as well as codes that can pose as topics during the interview
- the authors are after the literature review knowledgeable in the area and are therefore able to judge what is important with regards to the aims of the study
- a totality analysis is more time consuming and also demands greater experience from the researchers with regards to interviewing and analyzing techniques

The analysis is based on an interview matrix. An interview matrix is a template based method to organize the qualitative data derived from coding. The columns of the matrix lists the data with regards to the coding and the rows represent informants’ specific answers (Höst et. al 2006). By sorting the data this way it will be easier to compare answers from different informants with respect to certain subjects and keywords. It will also make it easier to get an overview of the entire groups view about a subject.
Table 3.1 Example of an interview matrix

<table>
<thead>
<tr>
<th>Coding</th>
<th></th>
<th>What do you like most in your favorite car</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Sports car</em></td>
<td><em>Status</em></td>
</tr>
<tr>
<td></td>
<td><em>Station wagon</em></td>
<td><em>Design</em></td>
</tr>
<tr>
<td></td>
<td><em>German brands</em></td>
<td><em>Sound</em></td>
</tr>
<tr>
<td>Person 1</td>
<td>I like Porsche</td>
<td>I chose Porsche because of the looks and it goes really fast</td>
</tr>
<tr>
<td>Person 2</td>
<td>I like big cars</td>
<td>I want to put many shopping bags into my trunk</td>
</tr>
</tbody>
</table>

The sorted data will be compiled and presented in the Results (chapter 4). In the analysis the answers from the different groups of informants will be compared to each other as well as compared to literature on the subject and put into a relevant context with regards to the aim and purpose of the study.

3.3.5 Preparation

A qualitative interview inquiry has its advantages as well as problems due to its open structure. The procedure by which a study is conducted is not standardized but there are standard approaches to an interview inquiry. One standard approach that is presented in the literature is a seven stage linear progression of the interview inquiry, the stages are (Kvale et. al. 2009):

1. *Thematizing*, deals with the formulation of research questions and presents a theoretical clarification of the theme. What to be done in this stage: Articulate why this study is executed, obtain knowledge of the subject, familiarize oneself with the interview techniques and decide which to use.

2. *Designing*, deals with the planning of the study - such as writing a interview guide and selection of who to interview.
3. *Interviewing*, concerns the actual interviews. The interviews are performed with the help of the interview guide.

4. *Transcribing*, preparing the gathered material for analysis.

5. *Analyzing*, decide which method of analysis is the best with regards to the aim of the study and the nature of the interview material.

6. *Verifying*, determine: reliability - how credible are the data and is it consistent? Validity - will the study investigate what it intended? Generalizability - can the finding be transferred to other situations?

7. *Reporting*, make the results and the method of the study accessible in a form that lives up to scientific criteria. It should take ethical aspects into consideration. Results in a readable product.

These steps might help novice interviewers sidestep potential problems that may arise. Our method will very much follow these steps. However we will consider different choices of analysis and also choose a method of analysis before we design the interview study. This interruption of the proposed linear progression is done to ease the final analysis and make it more amendable (Kvale et. al. 2009).

### 3.3.6 Interview Guide

As mentioned in chapter 3.3.2 about qualitative interviews the purpose with an interview guide is to be a guideline for the interviewer during the interview. To create an interview guide one first need to know how the disposition of an interview ought to look like. With that in mind an interview can be divided into four phases (Höst et. al. 2006):

**Context**

The informer shall get a short briefing off what the aim with the study is, why he or she is interviewed, how the information will be analyzed and if the interview will be recorded.
3 Method

Introductory questions

To get a good atmosphere and in order to make the informer feel comfortable it's important to begin the interview with simple questions which have straight answers, e.g. age, education and job assignment.

Main questions

The main questions shall be asked in an order that the informer feel is logical, not necessarily the order the interviewer think is logical. At the end of this phase it is appropriate to ask some neutral questions whose purpose is to make the informer feel in good mood, this will ease future cooperation from the informant.

Summary

At the end of the interview the interviewers will give a short summary of the conversation and describe which information they have caught. This will make it possible for the informant to ad or edit some of the information he or she gave, hence increasing the reliability of the interview.

The authors have produced an interview guide that will help them to cover all these phases during the interviews. The interview guide can be found in Appendix A.

3.3.6.1 Phrasing Questions

Even though the interviews are of an open mode character, the guide will include questions as well as an outline of topics. Therefore it is important to be able to phrase them correctly.

An interview question can be analyzed with respect to two dimensions: thematical and dynamical (Kvale et. al. 2009). Thematical questions should give knowledge and answers to the questions regarding the research topic. Dynamical questions should encourage positive interaction between the interviewer and the informer. A thematically good question is not necessarily a good question from a dynamic point of view.
With this two-dimensional approach to questions it can be good to phrase two sets of questions; one for each role, i.e. the researcher and the interviewer (Kvale et. al. 2009). One example:

*Research question (Thematical):* Which form of learning motivation dominates in high school?

*Interviewer questions (Dynamical):* Do you find the subjects you learn important? Do you find learning interesting in itself? What's your main purpose in going to school?

By posing two sets of questions we translate thematically good questions into dynamically good question and vice versa.

### 3.4 Observations

Observations can be described as a span of time where you are together or in conjunction with a group that you want to study (Holme et. al. 1997).

The execution of an observation can be performed in a number of ways. The choice of method to carry out the observation with can depend on which information you want, which group you are going to study or which technique you are going to carry out the observation with.

In the case of this thesis the observations are used as a complement to the interviews, i.e. the authors use it to put the informants’ responses into a relevant and current context. This means that observations will mainly be used during our interviews in the US since much of the information gathered there will be site-specific. As opposed to information gathered via interviews in Sweden, they will have a more general character and will not be as closely tied to the informants’ current project; therefore observations will not serve an equally great purpose in Sweden.
3 Method

3.5 Qualitative Questionnaire

A questionnaire is very similar to an interview, they can be quantitative or qualitative, the selection of informants\(^1\), construction of questions, coding, and the processing of data also bare similarity to that of an interview (Trost 2007). The obvious exception between interviews and questionnaires is that the informant notes his or her answers without the help of an interviewer when answering a questionnaire. To construct a questionnaire one needs to go through a couple of steps: posing the questions, select the informants, writing a cover letter, choice of distribution, gather and analyze the data (Trost 2007). The purpose of the questionnaire we developed was to gather information regarding the experiences and expectations of BIM from employees at Skanska Sweden. The questionnaire and accompanying cover letter can be found in Appendix B.

3.5.1 Selection of Informants

The informants selected to answer this questionnaire can be said to belong to one of two groups (in some cases to both): people with BIM experience and people working at a supervising level in the construction phase. Due to certain limitations, i.e. the fact that there are not an abundance of people with BIM experience within Skanska Sweden Civil; we have not been able to select informants randomly. Instead the questionnaire was sent out to people belonging to one of the groups.

3.5.2 Posing the Questions

A questionnaire can contain questions demanding quantitative answers (closed questions) as well as qualitative answers (open questions). All of our questions in the questionnaire are of an open type. There are some important things to consider when styling the questions in this type of questionnaire (Trost 2007):

- Pose one question per question. I.e. do not ask 'Should BIM be used as facility management tool and a tool in the construction phase?'. a 'Yes'-answer to such a question is ambiguous; should it be used as a tool in both cases or just one?
- Generally one should avoid the use of negatives

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\(^1\) Informant is defined in the same way as in the Interview part of the method chapter
Höst et al 2006 continues on the same subject by stating some aspects that needs to be taken into consideration when posing the questions, among others:

- Order of the questions
- Avoid leading questions

When styling the questions in the questionnaire, consideration was taken to the aforementioned points. Something we did not have to take into consideration was the use of everyday language, this since we distributed the questionnaire to a group of people all familiar with industry jargon.

### 3.5.3 Method of Analysis

Since all of our data gathered from the questionnaire is qualitative, any statistical analysis is non-relevant. Instead we will analyze the data in a similar manner as with the interviews. The answers will be summarized according to a coding; however we find that there is no need to transfer the answers to a matrix as we do with the interviews, this since the questionnaire in itself suffices for this job. Answers to the questions from different informants will be compared to each other as well as to data gathered in interviews. Completed surveys will be presented in Appendix F, and the results part covering the data from the questionnaire will be based on the unabridged answers from the questionnaires – the answers will however be translated from Swedish to English in the results section, and undergo spell checking.

### 3.6 Verifying

#### 3.6.1 Reliability

Often in experiments conducted within the natural sciences reliability refers to the ability to reproduce the results of the experiment; i.e. the consistency of the results (Kvale et. al. 2009). Reliability is also said to refer to the trustworthiness of the argument (Kvale et. al. 2009). In interview situations reliability concerns whether the informant will change his or hers answers, either during the interview or when being interviewed by a different interviewer or on a different occasion. There also exist issues of reliability when transcribing interviews, information might be lost wile transcribing. However when it comes to qualitative studies the concepts of reliability and validity are intertwined to such a degree that in some qualitative research the term reliability is not used instead the validity term is all-encompassing. (Patel et. al.).
3 Method

In this thesis there are some reliability issues to be dealt with. First it is important not to pose leading question, since they tend to influence the informants answer, because of this the questions posed have gone through a round of submission of content where our instructor have made comments.

The reliability concerning the trustworthiness of the study is mainly handled by having an extensive and detailed method chapter; this will enable the reader to make an enlightened assessment about how the study has been performed. Hence it is important to have a stringent method chapter so that the reader can easily track each step in the process of the study. The reliability of the trustworthiness is referred to as *communicative validity*, one way of working with the trustworthiness of the study is to have experts (such as our instructors) continually throughout the study give feedback regarding interpretations and conclusions; this process is to be carried out (Patel et. al. 2003).

3.6.2 Validity

The aim with a qualitative study is, briefly put, to investigate, analyze and draw conclusions in a specific area. The concept of validity is something that covers the whole of this process (Patel et. al. 2003). Validity as a concept deals with whether one actually investigates, or measures, and what one intends to investigate. Further Kvale et. al. (2009) states that "a valid argument is sound, well-grounded, justifiable, strong and convincing".

A difficult part in the process with regards to validity is that of transcribing the collected data. It is hard for the interviewer to catch the informer’s body language, occasional irony and the implicit message put forth, hence the message the informer want to transmit may be misread. One way to raise the validity during the interview, which is used in this study, is to carefully question the meaning of what has been said, and by that get feedback on the spot (Kvale et. al. 2009). To get a good validity of the collected data the researcher needs to be aware of and reflect over his or hers influence on the collected data (Patel et. al. 2003).

Another way used to increase the validity in this thesis was triangulation. Triangulation implicates that the researcher use different sources in the investigation, e.g. different informers (Patel et. al. 2003). Yet another way used to increase the validity in this thesis was to summarize the interviews and give the informants access to the information. The informers can then give feedback to the researchers and clarify misunderstandings that are made during
the transcription (Höst et al 2006). In this thesis only the latter of the two will be used, even though we interview different people holding the same position, it cannot be said to be enough for decent triangulation.

3.6.3 Generalizability

The definition of generalizability is (Kvale et. al. 2009):

"The extent that findings in one situation can be transferred to other situations".

It is considered possible to generalize the outcome from the interviews if the selection of the informers is made by a random selection of the population (Holme et. al. 1997).

In our case we interview a small group that is selected on behalf of their experience of interviews as well as their position within Skanska. Hence, the selection will not suffice in terms of being able to generalize the result. Even though the result cannot be generalized it will still provide an insight and a deeper understanding in how Skanska work with BIM presently.
4. Results

This chapter presents the results from the interviews and the questionnaire. The chapter consists of four parts: First the interviews conducted in Sweden, then two parts covering the two projects in USA and finally the result from the questionnaire answers collected in Sweden and. The result from the interviews is presented in this chapter in the form of compilations with regards to subject; to further accent the informers' standpoints regarding the subject quotations from the interviews are used. Quotes from interviews performed in Swedish have been translated, the original quotes in Swedish can be found in Appendix D. To make it easier for the reader to find the untranslated quotes in the appendix the authors have used brackets with numbers, e.g. [3], which refers to the third quote in the appendix.

The answers from the questionnaires are presented in the form of compilations with regards to subject.

4.1 Interviews in Sweden

The informants in Sweden came from the following projects:

- **Norra Länken 11 (NL11)**, part of an infrastructure project in Stockholm consisting of tunnels between Norrtull and Uppsalavägen E4/E20. The site is situated at the busiest intersection in Sweden, in an inner city environment. It is a bid-build contract worth 412 million SEK.

- **Norra Länken 52(NL 52)**, part of an infrastructure project in Stockholm consisting of tunnel, bridge and slip roads. The site is situated at the Värta-harbor, the main harbor in Stockholm. It is mainly a bid-build contract, worth 870 million SEK.

- **Lindhagensplan**, infrastructure project in Stockholm (tunnel/over-decking). It is a part of a design-bid-build contract with a total value of 420 million SEK.

- **Bromma Center**, it is a re-building project where an old hangar is rebuilt into a shopping mall. The contract is worth 700 million SEK.
4.1 INTERVIEWS IN SWEDEN

4.1.1 Work Planning

The general opinion is that there is not enough time spent on planning the projects, many feel that much of the deviations that occur during construction phase could have been avoided if more time was spent on planning. These are quotes from one Project Manager and one Skilled Worker:

"I would say that you can make the planning phase better, but the big problem is that there is often no time. Many out of our employees go from one project directly into the next one." [1]

"If you had an extra day to plan things in the construction phase, it would be less errors in respect to which materials you use. If something is missing when you’re on the site you will stand there with the machines and it costs money." [2]

4.1.1.1 During Construction Phase

There are many meetings held throughout a project, this is an extract of those:

- **Planning meeting**, held usually once a week. On a large project which is divided into blocks there will also be separate meetings for each block. In these meetings they discuss the activities that are planned for the next week. This facilitates, for example, the work of the surveyor’s assistants, e.g. they can find out if there are any special data that needs to be created until next week’s activities.

- **Coordination Meeting**, meetings are held once a week to coordinate the different activities between the contractor and the subcontractors. The meetings cover topics such as safety, schedule, risks, procurement, finance, coordination, and more administrative questions. At these meetings, all supervisors should participate.

- **Project management meeting**, a long-term meeting where the Production Manager, Project Manager and assistant Project Manager is present. The meeting includes a discussion of risks and opportunities of future activities.

- **Risk meeting**, held once a month. The meeting seeks to capture all the risks that arise from the activities to be made during the period and provide input so that each block can identify the various risks in their activities.
Here is a list of some tools that can be used to facilitate the construction phase:

- **Work preparations**, preparations are usually made at block level. Work preparations are made for an activity that have a risk of personal injury, or is a complex task where there is a risk of construction defects and thus may cause an increased cost. It is mainly Block Managers that coordinate the work with the work preparations. In big projects these managers often have experience as Production Managers or project managers. Foremen and skilled workers are also involved in working with the work preparations, they contribute mainly with their knowledge in terms of constructability and how the activities should be carried out. If a work preparation is very difficult the Production Manager will be involved in its development. There has to be a work preparation done on all activities that is included in the risk inventory.

- **Work orders**, the larger activities and those who have a working preparation will be planned with a work order. The work order indicates where the activity will be carried out, with what means and with which material. If a work order is planned properly there is no need to go around the construction site and look for materials and equipment that shall be used in the activity.

- **Visual planning**, in order to facilitate communication between different blocks and subcontractors one can make marks in drawings to illustrate where an activity shall take place. The drawings can be updated or replaced when the activities are constructed. Drawing content will be transmitted at coordination meetings between the blocks.

Regarding the design drawings route before reaching the construction site (the documents are approved and can be used in construction), a Production Manager said:

"From the time the designer makes the drawings, it can take two months before we have them on the construction site. The steps are in-house review (5 days), external review (1 month), and reception control (5 weeks)." [3]
4.1 INTERVIEWS IN SWEDEN

4.1.1.2 Time Planning

Based on the construction phase time plan an 8-week time plan will be formed, this time plan
serves as a governing planning tool. The 8-week time plan may differ significantly from the
construction phase time plan, mainly because there are often numerous changes in projects
exercised by the owner.

“It is difficult to get all employees interested in the construction phase time
plan; it is a huge job to get acquainted with the time plan. Our time plan
consists of thousands of activities and then there is no one who is willing to
get familiar with it.” [4]

Coordination between the blocks, which is facilitated by the 8-week time plan, aims to
determine which block should execute which activity, when the activity shall be executed and
where the activity shall take place. There is also special time plan meetings held, where
mainly the next month's activities will be treated. In special cases these meetings will treat
activities that are up to six months into the future, this depends on the task's complexity and
scale. The time plan meetings will result in a report showing which investigations should be
done for the specific activities, when the investigations should be ready and when the various
activities of the respective blocks will start. A Production Manager said:

"The planning and a construction phase time plan are some of the most
important tools to get a good financial result and efficiency in the projects
as well as a safe construction site." [5]

If you, in advance, can see a risk or a problem associated with an activity, which may lead to
a deviation, the Production Manager can plan what can be done if something goes wrong.
That is, he or she can make sure there are other activities to which one can relocate the
resources, this in attempt to minimize down time. The relocation of resources may increase
the costs, this partly because of the need of preparations made before the activities can even
start. However it is very difficult to document and render which factors that will be influenced
by the relocation of resources, e.g. which impact the deviation will have on future activities.
4 RESULTS

A Block Manager pointed out another problem and said:

“We have also received many changes, from the owner, after we have constructed things. This in turn results in extra work for us, we had to chop concrete, place new pipes and then pour new concrete. There will be a ‘changes and additional work’ (CAW), which will be billed separately. Although we get paid for it, the CAW will become a concern when we have to revise the time plan and postpone other activities.” [6]

4.1.1.3 Communications

For complex projects where activities will be carried out on various parts of the construction site at the same time, it might be difficult to sustain good communication between the various blocks and subcontractors, even though all activities are interdependent. This is unfortunate since good communication enables everyone to know what to do. One project was trying to solve this by visualizing the different stages of the project on floor plan drawings; they would sketch the activities that should be carried out at the same stages of the project on a drawing. One drawing would include for example work in progress, finished works and transport routes. One Skilled Worker frankly pointed out:

"It does not matter if you are the world's best carpenter, if you misunderstand one thing it will turn out very wrong!" [7]

Some of the informants suggested that the communication between the designers and the employees on the construction site was sometimes inadequate; this is quotes from a Production Manager and a Surveyor’s Manager:

“We have also had problems with the proposal documents on the concrete structure; we have been forced to change them several times. This may partly be because we have different views of the construction; we look at it from a construction phase perspective, the architect from an aesthetic perspective.” [8]

“On design-bid-build projects we have a closer cooperation and dialogue with the designer. This collaboration allows the construction work to run smoother compared to a bid-built project.” [9]
One Production Manager gave an example of a deviation that might occur due to the lack of, or quality of, communication between designers and employees in the construction phase:

"A classic deviation is the joint sealings; in a design-bid-build you have solved these problems before the designing documents are produced. While at a bid-build contract there is often a need to make deviations from the design documents, so called construction phase adjustments." [10]

### 4.1.2 Logistics

#### 4.1.2.1 Material Handling

If there is time before a project starts, you can spend resources to get an accurate time plan, if you have an accurate time plan you are able to connect it to a purchase plan. The purchase plan includes what material for the construction to buy and when, taking account among other things delivery time and the presence of a general agreement.

On one project visited in this study, they felt that there was some trouble with the material management, sometimes they lost things or placed objects of the same kind at different locations. As a result of this they sometimes had to search for things when they were about to use them. They also indicated that there had been some problems with the marking of materials. E.g. the supplier of reinforcement bars had not made requisite markings of the bars; hence some reinforcement bars were hard to track once they were to be installed.

A major concern on some projects, where they need to excavate a lot, is what to do with the masses. One Block Manager said:

"We are constantly trying to think where we are going place masses. As soon as we dig a pit, we make a decision whether we should haul away the masses or if we can recycle them on site." [11]
In one interview a Foreman called attention to fact that it is complicated to decide where to place the excavated masses, the informant said the following when talking about a previous project he had been on where they had been blasting mountain:

"On other projects where we were blasting mountain, and then crushed it on the construction site, we placed the masses on the construction site. This resulted in that we had to move the masses several times, even though we thought it was a good place to put them on in the beginning... It is good to have storage space outside the work area." [12]

### 4.1.2.2 Deliveries

The construction sites visited for this study are relatively big but they had small areas to store materials in on site. Because of this they all tried to order large parts, such as pipes or prefab elements, as close to installation as possible.

On one of the projects visited they had planned where the deliveries would enter the construction site, the Production Manager on that site said:

"On the PSD-plan, we will mark up the various construction entrances, and then distribute the plan to the suppliers so they know to what construction entrance they will deliver the goods. On the drawing, it shall also be designated where suppliers will have to wait before they get access to the construction site. We have a guy that can open the gates into the construction site via his cell phone." [13]

In one interview when talking about the difficulty with logistics in terms of delivery times a Block Manager said:

"It is pretty difficult to plan the deliveries because they (suppliers) find it hard to keep the deliveries on time. Then you have to call and nag. This is one of the main points; get the logistics, in terms of materials, to arrive at the right time." [14]
4.1 INTERVIEWS IN SWEDEN

4.1.3 Deviations

4.1.3.1 Designing Documents

During the interviews many informants commented that the design documents varied a great deal in quality, some of the informants put it quite bluntly:

"Generally, it is quite often errors in the drawings." [15]

"The plumbing and mechanical documents are subpar; there is not a pipe that is correctly placed in the drawings, more or less." [16]

"I think we should be able to require that the designing documents should be good enough to use on the construction site, it is not our job to be examiners on-site, our job is to construct it!" [17]

Further a Production Manager pointed out his view on the development of drawings:

"I have not been around for so long, but they say that the drawings are not getting better and that is strange, given that we get better and better tools" [18]

Another common topic during the interviews when discussing design documents was the difference between the two major business models: design-bid-build and bid-build. The general idea was that with a design-bid-build the design phase took more into consideration how the structure was to be constructed. Here follows a selection of quotes from different parts of the project management team:

“Design documents in a bid-build contract are not made solely so that we can construct according to them; they might be made to work in contractual terms.” [19]

"Often there is much less difference between the design documents and the as-built documents when you have a design-bid-build project, in which contractors, who will construct the structure, have been involved in the design phase from early on." [20]
"My experience of construction documents is that in a bid-build contract they have a relatively lower-quality in the documentation compared to a design-bid-build contract. The documents at a bid-build contract is not as thought out, they have no real idea of how we do the construction work ... Sometimes it is obvious mistakes, like when we received a document in which a pipe was placed through a pile group. As a result, we had to excavate 3 meters in the middle of a pile group, when they instead could have put the pipe next to the pile group and still have received adequate function." [21]

### 4.1.3.2 Deviation Handling

One Block Manager explained that to have good deviations handling one needs to see the deviations in the documents, and this is not always so easy. It is usually the Surveyor’s Assistants that have the greatest insight and knowledge when it comes to reading the drawings; furthermore they are the first to receive the drawings and are therefore also the ones that spot the most errors in the drawings.

According to a Project Manager there is sometimes a tendency in design-bid-build contracts to handle over tricky parts of the design, from the design phase into the construction phase, through so-called ‘resolve on site’, ROS.

Under an interview a Block Manager said:

> “As a rule; large deviations are detected in advance. It is not the case that the construction is in progress when you notice the large deviations. The deviations that are detected when the construction is in progress are usually small. Hence it is unusual with standstills.” [22]

If a minor deviation occurs during the construction phase with regards to the design documents (e.g. a tree cannot be planted as planned since it stands on top of a loom), often the designer, owner, or construction project management can give a quick answer as how to solve the problem. The solution is then entered into a diary or in a deviation report, a Foreman said:

> “Many of the deviations can be resolved on the construction site and then written down in the diary. For most of the deviations there is no need to create new design documents.” [23]
If a major deviation occurs in the construction phase in relation to the design documents, the deviation handling process will go through the following steps:

- The Foreman writes, with the project engineer, a deviation report. The deviation report contains information of what the problem is.

- The Project Engineer documents the deviation.

- The Block Manager takes note of the deviation.

- There will be a discussion with the survey block regarding the deviations effects on the as-built documents. A surveyor’s assistant then modifies the drawings with regards to the deviation and adds information about how the problem was solved in the deviation report.

It is of great importance to get a decision regarding a deviation in writing, e.g. via e-mail. This since it is difficult to know who, what and when someone said something if you do not have it on paper.

### 4.1.3.3 Different Versions of Drawings

When it comes to managing the drawings, it is of great important to have distinct roles so that there is always someone who is responsible for the revised drawings; it is usually the survey block that have this responsibility. The arrival of a revised drawing can be summarized in the following steps:

- The person who is responsible for the drawings will receive the revised drawing.

- The drawing will be stamped with the arrival date, sorted and the old drawings on the gallows are replaced. The old drawings are then destroyed, except for one version of the old drawings that will be saved, this to make it possible to follow the changes that have been made.

- The drawings are then distributed to relevant stakeholders.

One challenge when it comes to the handling of drawings is to ensure that the skilled workers always have the latest revision of the drawings. This since the skilled workers does not go into the drawing room to ensure that they have the most recent version of the drawing. The
RESULTS

Responsibility for making sure that the skilled workers has the most current drawings falls most often on the Foreman.

When drawings arrive late at it might result in that the preparation of some activity, which should have been done before the construction work starts, is not possible to perform. In the long run this makes the work environment stressful. E.g. one project visited in this study got their drawings very close to the construction, this required employees to perform intensive studies of the geometry on the various parts fast - this made the employees stressed.

4.1.4 Expectations of BIM in the Construction Phase

During the interviews, a discussion was held with the informants regarding their expectations of BIM in the construction phase. The information that we collected is summarized in the following list:

- Easier to read drawings, such as telecommunications drawings in which a single line in reality can consist of lots of cables which have a large sprawl.

- When laying complicated looms the model can possibly show approximately where the existing looms are located.

- To be able visualize certain activities one Production Manager said:

  “Now we will pour concrete here and because of that we should have a transport route there, this means you cannot drive there, etc.” [24]

- With regards to work planning, such as work orders, you can better plan in what order the tasks will be performed to optimize the construction phase, or to see which activities will clash with each other. Further a BIM could simplify communication regarding the construction phase time plan, e.g. one Production Manager said:

  “It is difficult to get all employees interested in the construction phase time plan; it is a huge job to get acquainted with the time plan. Our time plan consists of thousands of activities and then there is no one who is willing to get familiar with it.” [25]

- More extensive use of machine-guidance, to use for excavations and digging pipe-trenches.
A 3D-model would facilitate the work for the Surveyor’s Assistant, a Block Manager said:

"Now we will receive a flat drawing and a Surveyor’s Assistant will sit down and make sections of all parts of the road with the correct elevations, this work will be much easier if you use more 3-D design." [26]

Better quantity take-offs, to be able to store information about excavation and filling via the machine-guidance model and through that better plan what to do with the masses.
4 RESULTS

4.2 Croton Filtration Plant

Croton Water Filtration Project is a water treatment plant placed in Woodlawn, New York City. The plant is placed on a golf course and when the construction is finished it will be covered with grass and there will be a driving range on top of it. The project is a lump-sum project and Skansa’s part is worth 1.4 billion USD. The plant is the first of its kind with its high-tech installations which include an Ultraviolet Light Disinfection System. Water will be pumped up from the lowest to the highest level of the plant and thereafter gravity will be used to let the water run through the different cleaning processes. When complete, the plant will treat 1.1 million cubic meters of water a day, which corresponds to 20 % of the water consumption in New York City. During this project a BIM model was created to primarily tie the activity schedule, including dates, to the concrete and mechanical work in the model thus making it 4D-model.

Figure 4.1 View of the construction site in June 2009 from the southwest corner, picture from project presentation at Croton Filtration Plant.

4.2.1 Working process

4.2.1.1 Creating the Model

Croton first received a 3D-rendering in CAD, dwg-files, from the owner. The model was broken down into quadrants of the plant; while the construction phase time plan is broken down into smaller parts. They transferred the model to Skansa Teknik in Sweden via a FTP-server; they in turn sent the files to a company in India, SCUP. SCUP broke down the objects into smaller parts which correspond to the activity schedule. The new 3D-models were then
uploaded into a FTP-server where Croton could download them. When Croton had the new 3D-model they exported an nwd-file from AutoCAD and then import these files into a master file in Navisworks. The activity schedule, created in Primavera, was them imported into Navisworks. When the schedule was imported to Navisworks they were able to link the activities from Primavera to the elements in the drawing-files. The linking process is the most time-consuming due to the amount of activities in this project. Once the activities, including the specific dates, are linked to the elements you are able to simulate the construction process. Now you have a 4D-model.

The model contains information from the HVAC, plumbing, mechanical and structural contractor but the electrical contractor has none of his information in there. The reason that the electrical contract drawings is not in the model is that the contractor was late with submitting his drawings.

4.2.1.2 Work Planning

Croton has used the 4D-model to ease the communication between Project Managers and Production Managers / Foremen regarding whether the activities is running on schedule or not. Of course this is possible without a 4D-model by handing the Production Manager / Foremen a print of a p3-primavera file. But if the Production Manager / Foremen are not accustomed to activity descriptions, date classifications, relationships, etcetera someone needs to explain everything for him. According to one Project Manager this may take a couple of hours. Further the Production Manager / Foremen will question the input to figure out why he is behind the schedule.

The data in a 4D-model is more user-friendly, which will ease the communication. By using the 4D-model to visualize the working process you will make it easier for the Production Manager/Foremen to see where he is running behind schedule and which impact it will have on future activities.

Furthermore the model allows employees at the Croton construction site to sit down and analyze all the positions of the actuators for example and match them to the information that the manufactures gives them. E.g. there are different options on how to install the valves and the model gives the opportunity to more easily optimize the installation angle of the valves.
4 RESULTS

4.2.1.3 Time Planning

The 4D-model only contained information regarding the work that was part of Skanska’s contract, e.g. structural and mechanical plumbing. Further Skanska has their own activity schedule and the other contractors have theirs. Since the activity schedules are not tied together the model cannot be used as a tool when it comes to coordinating with regards to time. With this in mind we would like to quote a Production Manager responsible for the coordination between Skanska, subcontractors and other contractors:

“The coordination occurs basically on a communication level not so much from the schedule or computer model, it would certainly be better if it would.”

4.2.1.4 Skanska’s Use of the Model

Construction Site

On the Croton construction site there are posters showing different aspects of the job in 3D. These visualizations have got a good response from the employees; they are used to see 2D-drawings in black and white. According to a foreman the model has been a very helpful tool when it comes to see what they are going to build, more from an informative standpoint than a building standpoint. The model has been used more in detail in some tricky parts of the project. E.g. where it was very difficult to get a picture of what they were going to build when the information was in 2D-drawings.

Coordination

When it comes to coordination between Skanska, subcontractors and other contractors the model has been used to get a preliminary view of what they are up against. For example where they had to install double wall containment pipes as well as HVAC duct work and drain lines which was crammed into a little spot. By looking at the model they could see what it would look like so they at least could plan how they should get the double wall containment pipe in to the structure.

Planning

The model can be used as a visualization tool. A Project Engineer told us that some employees don’t get involved in either 2D-drawings or the 4D-model they just get the equipment and do their work, e.g. installation of valves. But if the Project Engineer shows them the model on the screen or at least a snapshot from the model the employees get a very
good visual of their work, how big some of the installation part is, which parts that will be
ingstalled later on, parts where they need to be very accurate so there won’t be problems with
the maintenance of the installation.

The model is also a good tool when it comes to communication with subcontractors. For
example one of the subcontractors designed a valve which did not fit a pipe support. When
the Project Engineer talked to the subcontractor on the phone about this problem he could
send the subcontractor a snapshot from the model illustrating the problem. Since the model
includes the actual valve, not just a symbol as in a 2D-drawing, as well as the pipe support the
subcontractor can get a good visual of the situation and this makes it easier for him to
understand the problem.

When it comes to working with the model in the production phase compared to work with
2D-drawings we would like to quote a Project Engineer who said:

“The model makes you a time saver, because you make fewer mistakes. You
make parts that you are going to assemble in the field and it makes you
think ahead. It is a time saver; big time.”

Early stage
When it comes to a project as big as Croton Filtration Plant there is hard to figure out what is
going to be built if the only information you have is in the 2D-drawings. This is why we
would like to quote a Project Manager at Croton:

“If it is too hard to figure out how to construct with 2D-drawings you are
going to create a 3D-model which will help you to understand the
complexity of the job. Necessity is the mother of all inventions. E.g. in this
job the estimators built a scale model of the plant just to visualize it. If we
had the BIM-model it would have helped immensely. Now that we have the
4D-model we don’t look at the old model because we have it
electronically.”
4 RESULTS

4.2.2 Logistics

According to a Project Manager at Croton the model has been very helpful in making early decisions, or changes, which needs to make the project more profitable or safer. The model enables you to see the project from many different perspectives in a short time, not just one or two. One example where Croton used this is when they decided where to place the tower cranes; these cranes couldn’t be placed too far out from the structure due to their reach, capacity and limited space of the construction site. They looked at the model to see where the cranes would be placed. Some of the criteria that they considered were the capability to dismantle during demobilization, not being in the way of other prime construction work, and swing radii of other cranes that will be utilized in the project. A quote from a Project Manager regarding the placement of the cranes:

“If we wouldn’t use the model we would have to make copies of drawings on transparent paper and superimpose these drawings to visualize different scenarios. We would have come up with the same decision but it would have taken much longer. Using the model we were able to make the decision within half a day instead of several days.”

4.2.3 Deviations

4.2.3.1 Deviation Handling

The solving of deviations at Croton is usually done the old fashioned way, each contractor puts together their own drawing and then the drawings are brought to Skanska’s office. They put all the layers together and check it for hits.

According to a Production Manager the most hits in the project has been with electrical. The plumbing has also been a little of a problem since the design has been changed substantially (from the owner) during the project. Fortunately the plumbing contractor have updated their drawings accordingly.

A quote from a Project Engineer regarding the use of the model when it comes to changes in Skanska’s part of the project.

“A lot of times the design changes during the project, the model helps us to drastically minimize the human errors on site due to the ability to analyze the geometry more precisely.”
4.2.3.2 Skanska’s Use of the Model

The model can be used as a communication tool at meetings. It enables you to implement the changes live during meetings and thereby you are able to visualize the effects from changes made by some designer. For example you can see that the change is going to affect a specific valve, or if you e.g. move a pipe you will have to move the equipments that are attached to the pipe and there may clashes occur.

One other part where the model can be used is when you consider the future maintenance of the structure while designing. The model is a tool that makes it easier for you to make good decisions, e.g. when it comes to the layouts of the valves.

4.2.4 Problems and Benefits by Utilizing BIM

4.2.4.1 Problems

The development of a model

A major disadvantage regarding the coordination between the different contractors in the project is that the 4D-model was developed so late in the project; much of the design was already made. According to a Production Manager at Croton it would have been more beneficial if the model was created earlier on in the project. Another problem with the model is that it doesn’t have enough detailed to be used for the coordination between the different contractors.

A quote from a Production Manager regarding BIMs present status:

“I think the problem with BIM, at least at this point, is that it takes a lot of work and a lot of effort to build the model and put all the information together. And all the work with the model should be done before the project starts.”
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Initial Costs

This is what a Project Manager said regarding the cost:

“The software (Navisworks) cost us about $6,000 per license and then you need to upgrade the hardware. At the very least you would spend $100,000 to create a 4D-model which 15 people will use excluding costs for their initial training... There is no template software which you can plug in to a project and it gives you BIM. We need a lot of effort to create a BIM-model. We need to make an assessment whether it is worth it or not, such that large complex projects with big budgets vs. small simple projects with limited budgets will be one of the differentiation factors.”

4.2.4.2 Benefits

A quote from a Project Engineer regarding the use of BIM when it comes to coordination and planning:

“Also a lot of the coordination efforts will be resolved a head of people actually going to work it is going to be solved on paper... there is definitely savings to be found.”

The new generation with large computer experience will according to a Project Manager play an important role in the development of BIM, the Manager said among other things:

“For young very technological capable people, the learning period is almost nothing. Within a few weeks they are up and running.”

Visualization

A quote from a Foreman:

“Some people can look at 2D-drawings and see the building built in their mind, not everybody can do that and this where the visualization really helps.”
When it comes to communication and the use of a BIM-model in that aspect we would like to quote a Project Manager at Croton:

“Imagine someone trying to explain a problem to you and you can’t comprehend it, so he sketches it on the back of a napkin but it is too complex to visualize so you turn to a person sitting on the other side of the table. He has a laptop with BIM on it and says: -Here it is…Boom its right there.”
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4.3 The New Meadowlands Stadium

The New Meadowlands stadium is a large sports stadium with a capacity of 82500 spectators located in East Rutherford New Jersey, about 18 kilometers to the west of Manhattan. The stadium will primarily be used by the NFL teams the New York Jets and the New York Giants. These teams are also the owners of the project. The project itself is a Design-Build lump-sum project worth 1.6 billion USD and is executed by Skanska USA Building. The structure is of concrete and steel, they used 26000 tons of steel and roughly 3000 prefabricated parts of concrete. During this project a BIM model was created to primarily ease coordination and as a means to control the logistics of the 3000 prefabricated concrete elements.

Figure 4.2 The New Meadowlands Stadium from the Southeast corner,

4.3.1 Working process

4.3.1.1 Creating the Model

Skanska’’s structural engineers used Revit to model the steel structure. The structural model was then turned over to the steel fabricator, Skanska Koch, which used Tekla to create the steel structure. Koch returned a very accurate model (1/16 inch). The next step in creating the model was to combine all the fabrication models into sideline and end zone sections. Thereafter they handled over the model to SCUP in India, SCUP created a model out of the steel model and architectural drawings. This model serves as a base for the coordination models, i.e. parts of the model where the subcontractors have added their design, which will be created during the project.
The project was divided into 117 areas, i.e. 117 coordinated 3D-models needed to be created. The working process when it comes to coordinating each subcontractor’s model was developed during the project. The final working process was based on having one subcontractor working with the model at a time. This process gave Skanska a good way to control the designing progress; they only had to deal with one subcontractor a day instead of five subcontractors every day. In this process you will identify the subcontractor’s problem and resolve them before the next subcontractor starts to design their part. Every time you log in to the system and a new version of a file is uploaded there will be an alert, and if there is a major change the editor will back up this alert with an email where he describes the change.

The aim in this project was to turn over one area every other week. Each subcontractor got to work for two days with the area. The sheet contractor would go first (all he had to respect was the architectural elements and the steel), plumbing was next (had to respect the same thing as the sheet metal plus his work) this work process continues for the remaining subcontractors which are (in order of going into the model), mechanical, then fire protection, and last electric. On the final day Skanska gathered representatives from all the subcontractors to a meeting under one roof at the site. It was a VDC Manager who managed the model and scheduled the meetings; he loaded a projector and showed the coordinated model that contained all the subcontractor’s models. A VDC Model Manager explains:

“All our mechanical trades were submitting 3D-models to us, some companies had that capability in-house others had to hire outside help. Most of the models were pretty detailed; they contained a lot of information in terms of piece numbers, hangers and stuff like that. This information was benefitting us throughout the whole process; the more details like that the easier the job becomes.”

At the meeting all collisions that were still remaining (sometimes 100s) had to be solved. At the meetings the subcontractor’s representatives should be able to make design decisions that is they should be represented by a Project Manager or a high level detailer; someone who is liable. The last thing Skanska wanted was to have a representative from a subcontractor who could draw in 3D but cannot tell them if we can move a pipe up or down. There would also be a Project Manager from Skanska on these meetings who could make decisions when our subcontractors could not reach an agreement, that is which contractor that should move his
4 RESULTS

stuff so that there wouldn’t be a collision on the construction site. Sometimes a Production Manager from Skanska would sit in on the meetings to help with constructability issues.

At the end of these coordinating meetings the representatives from each subcontractor would have to sign off on drawings so they get finalized. Once the drawings are signed they can go out into the field and can be used as design documents in that area.

4.3.1.2 Information Flow

One of the things Skanska tried to do on this project was to make sure that everybody had access to a website where they could pick up the latest information. They didn’t have a specific entity that managed this process (that everybody had the latest information). Instead they used an alert system which informed the user about updates of information. A quote from a VDC Manager:

“The most important thing is that your subcontractors have the same information and everybody is on the same page. We don’t withhold any information; there is no reason why everyone should not have the same information as we. This openness with information served us very well because we had everybody on the same page, one subcontractor could not turn around and say ‘You didn’t tell me that’.

What Skanska expect from the subcontractors is that they update the 3D-model just as they would have made hand notes on a 2D-drawing; they are held responsible to the 3D-model they provide.

When the coordination meeting with the subcontractor, regarding a specific area, was finished Skanska brought in their Production Managers and Foremen to run through the construction sequence. The Production Managers and Foremen contribute with experience from construction and helped with constructability issues.
4.3.1.3 Skanska’s Use of the Model

Coordination

The model is basically used as a coordination tool between the owners, Skanska and their subcontractors. With a project of this size, with many subcontractors, tight schedule and two owners is it very important with good communication. This is where the 3D-model has been of great importance for the project, one Production Manager said:

“If the coordination work had been done in 2D it would have taken three times as long. We would never been able to get the project done in time...
When we talk about how layered our systems are, without the model you could maybe look at two drawings on top of each other because there are so many lines. But since we have six different subcontractors which have their own drawings it is almost impossible to overlay those. But in the model you can actually fly through the space and the program has collision control which you can tailor to fit your requirements.”

Construction Site

The model has also been used for structural work. E.g. when a Production Manager tried to figure out why there were slight variations or problems in some area, he can focus on some area in the model and it provides dimensions that can give you answer on where the deviation is, not always exact dimensions but it would lead you in the right direction.

On the construction site the model was used to ease the communication with the skilled workers. By taking snapshots from the model, e.g. on a foundation, they would be able to show the workers different parts in different colors which was a good complement to the 2D-drawings.
4 Results

It is important to make sure that the model is accurate; this means that deviations need to be recorded. The model should be as accurate as the as-built-drawings. This quote gives us a picture of what one VDC-Manager thinks about keeping the model up-to-date:

“It is important to update the model by getting feedback from the guys out on the field. This includes all the subcontractors and we don’t want changes to the plans because changes means that we have to go into the model and layout what the change was and how it will affect the project (and then alert the subcontractors about the change). Updating the model is just something you got to keep on top off, once that ball gets going you really got to go with it during the entire project.”

4.3.2 Logistics

The New Meadowlands Stadium, NMS, used radio frequency identification for their precast concrete elements. There were about 3,000 precast elements and each of them had a RFID-tag installed. Information on the element status was stored in a data base which was connected to the BIM-model. There were five different statuses for the element; manufactured, in transit, delivered, installed/erected, damaged or not. The representation of the element in the model depended on its status. E.g. if the element was delivered but not installed is would have blue color in the model but once it was installed it became grey. To optimize the model so it would not be so demanding to work with it only showed the present status of the elements. If the user for example wanted to know when a certain element was delivered once it had been installed he would have to look in the database.

The work with the database was outsourced to another company that pulled information from the Tekla model and tied it to a database. They then uploaded the database, which included RFID numbers for every element, to their server and tied their server information with information from the model.

This work made it possible for Skanska to track and see status of the precast elements via their RFID-tags. The status of the precast elements is updated automatically; the only thing they had to do is to scan the element with a RFID-scanner. As it is scanned the information is uploaded to a server and then the information is integrated to the model which now shows the status of the precast concrete element.
4.3 The New Meadowlands Stadium

It would have been possible for Skanska to have RFID-tracking on the steel structure as well; the reason why they didn’t use it on the steel structure was that they wanted to start using a model that was manageable.

This quote will clarify the use that a Production Manager (Superintendent) has had with the RFID:

“As a field Superintendent I wasn’t directly involved in the prefabrication of concrete. But when we had a problem with an element e.g. some time the element was fabricated but not delivered or even loaded on a truck. In these cases I looked in the model to check the status of the element and then I could take necessary action, e.g. call the fabricator and tell them to deliver the element as soon as possible. I think that this was a good way to keep track of stuff.”

4.3.3 Problems and Benefits by Utilizing BIM

4.3.3.1 Problems

BIM Is Time Consuming

The subcontractors felt that they did not have enough time to update the model due to the pace of the project; therefore the coordination between the subcontractors became a problem. This in turn resulted in many clashes, which had to be worked out during the coordination meetings. After a change was decided during a meeting it needed to be implemented in the model. However the people responsible for updating the model were already working on the next area and thus did not really have enough time to update the model with the change. The drawings that are issued on the construction site are created from the 3D-model, if the model is not updated the construction drawings are not updated either which will cause problems on the construction site.

Regarding time spent on modeling different parts one MEP Manager said:

“If you don’t have all the objects you have to create them. It would be very helpful if the manufacturers could create a 3D-model of every part that they sell, so we don’t need to model it ourselves.”
Regarding the detail of the model one Production Manager said:

“When it comes to deviations and changes, sometimes it takes so much longer to get something pulled out of design than it takes to build it. Aside from doing that actual task you will have to coordinate many things around that because you weren’t able to install that particular piece of work.”

Software and Expertise

A problem that occurred during the project was subcontractors that didn’t have in-house expertise of 3D-modeling. Instead they hired people from outside to help them, and they delivered a good product but they were often behind and not fully up to date with what was going on. This sometimes made their model inaccurate.

First Skanska only required the subcontractors to have the ‘Navisworks Freedom Viewer’, which is free. They then provided the subcontractor with nwd-files that showed all collisions between Skanska and the subcontractors. But later in the project Skanska found out that the subcontractors started to upload nothing more than their best guesses. This because they could not take measurements from the nwd-file, they could just visualize it. Since this didn’t work out very well Skanska finally required the subcontractors to purchase the Navisworks software and do collision control in-house before sending the model back to Skanska. This cut the number of collisions with almost 75 %.

Skanska allowed one of the subcontractors to use 2D-drawings for his coordination because that subcontractor had so many problems with embracing the modeling-process properly. This in turn was problematic when a change was made; the subcontractor took twice as long to turn around the new drawings.

The software that is used in the project could be more user-friendly, those who do not use the model on a daily basis find it hard to use.
4.3.3.2 Benefits

Regarding the increasing cost of modeling in 3D relative to 2D-drawings one MEP Manager asked rhetorically:

“If you do the process right it is all planned in advance... If it is one, two or three drafters but there are 30 guys working in the field in five or six different areas. If there is one conflict in each of the areas which takes two or three hours to solve, that is 60-90 man-hours, how many drafting hours does it take to save this lost time?”

Regarding the accuracy of the steel structure in this project compared to projects that does not utilize BIM a Production Manager said:

“I think the model is a definite plus for the steelwork, the pieces fit better together. “

One Production Manager said with regards to the use of the BIM-model in respects to the 2D-drawings:

“In this project we had so many piece drawings and erection drawings; sometimes you couldn’t be sure that you had the most up to date drawing. But the fabricator was very good at updating the model so you could go to the model with confidence and know you have the most current information there, but perhaps not on paper.”
4 Results

4.4 Questionnaire Regarding BIM in the Construction Phase

In this chapter results from the questionnaire are presented. The data is presented as it was received from the informants, the answers has however been translated - for complete untranslated answers please see Appendix F. The numbers preceding each answer represents an individual informant. The informants consist of: three Production Managers, one Design Phase Manager and two CAD Engineers. All informants did not answer all question, therefore there are fewer answers than informants one some questions.

4.4.1 Questions Regarding Previous Experience

Are you or have you been working on a construction site (in the construction phase) that uses some form of building information model (at least a 3D representation of the building)?

# 16 - Yes, in a tunnel project for the tunnels casing.

# 17 - No, I have not been in contact with BIM in the past.

# 18 - No, not in the past, but we are developing a BIM for our current project.

# 19 - Yes, at our current project.

What information was included in the model?

# 16 - Geometric data and a basis for machine guidance

# 18 - Will include geometric data, clash control and the construction phase time plan in the beginning

# 19 – Construction phase time plan, machine guidance, etc.

How has the model facilitated the work during the construction phase?

# 16 - Visualization, communication, avoid clashes in the design phase, and simplifying the execution.
4.4 Questionnaire Regarding BIM in the Construction Phase

# 18 - Do not know yet, but the purpose is visualization, clash detection, and logistics

**Which software has been used to create the model?**

# 16 - Do not know.

# 18 - Think it is Navisworks.

**Experience from the work with the model?**

# 16 - The model is not finished, so it has not yet been used in construction phase.

# 18 - None yet.

# 19 - During the ongoing work on the construction site we unfortunately have no experienced employees who can master planning software and the 3D-model. The work with the model must be done continuously in order to have any use of it in the daily work.

4.4.2 Questions Regarding Expectations on BIM

**What expectations do you have on building information models as an aid in the construction phase with regards to...**

... logistics?

#15 - Great expectations. There is great potential to use BIM models, for example optimize the use of workplace surfaces. However this requires a lot of the model and is not the first thing to be implemented by us.

# 16 - Complete PSD-plan in the model, in which the elevations are included, with that temporary roads and such can be planned with greater accuracy.

# 17 - Do not know.

# 18 - Be able to plan transportation roads, inform which roads are closed, blocked or busy and when.

#19 - Large.
4 Results

... coordination?

# 15 - Coordinating the models from various fields is basic, but it should be done during the
design phase and as little as possible during the construction phase. I see great potential in
utilizing BIM models to coordinate activities or work teams so that the interferences are kept
to a minimum. Although this requires a major effort in the design phase, there is a large
potential to save time and money.

# 16 - Connect the construction phase time plan to the model in order to avoid clashes in
various stages of projects.

# 17 - Do not know.

# 19 - Large.

... work planning?

# 15 - Great expectations. With BIM models large and complex projects have great
opportunity to improve the planning of time and work, thus saving time and ultimately
money. This in the short-term.

# 16 - Avoiding clashes and other deviations because the planning can be made more precise
and the various activities and components can be executed or manufactured in the correct
order.

# 17 - Do not know.

# 18 - Raising the level of coordination, excavations areas, limited working area. In particular,
optimizing the construction phase process; e.g. which is the best execution order?

# 19 - It (N.B. ‘the BIM model’) needs to be created earlier on to be able to spot interferences
between different activities.
4.4 Questionnaire Regarding BIM in the Construction Phase

... deviation?

# 15 - Great potential. But we have too little experience with the use of a BIM models in the construction phase in order to have something substantial to point to right now. Although I see great potential for such things, e.g. compare theoretical quantities to actual quantities and so on, and thus getting a good grip on different types of projects and some experience regarding different parameters (N.B. in Swedish ‘erfarenhestvärden) that influence the project costs.

# 16 - Do not know.

# 17 - Do not know.

# 18 - Well, it is not the highest priority.

# 19 - No.

... management of drawings?

# 15 - Easy to implement and it will provide good profits in the short term. We see enormous potential in the systematic use of model data for machine guidance and for the Surveyors’.

# 16 - A great help for the Surveyors’.

# 17 - Do not know.

# 18 - Well, it is not the highest priority.

... anything other than the above-mentioned areas?

# 19 - There is a great advantage when you show the 3D-model for employees.
4 RESULTS

What problems might occur when using building information models in the construction phase?

# 15 - Presently, there is too little knowledge of what BIM is and how it can be used to facilitate the construction phase. Another problem in the current situation is that the models that come from different engineering areas are more or less adapted for BIM. To be able to use the models in the best way they need to be designed in 3D, and to some extent they need to be adapted for the construction phase.

There are as of yet no concrete, good examples that show the actual benefits of using BIM. However, they are imminent, and then the demand for BIM models will explode, at least that is what we believe. Then the problem will rather be the lack of skilled designers, hence the demand from the projects will exceed the supply.

# 16 - To receive the model in time and to update the model during the projects.

# 17 - Do not know.

# 18 - Today's culture in the construction phase is far from this situation today. There is generally low computer experience.

People do not see all the advantages in the beginning of the projects; they do not think it is worthwhile.

# 19 - Complicated. This is a tool, but it solves no problems, unfortunately, we still need read drawings and documents.

# 20 - There is a problem to get the model from the design phase done in time. Currently, the construction phase often starts based on preliminary documentation or an advanced notice.

To succeed, you will probably have to start the modeling work earlier on (already in the tender-stage)
In which part of the construction phase do you think it is easiest to implement a building information model?

# 15 - Drawing Management. All other uses of the model are more or less demanding on how the model has been adapted for that specific use. After Drawing Management it is easiest to implement BIM in (in order of priority): work planning, coordination, time planning, and logistics management.

# 16 - Work planning

# 17 - Do not know.

# 18 - Work planning, time planning, and simple 3D visualization.

# 20 - At this moment I am working on a 4D-model in a project. The model contains temporary measures of reinforcement, reinforcement of the foundation and the foundation (for a bridge).

The model was developed as a support for planning of the project. Although I see other possible uses, e.g. PSD-plan, work preparations, clash control etcetera. From the 3D-models, that the 4D model is constituted of, we export data for surveyors and for machine guidance.
5 Analysis

This chapter comprises of a discussion and an analysis about the present status of BIM in the construction phase within Skanska Sweden and Skanska USA. The authors will try to emphasize on such points as how BIM has been implemented, what can be learned from the implementation process so far, and what problems and benefits that is derived from the implementation of BIM in the construction phase. The analysis is based on the authors own thoughts combined with material presented earlier on in the thesis.

5.1 The Construction Phase in Sweden

In this part of the analysis the construction phase in Sweden will be analyzed. The authors aim to clarify how the construction phase is executed; i.a. if some sort of BIM is in use, which other tools are used to facilitate the process, and how the interaction between these tools looks like?

5.1.1 Work Planning

Even though resources are devoted to plan and organize projects, the employees in the construction phase think that there is not enough time for planning. The question is whether today's planning is managed in the best and most rational way. As said, substantial resources are devoted to devise numerous plans, such as: the construction phase time plan, 8-week schedule, purchase plan, cost calculation, PSD plans, etc. Is there perhaps something that can be improved in terms of the work done on these plans? When plans are ready for construction, it is not certain that they are up-to-date; changes that have occurred after the planning might not have been implemented in the plans. It is not easy to see how things that happen during the construction phase will affect the project from a time perspective.

Meetings: During the construction phase of a project numerous meetings are held. The meetings are of different nature with different participants. The most important meetings from a construction phase perspective are the ones intended to, in some way, coordinate and communicate knowledge about when, where and by whom an activity will be performed. There are two meetings that deal with these issues to a large extent; these are coordination meetings between different contractors, and planning meetings for the construction phase.
During the coordination meetings, communication between the various contractors is very important. Communication can however prove to be difficult when entrepreneurs from different backgrounds have different levels of understanding and knowledge of the different disciplines. This places high demands on the clarity of communication and that you can get everyone to understand the problems raised at the meetings. Tools commonly used at these meetings are drawings and sketches where the problem is described.

An example of a problem with communication is the one where a contractor needs to move one of their pipes. To get the necessary input for the change the contractor needs to look at all the drawings that describe the space where the pipe will be installed. You might, for example, need to take into account the sprinkler system, ventilation, telephone lines and water pipes. In this situation it is very important to make sure that everyone understands what, where and how the change will be done, this in order to find a solution that works for every party. Once a solution is found, the drawings need to be updated as to be able to build according to them. Each of the contractors then goes to their respective office and updates their drawings. If the communication in any way failed and one of the contractors have not understood what to do, he or she will make a change that is different than the one that was decided at the meeting, and because of this a big or small problem might occur in the construction phase.

Since all entrepreneurs have mutually independent drawings, there is no natural link between them in the system. A change in one drawing does not imply that one understands how that change affects other components on other drawings. This means that to form an opinion about what should be built, one needs to look at several other different drawings and then try to form an opinion about what should be built. The information extracted from these drawings is not user-friendly; it is very difficult to comprehend the information for an untrained eye. Even if the person who designed a certain part understands what all the dashed and dotted lines represent, this does not mean that another designer who designs other parts will understand what the lines represent. In other words, the communication between both designers, and contractors, and also between the owner and construction management, is of the utmost importance. The use of a 3D model, where all parts of the structure are represented as well as the interaction between them, facilitates both the decision making from the owners perspective as well as the planning for the construction phase.
5 Analysis

The regular approach with 2D drawings is a very vulnerable one since it is very difficult for the different contractors to see what effect a particular change will have for themselves as well as for the other stakeholders in the project.

Work Preparation: A well-developed work preparation will hedge against risks, both of injury and financial risks, associated with a certain activity. But to make a work preparation for a risky activity one needs to identify the risky activities and this is not always easy since it requires a great understanding of the construction process. Being able to visualize the process in 4D or 5D would help to identify risks in the construction phase – see which parts of the construction are difficult with respects to their proximity to other work or shear physical size, as well as their cost to the project.

Work orders: Work orders are used when performing large activities and the activities that have a work preparation. From a work order it follows where the activity is to be executed, with which components, and which tools are needed. If an activity, which has a work order, is moved someone needs to make manual changes in the purchasing plan and machine plan leading to extra work. If you were to use a model when working with the work orders you could connect the work orders to the construction phase time plan as well as the project finances, this would ease the labor involved with changes in work orders.

Visual Planning: Certain kinds of visual planning is also used in the construction phase, for example at some projects they use different floor plans on which they draw up explanations as to which activities are to be executed, how, and by whom the task will be performed. The purpose of this is to facilitate communication and thus making sure everybody knows what the different contractors are supposed to do. This is a tool that is easy to use (all you need is a copy of a drawing and a pencil), and it increases the different contractors understanding of when, where, and how a certain task is to be executed.

Working with drawings is however time-consuming, you need to manually update these drawings if there occurs changes in the construction phase. Even if the drawings can convey an overview about where to build, there remains the problem of communicating what you are going to build, how it looks and what components it should consist of. By using a 3D model to visualize the different stages of the construction phase, you facilitate the communication and allow for the flow of information to become more user-friendly. When a model is updated with changes made during the construction phase, these changes will appear for everybody
who uses the model, and the impact of the change will become apparent more or less immediately. This means that the work of manually updating all the other drawings can be disregarded – you just refer the different contractors to the model.

**Time Planning:** At a large project, it is not uncommon with construction phase time plans that cover several thousand activities. A Production Manager said it is difficult to get all employees interested in the time plan when it is so vast. The 8-week schedule is a solution to this problem; it breaks down the large time plan into more manageable pieces. This schedule is an excerpt from the construction phase time plan. However a Block Manager said that there are major differences between the construction phase time plan and the 8-week schedule. This means that it takes a lot of work to ensure that the different schedules and plans are updated, and the changes made in the 8-week schedule are not always implemented in the construction phase time plan, which means that it becomes out of date. It is also the 8-week schedule that forms the basis of the coordination between the different contractors and disciplines.

On one of the projects visited during this study, a Block Manager said that they had received many change orders from the owner on activities they had already carried out according to valid documents. The occurrence of these events appears to be quite common in the construction industry, although the majority of these are changes and additional work commissioned before anything is built. There are numerous reasons for the many changes between the as-built documents and the inquiry documents or design documents. One possible scenario is that the owner, as well as many others, has difficulties to form a clear idea of what they have ordered when the information relating to the structure is divided into a large number of drawings and other documentation. These continually made changes presents a problem for the construction industry, it is very difficult, not to say impossible, to estimate the influence of these changes when planning the project in advance as well as it is difficult to see what impact a possible change could have on other activities (that themselves might be changed).

To control this problem projects need a very good planner who has a complete understanding of the construction phase time plan and is well versed with the activities that occur on the construction site. The planner needs this in order to sort out how the changes that will be made affect other activities and to which extent they are affected. When you receive changes which affect the construction phase time plan, the time plan needs to be updated and the
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purchase plan as well as the machine plan also needs to be updated. In the cases where these plans are not connected to each other there is a great deal of work that needs to be done by the planner. The project management and the owners’ needs to be able to make informed, rational decisions, and to be able to do this they need to know how changes will affect the construction process. Since the design phase often cuts it very close to the actual construction phase there is little time to analyze the effects of a change, and which way is the best way. Instead the solution is often based on the best guess they have. In this area there is definitely room for improvement in the future. If a model is used, to which you linked time plans and finances, you can see the impact on the construction phase time plan and the project finances of a change in real time. With this as an aid it becomes much easier to optimize the changes so that they have as little negative effect as possible on the time plan and finances.

Communication: Some informants believe that, in large projects where work is carried out at several places simultaneously by different contractors, it is difficult to maintain good communication between the various blocks and sub-contractors. The reason for wanting good communication is that you need to know where certain activities are executed and by whom. This to enable planning of your own work and make sure that your work does not hinder others. This applies to transportation routes, use of tools and machinery, or the use of warehouse space for example.

To overcome this problem one studied project used floor plans to map out the finished activities, activities in construction and transportation routes. This is a good way to easily convey information between various stakeholders in a project. However it requires pretty much manual work, these drawings must be outlined on the basis of some form of time plan and coordination between stakeholders is a prerequisite to construct a drawing with the required content.

During the interviews many informants gave expression to that the communication between designers and the construction phase is often poor, communication between these parties is virtually non-existent before the construction phase starts. This lack of communication leads to faulty documentation i.e. changes will have to be made during the construction phase, the reason for this can be, explained by a Production Manager:
"… This may partly be because we have different views of the construction; we look at it from a construction phase perspective, the architect from an aesthetic perspective." [8]

This opinion is reoccurring in our interviews, many employed in the construction phase feel that the designers have too little knowledge as how to build things. But on the other hand, the feedback to the designers is very rare, according to the interviews we have done. To overcome this, the communication must improve.

5.1.2 Logistics

In the case of logistics at the construction site, more or less all the informants are of the opinion that there are never enough laydown areas. The lack of laydown areas necessitates a need for timelines of deliveries, the planning of the laydown areas, and accuracy in the construction phase time plan and purchase plan. From the interviews, the authors have gathered that employees would like to have more time to plan and carry out more detailed construction phase time plans to which you can link a purchase plan. Generally speaking, one can probably say that there is never enough time to plan everything down to the smallest detail. And to plan everything down to the smallest detail would not be economically viable since there are far too many factors that can affect a construction project, and if you were to take into account all possible outcomes the process would become too lengthy and the produced material would be excessive.

All this leads to the conclusion that the problem perhaps ought to be tackled from another direction. One must, to a greater extent, be able to convey user-friendly information between the different parties of a construction project. Project employees ought to be able to plan, in a rational manner, where to place the temporary storage areas to avoid unnecessarily moving around materials and components at the construction site. It is very difficult for individuals to have such a comprehensive picture of the construction process, to keep track of activities that are to be performed several weeks into the future is difficult. Hence a BIM-model could serve as a tool when planning for storage areas, e.g. the BIM-model could be the basis for employees with the task of analyzing whether to haul away excavation masses or store them on site, this was one of the problems informants pointed out during the interviews. There is a need to be able to create a living document in which consideration to changes made in construction phase is taken in, and from that document be able to extract updated data.
regarding purchases, the required delivery times, storage areas and other questions regarding materials administration. This cannot be implemented in a trice; it requires a lot of work in order to obtain a working routine for this. This is where BIM gets into the picture, in a BIM-model you are able to plan laydown areas, temporary and more long-term ones, and see where it is possible to place certain materials and when the materials need to be installed in order to start building something on that temporary laydown area. Materials in the model can be made traceable so that it is possible to see that every necessary component is in place before a major activity. The model can ease the way deviations in the deliveries are managed, e.g. the model can contain the current status of certain elements (e.g. installed, delivered, not manufactured). The procedure of updating the status of such elements can be easily done with simple technology such as RFID or barcodes.

This must be done to simplify and streamline the work in the construction phase, so that there will not be situations similar to one in one of the studied projects, where the informants perceived that they had problems with the handling of materials - things were lost or often in the wrong place.

Even if a BIM-model could help in many ways, it does not help to stop all the delays from the suppliers. The problem with the need to call and nag on suppliers remains. However, one can with a BIM model, given the right data, easily find out whether a supplier has a item in stock, or if he sent it, etcetera.

5.1.3 Deviations

The deviations discussed in this chapter relate to construction projects of the type bid-build, this because the projects studied in Sweden has been of this nature. Deviations in relation to the design documents are perceived as common in the construction phase. However it is important to distinguish between the two main types of deviations:

Large deviations: these are deviations that cannot be solved out on the construction site; with these deviations there is a need to either get a decision from the owner or the designer. Large deviations are often of such a magnitude that they result in new design documents. These deviations are generally discovered before construction starts, and can thus be corrected before the shovel hits the dirt. Deviations can range from outright contradictions to more fundamental errors that are affecting the supporting structure. If this kind of deviation would
occur during the construction, it means that the work have to stop at that spot. Then if it is possible, the resources needs to be moved another activity, otherwise there will be downtime in construction with increased costs as a result.

**Small deviations:** these are deviations that usually can be solved directly on site or via a short chain of command to the project management or owner. Small deviations have an extent which makes it unnecessary to develop new design documents. However, these deviations need to be recorded in a diary. If this kind of deviation were to occur during the construction phase, a solution tends to be found within the next few hours so it is rare that these small deviations create costly construction stops. However these small deviations occur quite frequently so at an aggregate level they make up a larger deviation. One possible reason an informant indicated that small deviations did not create so much problems might be that these small deviations are so frequent that they are seen as normal.

Although most of the deviations are found before construction starts and thus do not make an impact on the construction phase, one should be able to expect that the design documents holds such a standard that they can be built after, a Block Manager noted:

"*Generally, it is quite often errors in the drawings.*" [15]

A Production Manager said that the quality of the documentation had not improved over the last 20 years. This strikes the authors as very odd, when moving from drawing by hand to drawing in CAD you would expect that the quality would increase. One reason might be that a potential increase in quality was evened out by an increase in the output of drawings from the designers.

Even if you're going to build exactly the same thing, the informants experience is that the documents will be of a higher quality in a design-bid-build endeavor.

One Block Manager said that one must be able to see the errors in the design documents in order to have a good deviations handling. However this feels like a shift of responsibility from the designers to the contractors and surveyors.
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Different Versions of Drawings: During the construction phase there is a need for procedures as for how to work with new and updated drawings. It is essential that the latest version of the drawing is the one used out on the construction site. However this can prove to be difficult since the revised or new design documents arrives very close to the start of construction in the designated area. Apparently the communication does not work as it should. The time it takes to get a new approved design document can take from a few days to a couple of weeks, depending on the extent of changes and who makes the changes.
5.2 Croton Filtration Plant

In this part of the analysis the authors will analyze the work process at the Croton site with regards to how they have implemented and used BIM in the construction phase. The problems and benefits that users of the model have experienced so far will be identified, discussed and analyzed.

5.2.1 Creating the model

The project management began to consider implementing a BIM model at the construction site when they got a 3D-model from the owners; the owners had in their turn gotten the model from the designers. However, this 3D-model was not suitable for the construction phase e.g. certain objects in the model was not broken into suitable parts, floors that were hundreds of square meters was not broken into casting orders etcetera. But the project management still chose to go ahead and try to develop a BIM-model with the 3D-model as a base, although they would have to heavily adapt this model that they got from the owners. It is not unlikely that they had chosen to make a model, even if the owners had not provided a 3D-model. The processing work of the BIM-model went through Skanska Teknik in Gothenburg to SCUP in India; this cooperation was perceived by the interviewees as successful.

The actual data transfer, both between the U.S. and India but also between the different software products had worked well. This is attributed to the fact that the employees on site was aware of the work required to manage and maintain a BIM-model. They had an employee who had the primary responsibility of caring for the model. There is much work needed to manage a 4D model: first, all the schedules and time plans needs to be incorporated, then the model needs to be updated according to changes made in the schedules and time plans, as well as changes in the actual structure. One of the reasons that the work with the model had gone well is regarded to be because the project had, more or less, a full-time employee to perform these tasks. Furthermore, it should also be mentioned that the impressions the authors got from the project management regarding BIM and their model was positive - this of course also plays a role when it comes to the success of the model. If employees get the impression from management that the work with the BIM-model is important, the work will become more serious. Working with the BIM-model must have the same status as any other important job – it is nothing you can do haphazardly, because then you lose almost all benefits. The model will become obsolete and no one can use it with confidence. But one should bear in
5 Analysis

mind, as was noted during the interviews, it takes a lot of work to create and maintain a BIM-model. One Production Manager said that there are no software programs or templates that you just plug your data into and it automagically generates a BIM-model.

Another issue that arose during discussions about how the model had been created was the issue of owners. The owners in this case, the DEP, is a conservative owner in the sense that they do not take chances and invest in new construction techniques. This is not surprising, the DEPs money is tax money and this makes them less prone to take on the risks associated with new production techniques. With their conservative stance they were not willing to pay for a BIM-model. Some informants speculated that if there had been another owner, who was willing to invest in a BIM-model the model had become much more detailed. Yet another reason why the model did not provide more details was that Skanska did not have all the contracts for the construction, e.g. the plumbing and electrical work was not performed by Skanska. The reason for this was a law which stipulated that small local companies needs to be employed by the owner to a certain extent. The fact that these companies were small meant that they did not always have knowledge and or the resources to manage a BIM-model. Some kind of gist of this is that a design-bid-build process facilitates the process of creating a model. This since with such a business model there is one single contractor who can manage all aspects of the model and make demands on its suppliers and subcontractors. Unfortunately, this was not possible in the Croton case because of meddling legislation. As the model did not contain information from all the sub-contractors it could not be used for the coordination work. Noteworthy is that the informants familiar with the coordination process had preferred a 3D coordination.
5.2.2 Work Planning

The model used in the construction phase at Croton Water Treatment Facility is, as mentioned before, a 4D model. A 4D model is by definition tied to some form time plan, thus making it an obvious planning tool.

One of the main uses of the model at Croton is planning and making work preparations for the installation of the large valves. The engineer responsible for the valves was extremely happy about how the model had worked out. He used it in deciding how the valves would be installed. This work is difficult since the spaces where the valves are to be installed are very tight and the valves must be installed in a way that enables the actuators that sit on them to function properly. He also has to make sure that maintenance work on the valves are made possible, service technicians must be able to access the valves to perform the maintenance work. If he had questions regarding whether a particular type of valve could be installed in a certain way, he just took a snapshot from the model and sent the picture to the suppliers of that valve, by doing this he managed to stave off the difficult and time consuming task of using words and 2D drawings to explain the complex geometries. That same aspect, to be able to visualize, the same engineer had great benefit from when he explained how some valves was to be installed. He was able to pick images from the model that showed how a valve was supposed to sit after the installation. This engineer’s earlier experience was that, because of the complexity of the valve installations the Skilled Workers sometimes had a hard time grasping the drawings, so when installing the valves they sometimes got it wrong – for example placing actuators at a faulty angle. This is a good example of how a BIM-model in an easy way helped the planning and execution of an activity.

Another area where the model was considered to have contributed much was the communication between Project Managers, Production Managers and Foremen. Using the model, one could easily show whether a certain work crew were behind schedule, they played up an animation showing how the work would progress during the next period of time – if somebody was behind schedule the objects they were suppose to construct turned red. Through the animation, it became more comprehensible to understand what impact the delay would have, this in comparison with trying to understand complex Gantt charts. This very point was noted by the project management: There are a lot of employees who have too little experience of reading the activity schedules; they cannot grasp the consequences of a delay by looking at a time plan. But if you show a simple animation which visualizes the construction
of a certain part things become much clearer, this means that the lapses in communication is reduced and that the Foreman may do what they do best, namely construct, instead of spending their time learning about and understanding different schedules and diagrams.

5.2.3 Use of the Model

Logistics

Regarding the use of the model to control the logistics one Project Manager said that the model had been helpful, again because it visualizes the structure as well and it visualizes the actual construction over time. To have this available in the model early helps to make early decisions that are good for the project. The example that shows this with most clarity is the work in determining where the cranes would be placed on the construction site. To ensure that the cranes could lift cargo everywhere on the construction site it was required that a few cranes were placed within the structure. Deciding where these were to be placed was a difficult task, they had to stand in places so they could reach the inner parts of the structure, but at the same time they could not stand in the way of important installations and transportation routes inside the structure. By looking at the model and really in detail study different places and how these places would change over time they could place the cranes in such a way so that the negative impact on other parts of the structure was minimized. In Figure 4.1 the reader can see how a crane is positioned in the middle of the construction site. However, this was the only way they used the model to analyses issues concerning logistics. People at the project thought the logistics had worked well, but with that said, it is not said that there are no other potential benefits in terms of logistics from additional use of the model. An example of something you could do without enormous effort is to add elevations and other types of data concerning the ground. By doing this they could do such things as to optimize the positions of crane lorries and laydown areas. For example one could analyze situations as: where should this material be stored so it can be reached by a particular crane at a given time and how will all this affect the other crane lorries and laydown areas. Via the model they could arrange the construction barracks in an optimized way, so that transport distances for Skilled Workers are minimized. As the design at croton is a pour-in-place consisting of nearly 180 000 cubic meters of concrete, there are many concrete trucks that comes and goes, and perhaps it is not always obvious which ways these trucks should take, what time they should arrive, and so on – however all this information can be entered into a BIM-model as activities, then the user of the model can get a picture of the traffic flow and plan it accordingly.
5.2 Croton Filtration Plant

Visualization

During the interviews, there was an advantage with BIM that came back again and again: visualization. From all parts of the project employees said that the fact that you can easily and quickly be able to grasp what might be built is very helpful. Although the model itself was not used for the coordination explicitly, they had still used the model at some coordination meetings; they used it at times to gain a better understanding of the characteristics of certain rooms and parts of the structure. The model could also be used, as mentioned earlier, outside on the construction site not just inside the construction barracks, the project management and engineers could take snapshots from the model that clarified some parts of the construction and gave those snapshots to the Foremen. These snapshots then helped the Foremen and Skilled Workers to decode the standard 2D drawings and get an understanding of what was going to be constructed. Below are a few photos that show how the model looks like in comparison with reality.

![Figure 5.1](image1.png) Comparison between reality and the BIM-model, the room in the picture is where the water is treated with UV light.

![Figure 5.2](image2.png) Comparison between reality and BIM-model, the picture shows the space where the water is taken into the filtration plant.

The reason visualization got so much attention is partly because the model did not contain that much other information, hence the informants could not point to so many other aspects of
models use. But the authors consider that the attention to the visualization is mostly due to the fact that it simplifies so much work. Of course, you can use standard 2D drawings and Gantt charts to get a grip on some parts and periods of a project, but in comparison with looking at a 3D-model or studying the animations you can generate from a BIM-model, the old way of working is much more time consuming. Instead of scrolling through five to ten drawings to understand some sections you just check out the model and more or less immediately get a picture of the section as well as an understanding of the geometry. Instead of getting acquainted with the Gantt charts and how various activities are related to each other, you can just playback a certain part of the construction phase and quickly form an opinion about what should be done in a given period.

Perceived Problems with Utilizing BIM

One problem with making a BIM-model is the major expenses associated with that work: software needs to be purchased; staff trained and often there is need for new hardware. Sometimes these costs burden the individual project and sometimes it is Skanska AB who takes on the cost. On larger projects, such costs could be taken on at a project level and they still probably would have positive ROI – i.e. if the project is large enough the outcome of the investment is likely to be positive. But for smaller projects, the authors feel, it is important that the costs associated with BIM are not left to the individual project to take on themselves, rather the cost should be taken by Skanska from a central fund. This procedure should be obvious given that the person being trained and the software it uses will participate in several projects and therefore the costs should burden of all the projects that has benefitted from the software and education equally. Further, if the goal is to implement BIM one needs to make sure that there is sufficient incentive for the projects to implement it, i.e. make it more profitable for the individual projects by providing funds for education and software.

One lesson they learned at Croton was to start the work with BIM earlier than they did. Creating a BIM-model earlier on could facilitate and deepen cooperation between the contractor and subcontractors, this because they are working in a common virtual reality - a common database. The coordination process would also get a more natural position during the construction process, subcontractors and other parties working in the BIM-model simply cannot leave out as much when it is drawn in 3D. Furthermore, the clash control can be automated with BIM software; this of course further eases the coordination work.
When talking about cooperation, the authors would like to ad that they think it would probably ease the construction process if the stakeholders during, at least, the design phase worked together under one roof. During the design phase there should also be representatives from the construction phase to contribute with their phase specific knowledge. To sit the project teams under one roof in this way is with Toyota language called that you sit in a 'War Room', all the necessary disciplines are combined in one command center. This cooperation should then be moved out to construction site if possible and necessary, i.e. when it is still much of the design work left when construction starts. This in order to maintain the feeling that everybody works in the same project towards a common goal, regardless of the phase of the construction process that an individual employee is in.
5.3 The New Meadowlands Stadium

In this part of the analysis the authors will analyze the work process at the new Meadowlands Stadium with regards to how they have implemented and used BIM in the construction phase. The problems and benefits that users of the model have experienced so far will be identified, discussed and analyzed.

5.3.1 Creating the Model

Skanska's Structural Engineers used Revit in the early stages to create a model of the steel structure. The model was then sent over to Skanska Koch, who is the Structural Steel Fabricator and Erector, they produced the final models of the steel structure by using Tekla. The models created were very accurate, this in turn made the reliability of the models high and the steel structure could be used as a point of reference for future work in the model. The different steel models were merged and formed a model that described the entire steel structure.

One problem in the project was that the architects only produced drawings in 2D. But with help from Skanska Teknik in Sweden they solved this problem by passing the steel model, consisting of the assembled models from Skanska Koch, and the architectural drawings to SCUP in India. Scup then made a model comprising both information from the 2D-drawings and 3D-model. This new model was then used as a base for the design of the stadium; the design was performed during the construction phase. The fact that a model could be developed despite the fact that different actors modeled in different software, shows that it is feasible to create a model even when different software is used.

Since this project is large and complex Skanska decided that they should design it in 117 areas. One reason why they divided the project into different areas was that it is easier to orient oneself in the model this way, because they know approximately where they are designing. Another reason is that a model that covers the entire project would be so large and contain so much data that it would demand enormous amounts of computing power.

Since the employees that were designing this project had not participated in prior projects that have used some kind of 3D-model, there were no standard procedures regarding how the work with the model ought to proceed. The work with the model was developed and refined during the project until they finally found a procedure that was adequate for the purpose.
From the beginning, it was not required that subcontractors had the full version of Navisworks, they only had to have the Navisworks Freedom Viewer. This procedure, however, led to that the subcontractors only did a sort of ‘best guess’ procedure as where to place their components. This since they did not have all the information about where the other subcontractors components really were. This approach resulted in many clashes between the contractors, which in turn led to very long coordination meetings which could last a whole day.

To solve the problem with the clashes, all of the subcontractors were forced to buy the full version of Naviswork and then Skanska only allowed one subcontractor to work with the model at a time. Consequently, the only thing the first subcontractor needed to avoid clashes with was the concrete structure and steel structure; they provided a model to Skanska, which did not have any clashes with the aforementioned structural components. The next subcontractor had to take into account the elements that the previous subcontractor had added to the model and, of course, the restrictions that the prior subcontractor had. The following subcontractors performed their work in the same way. This approach meant that Skanska could keep better track of how subcontractors performed their work, and it reduced the clashes between the contractors with approximately 75%. The remaining collisions that were in the model were solved during a coordination meeting; sometimes it could be up to 100 collisions that remained to be resolved during the coordination meeting. Since the design phase was close to the construction phase, the clashes remaining in the model had to be solved during the coordination meetings, therefore each subcontractor was required to attend with a employee who were able to make design changes. This approach enabled the coordination meetings to result in a document or a printout from the model, which describes the solution to the clashes, each representative from the subcontractors had to sign off on this printout, signing the printout meant that everyone agreed to the changes. The employees at Skanska who were involved in the design process thought that this final process of working with the model had worked very well.

However, there were some problems regarding the updating of the model with respect to the changes that was decided during the coordination meetings. The employees responsible for implementing the changes into the model were already working with the next area of the project when they received the changes from the coordination meeting. This in turn lead to that clashes solved in coordination meetings sometimes occurred in the construction phase.
because the changes from the coordination meeting were not implemented in the model. With this in mind one should, in future projects, try to develop a standard procedure for the work with the model and assure that all subcontractors makes the changes agreed upon during the coordination meetings. One solution to this problem is to establish a document including all the changes decided at the coordination meeting. A follow-up on this document ought to be done by the general contractor in due time before the construction starts, this to be able to send a reminder to the subcontractor who is late to his commitment. However, it is important to ensure that there is enough time for the subcontractor to update the model, this since the employee also should begin modeling the next area of the model. Naturally there would be better to increase the distance between the design phase and the construction phase so that there is enough time to implement the changes in the model.

The procedure of having one subcontractor work with the model at a time does not solve all problems. E.g. sometimes a subcontractor had to move a pipe that another subcontractor had placed in the model to make sure that his installation would fit. This is something that is very difficult to avoid, however, the 3D-model facilitated the communication between the subcontractors, and the good communication improved the understanding and therefore made it easier to find solutions to the problem. In cases where the subcontractors could not agree on who should move their parts in order to avoid clashes in the construction phase, Skanska had a Production Manager, who worked with the model and was familiar with the construction phase, whose job it was to prioritize and determine which of the contractors that would move his parts.

One difficulty that arises when there are many subcontractors on a project is that there are many models in circulation. It requires well thought out routines to get the logistics of the model to work properly. The project used a server where the contractors uploaded their latest updates of the model once they were finished with their work. Each time a user logged in to the server and there was a new version of any file a message was displayed. This could be backed up with an e-mail, which was sent to the contractors that was affected by the change. According to the employees who worked with the model this procedure worked well, there were no major problems that emanated from that any contractor had worked with an outdated version of the model.
5.3.2 Information Flow

To get the best possible result in this project, in terms of time and finances, Skanska chose to share all available information that they had with the subcontractors. This is, according to a VDC Manager, one of the most important things when it comes to getting a successful BIM project. If the general contractor or any subcontractor does not share all their information it will affect both the general contractor and the other subcontractors as well. This is because you do not have the opportunity to take all the facts into consideration when making a decision, this in turn leads to that the solution may not be the best, or it might lead to a redesign of the area because you find out that the new solution collides with another part in the structure which you have not taken into consideration when designing. If on the other hand, all contractors have access to the latest information it is not possible for anybody to say that they did not have the all information and therefore was not able make a design that suites everybody.

Another requirement that Skanska had on their subcontractors was that they would update the 3D-model, with information from the construction site, in the same way as they would with a 2D-drawing. The reason that Skanska wanted the subcontractors to add information about the changes made or clarifications in the form of text lines was to constantly keep the model as updated and accurate as possible. This in turn would facilitate the handover to the owner, since the model is as similar as possible to an as-build drawing. This procedure also gave legitimacy the model, since it was not subordinate to the 2D-drawings. This is an important part of making a BIM project successful, the project managers’ needs to clearly show that the model is important. This is because the model should not be a tool among others whose maintenance is not prioritized, if this happens, the model will become obsolete and employees involved in the project will not be able to use the model with confidence. Instead they will use the classic and proven tools and thereby the model will be phased out. After the coordination meetings when the documents, where the changes is implemented, was signed by the different contractors Skanska brought in a Production Manager and a Foreman to let them see the model and get a view of what would be constructed. They see the design from another point of view, and thus there is an opportunity to take advantage of their experience from the construction site and thereby decide in which order the construction phase ought to proceed. This highlights an important point that might not only refer to the construction phase, namely,
closer cooperation between the various stakeholders - a promotion of each other's skills to achieve the common goal; to deliver a good product to the owner.

5.3.3 Use of the Model

The model was used primarily to coordinate the work between Skanska and their subcontractors as well as to ease the communication with the owner. There are high demands on communication in a large and complex project such as this; moreover, the project has two owners. The project has also a very tight construction phase time plan. All this made it important that all stakeholders in the project fully understood what the owners wanted and how to construct it. Below are pictures showing the model in comparison with what is actually built.

![Figure 5.3 comparison between reality and model, is for a cut with very complex installations.](image1)

![Figure 5.4 comparison between reality and model, shows a picture of the south end zone from the east sideline.](image2)

A Production Manager who had many years experience in the construction industry and had also worked with models in projects prior to this, said that the project would have taken three times as long if you wanted to reach to the same goal by using 2D-coordination. Even if the informant is biased, and perhaps exaggerated in some extent, there are probably still reasons
why he did his statement, especially since he has participated in coordination meetings during the project in which the model has been used. The main reason, according to the informant, for the time savings in terms of both the design phase and the construction phase is that the project is so layered. Without a 3D-model, it would be possible to superimpose maybe two or three drawings on top of each other to get an idea of what to build. But in this project were there are six different subcontractors, each of them with their own drawings - to superimpose two or three drawings is not enough, this means that to coordinate with 2D-drawings would have been much more time consuming. But with the model where all parts and elements from all the subcontractors are implemented, it is possible to fly through the structure and thus be able to find clashes between the various contractors. Of course it is possible to form an opinion about what to construct by adding various sections where you draw in all parts and elements from all subcontractors, the main drawback with this is that you quickly will have to make many sections in order to explain complex installations. The different sections do not have links between each other, hence you have to implement the same change in a great number of drawings. This in itself is time consuming, but with a good structure there will not be any problem to make the necessary changes so that all plans are updated. However, there is a problem with having many drawings, with different revisions. The replacement of all drawings, both in the office and out on the construction site, will be both time consuming and there is a risk that all drawings will not be replaced. If you have a model which is constantly up-to-date, it is possible to look in the model and confirm that you have the latest version of the drawing.

Construction Site

The model has also been used on the construction site, e.g. when the Production Manager has been uncertain if some part has been constructed correctly, or wondered why the elevations of the precast concrete elements are not matching. Then they have been able to look into the model, where they could get approximate values of e.g. the elevation. This in turn made it possible to compare the reality with the model to get an idea of where the fault may be. Of course you can do the same thing by using 2D drawings that visualize sections from which it is possible to get approximate values of elevations and thereby get the same results. The difference between 2D-drawings and a 3D-model is that the model provides a more user-friendly representation of the structure; in addition, all sections are represented in a 3D-model which is an advantage when comparing with 2D-drawing, which sometimes does not cover
difficult sections in the structure. In the model, it is possible to walk around until you come to exactly the section you are interested in and then get the geometrical values that you are looking for.

The model has also been used in the construction phase, it has provided snapshots that have been used as a complement to the 2D-drawings at the construction site, the snapshots ease the communication on the construction site. The opportunity to go to the model and make close examinations on difficult sections, and then take a snapshot from the model in which various construction components are of different colors, gives a clear view and a more accurate picture of the 2D-sections.

An important aspect when utilizing BIM-models in a project is to ensure that the model is always up-to-date. The aim with the model ought to be that it is as accurate as an as-built-drawing. This demands that the employees on the construction site report the deviations from the construction phase so that they will be implemented in the model. This may be viewed as unnecessary and burdensome, but it is of utmost importance. This since it can be difficult to see which deviations that will affect future activities and thus increase the costs.

**Logistics**

By giving all the precast concrete elements an RFID-number they made it possible to integrate information regarding the elements in a database with the model. Skanska chose to have five different statuses on the elements; manufactured, in transit, delivered, installed / erected, damaged or not. All the work that was needed was to read the elements RFID-number with a RFID-scanner and note the status of the element. Once you have that information in the scanner you will upload it into the database, which in turn sent the information to the model where you then could see the actual status of the element. This was a tool for multiple purposes, Skanska could trace elements with the help of its status and then take appropriate action, and e.g. if they saw that a element they needed was manufactured but not in transit, they would just call the manufacturer and ask what the problem was. Skanska could also monitor progress, in terms of the prefabricated concrete elements, and see how many elements were installed, delivered, broken, and so on. The status reported in the model included only the current status, if you wanted to see the history of a prefabricated concrete element you would have to go to the database in order to collect that information. The reason
that Skanska chose to only show the current status in the model was to make the model as small as possible so that it would not be too demanding on the computer hardware.

However, there were a few problems with the use of individual RFID-numbers on the precast concrete elements. Since many elements were identical, which meant that they would fit in several different places, the employees on the construction site used the element that was easiest to reach and installed it in the place where they worked. This in turn led to that you had to edit model with regards to the numbers of the elements. In this case, it would probably have been better if the elements of the same type would have some kind of family number which would ease the modification in the model.

It would have been possible for Skanska to use the RFID-tags on the steel structure as well, the reason why they did not use RFID on the steel structure was that there was no one at the project that had used this technique before, hence that they wanted to have a manageable model that did not require unnecessary work during the construction phase. The steel structure was considered to be too large, i.e. there were too many parts, and not suitable to start with.

The technique with of using RFID-tags and storing information in a database has many advantages. Since the technology is both proven and cheap this makes it relatively easy to implement some form of tracking system in a model. RFID will also facilitate the construction phase since it is possible to see how far the installation of the elements has progressed, this can then be compared with the construction phase time plan in order to see if the construction phase is before or after the time plan. It is also possible to assess the progress, e.g. see how many elements that were installed during a week and compare it with previous experiences, and if there is an outlier in the statistics there may be reason to examine this anomaly closer.

The benefits of RFID-tags increases if one uses a model to which the construction phase time plan is connected, this means that you do not need to manually enter values to see if you are running before or after the time schedule; you will simply insert the status of the elements into the model and then you are able to simulate the progress and see whether you are on time or not. The next step in the utilization of the model is connecting project finances to the model, this will render it possible to check the revenues during a certain period of the project, that is, how much work has been completed and how much work that can be billed, and then compare it with the expenses to see how the project goes from a financial standpoint. This is
of course nothing new and unique to the BIM, the difference is that in pre-BIM projects you are forced to do a lot of manual work to be able to compare the income and expenses of the project; while in a BIM project you will have this information continuously. This makes BIM both time saving, since much of the work is managed directly by the model, and more accessible, since you can check the progress of the project more frequently in order to provide an early indication of whether the project costs exceed the revenues or not, this makes it possible to perform necessary actions quicker than in a pre-BIM project.

These are the obvious benefits of using RFID-tags or a similar technology, e.g. barcodes, as the use and understanding of these technologies increases so should also the benefits.
5.4 BIM in Sweden

In this part of the analysis the authors will identify the expectations of BIM in the construction phase and analyze their plausibility. An analysis as to the status of BIM in Sweden will also be carried out. The perceived problems with utilizing BIM will also be discussed and analyzed. The expectation of BIM from employees in Skanska Sweden varies a lot; one reason for this might be that the knowledge of BIM in is, in general, rather small. As we have seen in this thesis there is many parts of the construction industry that is in need of development, and this is where BIM might come in handy.

5.4.1 Experience of BIM

The experience of BIM in the construction phase within Skanska Sweden is small. As far as the authors are aware there are currently only one project were a model is in use during the actual construction phase, although there are a few other projects that will implement it in the near future.

The model in use at the construction site of the project that has implemented BIM in the construction phase contains the construction phase time plan as well as data for machine guidance among other things. However an informant at that project says that the experience from this work had not been good since they do not have any employees that can handle both the 3D model and the scheduling software, hence they cannot keep the model up-to-date. This stresses one important point; BIM is not easily implemented, for a model to be of use you must have personnel that can manage the model. This means that employees need education. Why educated personnel were not provided at this particular project did not appear in the answers given in the questionnaire. Perhaps there was a lapse in management, which stresses yet another important point; the project management needs to be dedicated to BIM. Otherwise the implementation work will be hard to carry out; they cannot pass all the work over to junior associates and continue working the old fashioned way themselves. It is the authors’ opinion that it is an awful waste to develop a model to be used in the construction phase but not making sure you have employees fit to manage it. Moreover informants in the US with BIM experience have pointed out the importance of always keeping the model updated and not letting this work slip behind, this since it only gets harder and harder to make use of the model if it is not updated; you need to get on top of the situation.
Apart from the project discussed above the authors have not come across any civil projects in Sweden where BIM is utilized in the construction phase. However, there are projects that will implement BIM in the near future, two of the questionnaire informants works at such projects. The authors’ impression is that the previous experience of BIM in the construction phase is small, but this comes as no surprise since the work with BIM is relatively new. But as mentioned above there are projects coming up that will utilize BIM. And the informants from such projects are mostly positive towards BIM and seem eager to start working with a BIM-model. The fact that they are positive towards implementing the technology is good, hopefully it means they are devoted to the implementation and will see to it that it is executed properly.

5.4.2 Expectations of BIM

5.4.2.1 Work Planning

The general opinion on where to start the BIM implementation within the construction phase is according to the questionnaire the work planning phase. When it comes to work planning the main expectation on BIM is that it should facilitate the planning of time and work. This is where the model is expected to give rise to the opportunity to make planning more accurate, i.e. you should be able to compare different execution orders or different ways to construct the structure in advance. This is a good example of what the BIM model can facilitate in the design phase or early in construction phase. However, this poses some demands on the model with respect to its content. In order to make a rational decision when it comes to comparing different ways to construct, both time and finances ought to be integrated into the model. This is to get a reliable outcome from the model, which depends on its input, without any manual calculations regarding the time and costs. Without this data the model does not facilitate decision-making to the extent that ought to be pursued.

The main expectation of BIM when it comes to facilitating the coordination in the construction phase is to minimize the clashes between the different stakeholders. When it comes to clashes between different contractors, this is not something that should be used as justification for the use of a BIM-model in a project towards the owner. Of course, the owner expects that the contractor will be able to coordinate the work so that no clashes, between the contractors, will occur in the construction phase. However, this is not this case; many projects are struggling with deviations, big and small, on the construction site. Some deviations might
occur because of the lack of communication between the contractors or that you do not give each other enough information to prevent collisions in the construction phase. This might partly be because that the construction industries focused on developing the drawing technique by using 2D-CAD, instead of modeling in 3D like some parts of the manufacturing industries did. CAD stands for ‘computer aided design’, but as of far the development of the drawing techniques has not lead to a significant increase of the quality in the designing documents, rather the development have reduced the time to produce a drawing. However, there are still similar errors in the drawings today as it was 20 years ago. During a lecture at KTH a lecturer was trying to explain a phenomenon by using a picture. The lecturer said:

"A picture says more than a thousand words, but you must not forget that this is reversible. Sometimes you need a thousand words to explain a picture."

This is something we believe is applicable to a 2D drawing in which every object is represented by lines. With this in mind, it might seem that CAD has not really met the expectations that the name suggests. By using a 3D-model in a project the communication between the contractors will be improved, since it is easier to explain a 3D object with a 3D-model than it is to explain a 3D object with a couple of 2D-drawings. By having a visual image of what is going to be constructed one can easier explain the difficulties and problems in the construction phase, thus increasing the understanding between the different stakeholders in a project.

The projects studied in the U.S. created their models after the tendering phase, this in turn leads to that the model was created very close to the construction phase and in some areas the designing of the model overlapped the work on the construction site. This is by no means optimal from a BIM perspective, the sooner you create the model the better it becomes in terms of coordination between contractors, planning of temporary structures and the ability to compare different construction options and thereby increasing the profitability of the project. Although the US projects were late with the development of their models they still found great benefits with the models in terms of coordination between the contractors. This may be seen as a transitional stage where projects work parallel with both designing in a model and in 2D drawings; this transition is similar to the transition between handmade-drawings and CAD drawings. This might lead to that the projects will become less and less dependent on 2D drawings as the time goes.
5 ANALYSIS

There is also an expectation that BIM can minimize the interference between different work teams on the construction site. This is of course possible when utilizing BIM in a project, but if you want to use the model in this manner, without making subjective judgments regarding the observations when simulating with the model, you need to have a rather advanced model with settings based on experience of how much space is required to accomplish a particular activity. Using the model in this way would not be easy or even possible before BIM Stage 3 or the Integrated Project Delivery is reached.

Drawings Handling:

Expectations of BIM when it comes to the drawing management are primarily the use of geometric information from the model that ought to facilitate the Surveyors’ work, there is also another interest in using the geometrical information and that is to use it as a basis for machine guidance. These expectations could be realized already in BIM Stage 1; to use the model for these purposes does not demand an advanced model with lots of data, the only information needed is the geometrical. This is also one of the areas of work that an informant believes to be on of the easiest areas to start the implementation of BIM in.

5.4.2.2 Logistics

As for logistics, most of the expectations of BIM in the construction phase is regarding temporary structures e.g. transportation roads, temporary roads and temporary excavation areas. The model is expected to facilitate the planning of these temporary structures. During the studies performed in the U.S., particular at the Croton Filtration Plant, there is a good example of how to use the model when making major decisions regarding temporary structures. The project had to place multiple cranes inside the structure; more details of the cranes are in section 5.2. The model provided information on the design and where various parts were to be installed. This information was accessible to all the decision makers, and with their knowledge the information was processed, the decision makers then made suggestions where the cranes would be placed, the different proposals were then discussed with their advantages and disadvantages. This process in turn eventually led to a decision regarding where the cranes ought to be placed.
The process that was applied on Croton is directly applicable to the Swedish expectations for BIM regarding the planning of temporary structures. However, the full potential of BIM is not used, in terms of planning of temporary roads, if you only have a 3D model representing the structure. The model ought to contain the construction phase time plan, which by definition makes it a 4D-model. By implementing the construction phase time plan in the model it is feasible to see where you can place temporary structures as to affect the construction phase as little as possible, but at the same time make sure that there is as close a distance as possible between the temporary road and the places on the construction site where the deliveries of the construction material will take place. Moreover, a 4D-model provide an opportunity to plan temporary storage spaces, e.g. masses from excavation or construction components, since you are able to simulate the construction process as to see where on the construction site no activity will be carried out in the near future. Of course it is possible to plan this sort of things without using a 4D-model but it demands a lot of work when taking account of hundreds of activities from a Gantt-schedule.

5.4.2.3 Expected Problems with BIM in the Construction Phase:

One problem revealed by an informant is the lack of knowledge in the construction phase of how to utilize BIM in projects, and how to use the model so that the model gives as much advantage as possible on the construction site. That the knowledge is relatively is supported by our study where the authors only found a few employees in Sweden with knowledge of BIM, we interviewed 8 people who worked in the construction phase and sent the questionnaire to 9 employees that, according to the information we received, would be able to answer questions on BIM in the construction phase. Possibly, this may be because the concept building information modeling, BIM, is not as widely spread at a construction sites. However, the authors tried to explain the concept and gave the informants room for questions if they did not understand.

The lack of knowledge regarding BIM in general and how to use it in particular is at the moment pretty apparent. If Skanska want to invest in BIM they should send clear signals to their employees regarding the potential use of it, for example by carrying out training for employees.
5 ANALYSIS

There also occur problems with creating a 3D-model when there are different models that are developed by various stakeholders that are more or less suited to be implemented in a BIM-model. This problem is believed to be caused by the use of different software by the different stakeholders in the project. To use BIM in a larger extent there ought to be decided which software to be used early on in the projects, and then stick to it. This will make the communication between the different software and different stakeholders run as smoothly as possible.

One informant also mentioned, in the questionnaire, that the current culture in the construction phase is far from BIM. There is also relatively low computer skills among a lot of the employees in the construction phase; this in turn can lead to that the advantages of utilizing BIM in the construction phase does not exceed the disadvantages of the pre-BIM construction process. One opinion from a Production Manager in the U.S. was that he believed that the new generation, who had greater computer skills, would have it easier to embrace new software, and that would play a major role in the development and the implementation of BIM in the design phase as well as in the construction phase. This is also the impression that the authors received during the work, the authors own opinion is that the young people in the U.S. had greater benefit from using the BIM-model relative to the older employees and that the young people in Sweden have been more positive about a change in the construction process and found more opportunities in the use of BIM relative to the older employees.

Another opinion from an informant, from the questionnaire, is that there is no example presently that shows the actual gains made in projects that have utilized BIM. This is a problem; however, this does not only the case for BIM projects. From the information received and analyzed, there is very few values of experience regarding specific activities carried out in construction phase. Because of this it is very difficult to evaluate which parts of the projects that have been executed in a satisfactory manner with regards to project finances. The executed activities can only be compared with their actual cost relative to their expected cost. This clearly makes it difficult to compare a BIM project with a common project as well as to compare traditional projects with each other.
6. Conclusions

_In this chapter conclusions made during the work with the thesis will be stated._

**6.1 Present Status of BIM within Skanska**

_One of the purposes with the thesis is to determine the position of BIM within Skanska Sweden and Skanska U.S. In this part of the conclusions we will present our conclusions as to which BIM stage the organizations have reached._

**6.1.1 Skanska Sweden**

Skanska Civil Sweden can be said to belong to the pre-BIM stage. This is based on the interviews and questionnaires performed by the authors in Sweden. None of the projects visited used BIM-models in the construction phase; their documentation was not linked to each other or to a 3D-model. However in two of the projects, NL 11 and NL 52, efforts were being made to change this, but at the time of the authors visit these efforts had not been implemented yet. The efforts being made in those two projects are:

- **NL11**, use a 3D-model in which contains geometrical data and will serve as a base for machine guidance. This effort will position the project in BIM Stage 1. Although it should be noted that the work with the 3D-model only covers a part of the project.
- **NL52**, are developing a 4D-model (construction phase time plan connected to a 3D-model) to be used for clash control, visualization and to plan logistics. This effort will position the project in BIM Stage 2.

One project in Sweden has actually tried to implement a BIM-model in the construction phase; however they did not have educated employees to handle the model.

Based on the study carried out in this thesis there appears to be a lack of knowledge when it comes to BIM in general and more specifically how to use BIM as a tool to facilitate the construction phase.
6 CONCLUSIONS

6.1.2 Skanska USA

Skanska Civil U.S. has come further in the implementation of BIM in the construction phase than Skanska Civil Sweden. This is simply based on the fact that there are projects in the U.S. that are using BIM-models in the construction phase but as stated in 6.1.1 this is not the case in Sweden. The readers should keep in mind that the authors only studied two projects in the U.S. and these projects were chosen because they utilized BIM and they were exceptionally big, hence these results cannot be generalized i.e. all civil projects in the U.S. do not utilize BIM.

The two projects that the authors studied in the U.S., Croton Filtration Plant and The New Meadowlands Stadium, both used BIM-models. The work with the model consists of:

- **Croton**, used a 4D-model for visualization, planning of installations as well as to plan some logistical solutions and to ease the communication between the Project Managers’, Production Managers’ and Foremen. These efforts position the project in BIM Stage 2.

- **Meadowlands**, used a 3D-model to coordinate the work between Skanska and their subcontractors and to visualize complex sections for the foremen via snapshots from the model. They also used the model as a tool for logistics; they traced precast concrete elements and kept track of their status via RFID-technology. This effort position the project somewhere between BIM Stage 2 and 3.

The work with BIM in the construction phase within Skanska U.S. is in its infancy. For many of the informants these projects were their first BIM projects, sometimes even their first project utilizing a 3D-model.
6.2 BIM Implementation in the Construction Phase

In this part of the conclusions the implementation process will be discussed; how have they implemented BIM in the U.S. and what lessons can be learned from their implementation. Through those standpoints the authors will give a list of what Skanska Civil Sweden ought to consider when implementing BIM in the construction phase.

6.2.1 Implementation Process

Both of the projects in the U.S. received a 3D-model from another stakeholder, at Croton Skanska got a 3D-model from the designer and at Meadowlands they got a 3D-model from the structural engineer. Those 3D-models formed the basis for the BIM-models used at the construction sites; the decision to make a BIM-model was made without the owners requiring it. Both BIM-models were developed with help from SCUP in India and Skanska Teknik in Sweden. To make use of the models in the construction phase many objects needed to be divided into smaller parts, this work was performed by SCUP. The software used, on site, to handle the model was Autodesk’s Navisworks in both projects.

Both projects had employees, on site, whose main work task was to keep the model up-to-date. These employees sat in on meetings where the model was used. Common for both of the projects was that the models served as a visualization tool which made communication between contractors and also communication between the Skanska employees much easier. Aside from this the individual projects had other uses of the model:

- **Croton**, since they chose to create a 4D-model they could use the model to communicate the construction phase time plan more easily, e.g. if a work crew is behind schedule their parts will turn red in the model as well as the other activities affected by that work crews delay.

- **Meadowlands**, since they had a very detailed model they could use it for coordination between the contractors. The coordination process was done one area at a time; the whole structure was divided into 117 areas. Coordination work was performed during two weeks per area, one subcontractor at a time was given two days to ad their design to the model given certain limitations. At the end of this coordination period there was a coordination meeting where the unsolved problems with the design were solved. At the coordination meetings each subcontractor was represented by someone who could
make design decisions. They also chose to use RFID-technology with the BIM-model as a mean to track status of the precast concrete elements.

6.2.2 Approach to BIM Implementation in Sweden

*During the study of the project in the U.S. the authors gathered knowledge about both the problems and benefits of utilizing BIM in the construction phase. This knowledge is in this part paired with the BIM theory acquired during the work with the thesis, and together they constitute the authors view as to what one should keep in mind when implementing BIM in the construction phase.*

The list below illustrates important pointers that contribute to the success of BIM-projects. Although one should keep in mind that most of these pointers also constitute a problem or a challenge, implementing BIM in the construction phase is costly and requires commitment from more or less all different stakeholders in the construction process.

- *Manageable BIM-model*, the model should not contain too much information and it ought to contain the right information for the project.
- *Devoted project management*, the work with the model needs support from the project management. It is important that they are aware of the benefits that comes with BIM and that they express that to their subordinates.
- *Educate employees*, make sure that there is enough knowledge to manage the model.
- *Manage the model*; make sure to have distinct and consistent routines for updating the model, and that the stakeholders working with the model are aware of the routines. With regards to this one should remember that there are not always distinct and consistent routines available since the work with BIM-models is new, often the way of finding these routines is through an iterative procedure.
- *Compatible software*, if the BIM-model is to be used for coordination work it is important that the software used by the different contractors is compatible and preferably the same software.
- *Start early*, the work with the BIM-model ought to start early in the design phase.
- *Start small*, the first projects should partly be seen as a learning process hence the scale of the implementation should be progressive.
6.3 The Potential with BIM in the Construction Phase

This part is based on theory as well as the study conducted in the U.S. It comprises of an account of how the expectations of BIM in Sweden relates to the results in this study. However it should be noted that it is the authors’ opinion that it is too early, or that the extent of this study is too limited, to draw any general conclusions about the potential of BIM in the construction phase.

Below is a table that shows the expectations on BIM in Sweden, experience of BIM in the U.S. and theory about the possibilities with BIM in the construction phase. Hence the table shows whether the expectations on BIM in the construction phase in Sweden is plausible.

<table>
<thead>
<tr>
<th>Expectation</th>
<th>Experience</th>
<th>Theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visualization, e.g. depict complex sections</td>
<td>Both projects used their model as a visualization tool; it has been very useful and appreciated according to all levels of employees.</td>
<td>In a BIM-project all complex sections ought to be designed in the design phase, i.e. there are no ‘resolve on site’ issues and there is no problem comprehending the geometry of the sections.</td>
</tr>
<tr>
<td>Coordination, e.g. clash detection</td>
<td>Has been used to a large extent at Meadowlands and to some extent at Croton. At Meadowlands they did all coordination including clash detection in the BIM-model, this worked out very well.</td>
<td>The coordination work is one of the corner stones’ when utilizing BIM; it is an apparent advantage of BIM. Different disciplines working in a common model forces the design to improve.</td>
</tr>
<tr>
<td>Logistics, e.g. handling the flow of materials</td>
<td>At Meadowlands they used the model together with RFID-technology to create a database to keep track of the precast concrete elements.</td>
<td>A 4-D model may comprehend information about expected time and space flow of trades on the construction site. This in turn enables planers to see potential bottlenecks.</td>
</tr>
</tbody>
</table>
### 6 Conclusions

| Temporary structures, e.g. roads, excavations | At Croton they used the model to analyze the placement of the cranes. | A 4D-model can be used to include temporary construction components such as accommodation roads and laydown areas. |
| Work planning, e.g. execution orders | At Croton they used the model for work preparations as well as visualizing project progress as a tool for future planning. They also used their 4D-model to decide when certain large components could and ought to be installed. At Meadowlands they used the model in the coordination work when deciding in which order the contractors ought to install their components. | The contractor is able to continually add data to a 4D-model, this in turn leads to that, for example, he or she can be able to see the construction progress. The planer can with the assistance of the model visualize different phases in the construction. This can be communicated to the construction site work crews but also to other stakeholders in the project. It will also be possible to use the model to visualize how a complex activity ought to be executed. |
| Handling of drawings, e.g. machine guidance, help for the surveyors’ | At Croton the model was not detailed enough to extract drawings from. At Meadowlands the model was updated and detailed to such a degree that it could be used with confidence when there were questions about the 2D-drawings. | If a BIM-model contains the entire structure in the form of objects with dimensions, position, properties and specifications, drawings can be generated using a BIM tool; arbitrary sections of the 3D model can be transformed to 2D drawings. |
7. Recommendation on Future Work

*During the work with this thesis the authors have encountered several interesting subjects relating to BIM, however they have not fallen within the framework of this thesis and because of this the authors chose to present these questions and topics here as recommendations for future research.*

- The impact of the business model on the efforts of developing a BIM model. The business models that could be studied with respect to this are bid-build, design-bid-build, partnering and private public partnership.

- Possibilities of linking FEA software to the BIM model to ease the design process.

- Use the BIM model in the pre-bid quantity take-off. BIM software is able to make quantity take-offs and rough cost estimates on the fly, hence it can be of great use in the tendering stage.

- Use of a BIM model as a tool for experience feedback – by logging data (such as work hours, machine use etcetera) as to how different projects or even activities progresses one can build a database of experience values. This database can then be used to control and monitor processes in other projects.

- Try to establish at what project size it makes financial sense to create a BIM without financial support from the owner - given that the project itself will carry the cost for education, software etcetera.

- The opportunities of creating libraries of components to use when constructing, and trying to use the components in the libraries to as high a degree that is possible. This as a means to get scale economy effects via extensive use of prefabrication.
References

Books:


REFERENCES

Articles


Seminaries

Betongfeber, *Betongprojektering och byggnade med BIM, ”Planning of Concrete Structures and Constructing with BIM”*, Stockholm, 2009-11-18

Reports


Information from Internet

# Oral Sources

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## References

### Questionnaire Informants

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Appendix [57 pages]

Content:
A  Interview Matrices and Guide [8 pages]................................................................. A-1
B  Appendix – Questionnaire and Cover Letter [3 pages]........................................... B-1
C  Interview Responses Sweden [15 pages]................................................................. C-1
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F  Untranslated Questionnaire Responses [7 pages].................................................... F-1
A Interview Matrices and Guide [8 pages]

Content:

- Support Matrix, Sweden
- Support Matrix, USA
- Interview Guide
**A INTERVIEW MATRICES AND GUIDE [8 PAGES]**

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<td>q) Information i modellen</td>
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<td>o) Tidsplanering</td>
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<td>e) Skillnad mot förr</td>
<td>j) Hur hanteras problem/avvikler</td>
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Interview Guide - informers without previous experience of BIM

Context
Förklaring varför informanten är närvarande:

- Vi presenterar oss
- Skriver vårt examensarbete på KTH som behandlar utvecklingen av byggprocessen inom produktionsskedet, med fokus på avvikelsehantering och logistik.
- Varför vi vill intervjuar just informanten; du tillhör en av två grupper vi valt att intervjuar, vi ska sedan jämföra era svar för att försöka dra slutsatser kring nuvarande arbetssituation.
- Vi/Skanska är inte intresserade av enskilda svar, utan är intresserade av helhetsbilden som lämnas, visa exempel på hur utformningen av matris/personuppgifter utformas
- Intervjun kommer att spelas in, de enda som har kommer ha tillgång till ljudupptagningen är Erik och Andreas. Vi kan dock komma att citera dig i vårt arbete såtillvida du inte vill det.
- Informanten får återkoppling om de vill; de kan få ljudupptagningen, anteckningar vi gjort under intervjun, deras del i intervjumatrisen.
- Det vore bra om de ville återkoppla då detta ger oss möjlighet att verifiera data.
- Några frågor innan vi startar?

Introductory Questions

Personlig bakgrund
- Namn:
- Ålder:
- Utbildningar:
- Nuvarande arbetsuppgift:

Tidigare arbetslivserfarenhet
- Beskriv i korthet din nuvarande arbetsplats
- Tidigare arbetsuppgifter
- Tidigare arbetsgivare
Main Questions

Ta reda på | Våra frågor
--- | ---
I den här kolumnen finns de frågor vi vill ha svar på under intervjuerna. Dessa frågor bygger på frågorna vi ställer i syftet. | I den här kolumnen finns de frågor vilka vi kommer ställa under intervjun. Vi översätter våra tematiska frågor till öppna lättförstådda frågor, se gärna 3.3.6.1 Phrasing Questions.

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<td>Hur börjar en vanlig dag?</td>
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<td>Hur planerar ni arbetet på arbetsplatsen?</td>
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<td>Hur fungerar arbetet med arbetsberedningar?</td>
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<td>Hur var det förr?</td>
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<td>Vem är ansvarig för vilken del när det gäller logistik på arbetsplatsen?</td>
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<td>Hurdan är kommunikationen i sådana fall?</td>
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<td>- materialflöden</td>
<td>Hur var det förr?</td>
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<td>- skillnad mot förut</td>
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<tr>
<th>Hur ser kunsakpen om BIM ut och arbetsplats situationen i framtiden? mht</th>
<th>Har du några åsikter kring hur handlingarna (ritningar, riskdokumentation, tidplan) är utformade?</th>
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<td>Hur var det förr?</td>
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**Summary**

Förklara vad vi snappat upp från intervjun - vad vi fann intressant. Tillåt informanten att tillägga något om denne känner att det behövs.
B Appendix – Questionnaire and Cover Letter [3 pages]

Hej (namn på informant)

Vi är två stycken KTH-studenter som för tillfället skriver vårt examensarbete på Skanska. Examensarbetet berör byggnadsinformationsmodellering (BIM) i produktionsskedet inom anläggningsområdet, vår fokus ligger på hur BIM-modellering kan påverka arbetet med logistik och avvikelsehantering på arbetsplatsen. Hittills har vi intervjuat 20 personer med olika befattningar inom produktionsskedet. Intervjuerna har skett dels här i Sverige för att få en uppfattning om hur produktionsarbetet ser ut samt för att bildas oss en uppfattning om BIMs ställning i Sverige, och dels i USA för att ta reda på hur verktyget har använts i produktionen där.

Anledningen till att vi kontaktat dig är för att vi gärna vill ha dina åsikter om BIM - dels eventuella erfarenheter, men även dina förväntningar på BIM i produktionen. Med hjälp av dina svar på den här enkäten så kommer vi kunna jämföra hur bilden av BIM i produktionen i Sverige överensstämmer med vad litteraturen har att berätta samt med resultaten från vår USA-studie. Att besvara enkäten är givetvis frivilligt, men dina svar utgör en oerhört viktig del i vårt examensarbete.

Enkäten är bifogad i detta e-mail och förutsatt att du väljer att besvara enkäten så gör du som följer:

- Spara enkäten lokalt på din dator
- Öppna enkäten i MS Word
- Svara på frågorna! Det finns ingen begränsning vad gäller antalet svarsträngar.
- Spara enkäten
- Maila den sparade och ifyllda enkäten till någon av oss (våra mailadresser finner du längst ner i detta brev)
- Klar!

Vi har förståelse för att ni säkert har väldigt mycket att göra men vi skulle ändå uppskatta om ni kunde besvara enkäten så fort som möjligt – helst innan 17e februari. Till de som svarar på enkäten inom den utsatta tiden (17e februari 2010) så väntar en belöning i form av två stycken biobiljetter!

Om ni har några frågor så tveka inte med att kontakta någon av oss!

Kontakttuppgifter:
Andreas Winberg
email
mobilnummer

Erik Dahlqvist
email
mobilnummer

Med vänliga hälsningar
Andreas och Erik
Enkätundersökning angående BIM i produktionsfasen

----------------------------------------
Namn:

Jobbtitel:

Ansvarsområde:

----------------------------------------

FRÅGA 1. Jobbar du eller har du jobbat på en byggarbetsplats (ute i produktionen) som nyttjat någon form av byggnadsinformationsmodell (ätminstone en 3D representation av byggnaden)?

Om svaret är nej på denna fråga hoppa till fråga 2

FRÅGA 1a. Vilken information ingick i modellen?
Geometriska data, tidplan, kalkylering, maskinstyrning etc.

FRÅGA 1b. På vilket sätt har modellen underlättat arbetet i produktionsskedet?
Visualisering, kommunikation, avvikelsehantering, koordinering, logistik etc.

FRÅGA 1c. Hur är modellen uppbyggd?
Mjukvara (Tekla, Revit, Navisworks)

FRÅGA 1d. Erfarenheter från arbetet med modellen?
Vad har gått bra, mindre bra i arbetet med modellen, vilka erfarenheter tar du med dig från arbetet
FRÅGA 2. Vilka förväntningar har du på byggnadsinformationsmodeller som hjälpmedel i produktionen med hänsyn till...

...logistik?
...koordinering?
...arbetsplanering?
...avvikelsehantering?
...ritningshantering (snabb tillgång till senaste informationen i modellen, måttavtagning)?
...någonting annat än ovannämnda områden?

FRÅGA 3. Vilka problem tror du finns med användningen av byggnadsinformationsmodeller i produktionen?

FRÅGA 4. I vilken del av produktionen tror du det är enklast att börja använda en byggnadsinformationsmodell?
Arbetsplanering, koordinering, logistikhantering, tidplanering, ritningshantering etc.
C Interview Responses Sweden [15 pages]

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### Informant #1

På fredagar har blocken samordningsmöte och där förbereds nästkommande veckans aktiviteter, revidering av 8-veckors tidplanen (vilken är baserad på ½ års produktionstidplanen) sker också under dessa möten. Denna information förmedlas på gruppmötena på måndagarna.

"Vi försöker hela tiden tänka på vart vi ska göra av massorna, så fort vi gräver en grop tar vi beslut om vi ska köra bort det eller om vi kan köra det inom området."

Arbetsberedningar görs för arbeten som har risk för personskador och komplicerade arbeten där det finns en risk att man bygger fel och därmed får en ökad kostnad.


Sedan har vi andra risker som vi jobbar med mer kontinuerligt.

"Det är stökigt här, vi har inga upplagsytor nästan"

Det blir billigare att köra bort schaktmassor på en gång istället för att flytta runt dem på plats.

Vi har en byggnadslastbil som kör material inom området som kör det dagliga och om det blir mycket så har vi möjlighet att ta in en till.

**Kommentar:**

Ang byggnadslastbil så har vi tre timbilar på plats men tar in flera leveransbilar efter behov.

Stora byggeelement, t.ex. stödmurar förser vi inte ta hit föres det är dags att ställa dem.

Så fort vi bara vet att ett datum är spiktig så ropar vi av leveransen, vi beställer sakerna bara att vi håller på leveranserna. Ibland får vi köpa material från leverantörerna fast de inte har levererat det.

**Kommentar:**

Ang inköpt material som inte är levererat så är det bara i undantagsfall som leverantör får fakturera innan leverans. Exempelvis om vi är sena på någon bygghandel som dom har fått leveransdatum på. Då kan det vara ekonomiskt tungt för dom att lagerhålla obetalda varor.

Att ha en ansvarig för inleverans och mottagningskontroll underlättar mycket för arbetsledarna som

Så fort det blir en minsta avvikelse som överskridet våra toleranser ska vi först och främst meddela beställaren och sedan skriva en avvikelserapport. Avvikelsen ska också skrivas in i dagboken och att beställaren godkänner det. Detta är viktigt inför slutbesiktningen så att de slipper ta det som en punkt.

Generellt sett så är det ganska ofta fel på ritningarna.

"VA-handlingarna är under all kritik, det finns inte ett rör som stämmer i princip."

Vi har även fått in mycket ändringar efter vi byggt saker och ting och fått göra om, bilatt betong och lagt nya rör. Detta blir arbetena som faktureras separat. Trots att vi får betalt så blir det ett orosmoment då vi måste revidera tidplanen och skjuta på andra arbeten.

Vår projektingenjör är teknisk kunnig och söter och granskar handlingarna väljigt noga innan han beställer byggmaterialet, i denna process upptäcks många utav felen i projekteringar.

m) På vår arbetsplats tar mättekniker tar hand om alla revideringar som kommer och för in dem rätt och arkiverar samt makulerar ritningar.

Man får se till att ha tydliga roller för att det alltid ska finnas någon som har kött på de reviderade ritningarna. Detta fallen ofta på någon mättekniker.

Det gäller att se till att gubbarna hela tiden har de senaste revisionerna av ritningarna eftersom de inte går in i ritningsrummet för att se till att de har den senaste revisionen. Detta jobb faller...
**Kommentar:**
Ang arbetsberedningarna så är även yrkesarbetare ofta med och tar fram dom inte bara granskar.
Det är svårt att planera långt fram i tiden, 8-veckorstådplanen skiljer sig mot 1½ års tidplanen. Det beror främst på att det är så mycket ändringar i arbetet.
8-veckorsplaneringen är det styrande planeringsverktyget, med planeringen undviker man att ”trampa varandra på tärna”
Om vägverket vill ändra utformningen av bygget så skickar de ett PM med en underrättelse.
Arbetsberedningar finns på vårt interna nätverk, beställaren som godkänt beredningen har en kopia. När det blir aktuellt så skriver jag ut en kopia till gubbarna som de får ta del av.
slipper jaga grejer hela dagarna.
Vi kan inte lagra så mycket på grund av bristande upplagsytor, vissa rördelar kan vi lagra men när det kommer till krossprodukter så får vi köpa dem. Detsamma gäller för de schaktmassor vi har, de får vi köra bort.
Angående stödmurar under f): Det är ganskan svårt att planera eftersom de har svårt att hålla leveranstiderna. Då får man ringa upp och tjata. ”Detta är en av de största punkterna att få logistiken när det gäller material i rätt tid.”
Det underlättar att ha en ansvarig för materia, leverantören ringar honom och han berättar var grejerna ska vara och sedan ringer gubbarna som ska ha grejerna till honom och då berättar han vart grejerna finns så slipper gubbarna leta.
Det svåra med logistiken är att man vill att varorna ska komma så det inte blir stillstånd samtidigt som man inte vill ha varorna liggande under en längre tid.
Vi har en YA som är lite av en ”föräder”, han har hand om de inkommande leveranserna. Han är vår kontaktperson gentemot leverantörerna och han gör mottagningskontroller på allt som kommer så att det är rätt saker, detta främst på arbetstredaren
Återkopplingstiden beror i stor utsträckning på hur stor avvikelsen är, det kan gå på ett par dagar eller så kan det ta månader.
Ofta brukar vi få ganska snabba svar från bygglåning men till att den kommer ut som en bygghandling tar ofta lång tid. Det är lite synd att ritningen dröjer men om inte bygglåningen ger svar snabbt så blir kan det bli stillestånd.
”Om det ska komma en ändring till exempel vecka 47 så kan man ge sig på att den kommer vecka 48... byggskated ligger väldigt tight mot projektering”
De små ändringarna som löses på plats uppdateras aldrig på ritningarna utan de kommer med i relationshandlingarna.
Konstruktörerna får sällan återkoppling på dessa små ändringar.
De som har hand om betongprojekteringarna är de väldigt sena och ligger hack i hål på de som utför arbetet och det kan bli en del väntetider på nya uppdateringar av ritningarna.

**Kommentar:**
Ang projekteringaren så ligger dom sent mycket pga att vi lyckats korta ner den utsatta byggtiden för projektet, detta medför att även projektörer måste ligga fäste.
Angående VA-handlingarna
”Det blir väll inte en korrekt handling förens relationshandlingen ritas”
Det är en hel del jobb med att göra relationshandlingar, de överensstämmer ofta
|   | gör han någon gång per dag. | ganska bra men man måste ändå mäta in varenda skarv och dragningen fast det stämmer ganska bra överens med ritningarna. |   |
Informant #2  
De olika blocken har egna möten där de går igenom och detaljplanerar de uppgifter som ska utföras under kommande veckan.

"Klassiskt" produktionsmöten varje vecka där man tar upp arbetsmiljö, tidplan, risken, inköp, ekonomi, ÅTA, samordning och mycket annat administrativt.

Arbetsberedningar görs på blocknivå. Blockcheferna har stor erfarenhet och är produktionschefer.

De arbetsberedningar som är väldigt besvärliga tittar även produktionschefen på.

Långsiktigt så har vi även möten med projektledningen där produktionsschef, projekttchef och biträdande projekttchef närvarar. Diskuterar risker och möjligheter.

Riskmöten en gång i månaden där man försöker fånga upp alla risker och ge input så att varje block ser de olika riskena.

Tidplanemöten där vi tar upp närmsta månaden framför allt (och upp till ett halvår) Mötet resulterar i ett protokoll där det står vilka utredningar som ska göras, när de ska vara klara och när de olika starterna för respektive aktiviteter finns med. Detta gör att varje block vet när de kan börja sitt arbete.

Dagliga inköp sköts av en föräckskille. Transportbilen kommer till honom och han tar hand om mottagningen.

På APD-planen kommer vi märka upp de olika bygginfarterna och sedan dela ut ritningen till leverantörerna så de vet till vilken bygginfant de ska leverera varorna. På ritningen skall det även vara anvisat var leverantörerna ska stå och vända innan de får tillträde till arbetsplatsen. Förrådschefen öppnar grändorna in till arbetsplatsen via sin mobiltelefon.


De stora leveranserna går ut direkt till arbetsplatsen där materialet ska användas, det finns ett större upplag där vi kan läggja upp saker om vi behöver.

På blockmötena tar man upp var man vill ha sina upplag för arbetet som ska bedrivas under veckan. För att få en blick av vart upplagen är så

Avvikelse på en aktivitet gentemot handlingen:
- Arbetsledaren tillsammans med projektinjenören skriver en avvikelserapport
- Projektinjenören dokumenterar avvikelsen
- Blockchefen tar del av avvikelsen
- Diskussion till mätblocket om avvikelsen påverkar relationshandlingarna. De ritar in avvikelsen på ritningen.


Min erfarenhet av bygghandlingar i en generalentreprenad är att de har en lägre kvalitet relativt handlingar i en totalentreprenad. Handlingarna i en generalentreprenad är inte lika igenomtänkta, de har inte koll på hur vi ska utföra arbetet. Det kan ibland vara uppenbara fel, som när vi fick en handling där en ledning var placerad genom en pålgrupp. Detta ledde till att vi var tvungna att schakta 3 meter i en pålgrupp när man kunde placera ledningen bredvid pålgruppen men ändå fått en fullgod funktion.

“Planeringen och en tidplan är några av de viktigaste styrmedlen för att få en bra ekonomi och effektivitet på jobben samt en säker arbetsplats.”

Det är svårt att få alla intresserade av tidplanen, det är ett jättejobb att sätta sig in i tidplanen. Vår tidplan består av tusentals aktiviteter och då är det ingen som orkar ta tag i det.

Visualiseringen som BIM medför är nog det jag tror att jag har mest nytta av. T.ex. logistik, nu ska vi giuta här och då ska man ha en transportväg där, man kan inte köra där o.s.v.

Han har en del bra grejer som man kan fördjupa sig i fortsättningen.
Vid komplexa projekt där vi kommer jobba på olika byggdelar samtidigt och alla dessa är beroende av varandra, så är kommunikationen svår. Vi försöker lösa detta genom att visualisera olika skeden på planritningar, vilka aktiviteter som genomförs vid de olika skedena. Visualiseringen omfattar pågående arbeten, färdiga arbeten och transportvägar.
Vi har även olika APD-planer för olika intervall.

| Handlingarna (generalentreprenad) är inte gjorda så att man kan bygga efter dem, de är kanske gjorda så att de kan funka kontraktsmässigt.  
Vi har även haft mycket problem med förslagshandlingar, förslagshandlingarna på betongkonstruktionen har vi varit tvungna att ändra på många ställen. Detta kan till viss del bero på att vi har olika syn på bygget. En klassisk avvikelse är gjutfogar, i en totalentreprenad har du rett ut problemet redan innan handlingarna tas fram medan man i en generalentreprenad ofta får göra större eller mindre avvikelser från handlingarna.  
Bygghandlingens väg innan den når bygget (handlingen är godkänd och kan användas i produktionen):  
Från att konstruktionen gjort handlingen är det två månader innan vi har den i produktionen. Stegen är internremiss (5 dagar), extern remiss ”vägverket” (1 månad), granskning (3 veckor).  
Arbetet med relationshandlingar kan bli omfattande om ändringarna inte införs kontinuerligt.  
"Jag har inte varit med så länge men de säger att ritningarna blir inte bättre och det är konstigt med tanke på att vi får bättre och bättre hjälpmedel" |

| Vid man in dessa på APD-planen. Vi har mycket material som måste förvaras, som ska tillbaka sen, det kör vi bort till det stora upplaget som är en bit bort. Leveranserna ska stå på ”vänt” på anvisad plats. De har fått en tid då de ska leverera, de ringer en tid innan de levererar, de ringer när de har kommit till vänt-platsen och sedan får vi lotsa in dem.  
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Från att konstruktionen gjort handlingen är det två månader innan vi har den i produktionen. Stegen är internremiss (5 dagar), extern remiss ”vägverket” (1 månad), granskning (3 veckor).  
Arbetet med relationshandlingar kan bli omfattande om ändringarna inte införs kontinuerligt.  
"Jag har inte varit med så länge men de säger att ritningarna blir inte bättre och det är konstigt med tanke på att vi får bättre och bättre hjälpmedel" |
Man tittar kanske lite dumsnålt och lägger inte ner tillräckligt med tid och pengar på att rita och projektera noggrant. Det kan man bli bättre på. Ofta blir det mycket mindre skillnader mellan bygghandlingar och relationshandlingar när man har en totalentreprenad, då har en entreprenör som ska bygga fått varit med och påverka projekteringen.
**Informant #3**

Möte varje måndag 9:30, saker som tas upp:
- Saker som behövs
- Planering inför nästa vecka

Om man hade en dag extra att planera så blir det mindre misstag vad gäller vilka material som ska användas. Om det fattas någonting kan man stå där med maskiner och det kostar pengar.

*På Nacka Forum:* Kommunikationen mellan UE och arbetsledare kan i vissa fall, när arbetsledaren har mycket att göra, falla på någon annan än arbetsledaren. Oftast är det någon av YA som har stor erfarenhet som får detta ansvar.

"Det spelar ingen roll om du är världens bästa hantverkare, missförstår du en sak så blir det jävligt fel"

Förr vad det gamla gubbar som styrade och ställde och gick på rutin som inte var vana vid dator.

Förr (10 år sedan) var det inte lika intressant vad vi som YA tyckte, nu får vi vara med och påverka mer.

<table>
<thead>
<tr>
<th>Informant #3</th>
<th>Om det är en person som gör fel så kan det bli struligt för många</th>
<th>- Brottom när de bestämmer vad de ska bygga, brottom så att man ska komma igång. Handlingar planeras efter resans lopp och då får man ibland göra om saker.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Möte varje måndag 9:30, saker som tas upp:</td>
<td>I framtiden tror jag att man kommer att ha tillgång till en dator i varje koja där man själv kan trycka in den del man vill ha och de delar man behöver.</td>
<td></td>
</tr>
<tr>
<td>- Saker som behövs</td>
<td>Det är lättare om de som ska ha grejerna beställer för då blir det nog oftare rätt.</td>
<td></td>
</tr>
<tr>
<td>- Planering inför nästa vecka</td>
<td>&quot;Markpriserna är så jävla dyra och så svåra att få tag i&quot;</td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
### Informant #4

**Möten:**
- Varannan vecka med gubbar och maskinister där vi berättar vad som ska hända under en treveckorsperiod framåt.
- Varannan vecka har vi möte med arbetsledare och tjänstemän där vi samordnar och planerar så vi inte får några krockar i produktionen.

**Riskinventering - Arbetsberedningar**
YA och Arbetsledare och blockchef sitter i en bikupa för att ta fram arbetsberedningen. De större jobben och de som har en arbetsberedning planeras med en arbetsordning och det leder till att allt material finns på plats så att man inte behöver åka runt och leta efter material som man ska använda.

**Produktionstidplan i botten.** Utifrån den sker en samordning mellan blocken för att man ska veta vem som ska utföra vad och var arbetet ska ske.

Visuell planering, vi har en ritning där vi markerar på vilka områden vi kommer utföra arbete under en viss tidsperiod. Dessa ritningar förmedlas på mötena blocken imellan. Detta funkar bra.

**Avvikelser dokumenteras i dagboken.**
Om någonting inte går att utföra hör jag av mig till den som har kontakt med beställare och han pratar med beställaren om problemet som uppstått.

Mycket av avvikelserna kan man lösa på plats och sedan föra in det i dagboken. De flesta avvikelserna behöver man inte få ut nya handlingar på.

Vi har en kille som är ansvårig för ritningarna. I galgen är det alltid fräscha ritningar.
| | Vi har olika personer som är ansvariga för olika delar av inköpen och samordnar detta. | | |
### Informant #5

Innan projektstart förbereds utsättningsdata. Planeringsmöte en gång i veckan, fredagar, där tas det upp:
- vad som är inplanerat till nästa vecka
- förmedla information om nästkommande veckas aktivitet
- lättare att planera och ta fram någon speciell data vid behov

Arbetsberedningar inför varje moment, utsättare kommer innan YA börjar arbetet och kan då glömmas bort i riskhanteringsdelen i en arbetsberedning.

Om ritningar kommer sent kan det leda till att förberedelser innan projektstart inte är möjligt. I förlängningen leder detta till att det blir stressigt (få fram erforderlig utsättningsdata). Exempel är på projektet då ritningarna kom in väldigt nära byggstart och intensiv studie av geometri i de olika monoliterna gjorde att man hela tiden kände sig jagad av tiden.

Vid totalentreprenad har man ett närmare samarbete och dialog med konstruktören. Detta samarbete gör att projektet funkar bra

#### Förslag på förbättringar

Vid generalentreprenad vill jag ha mer möten med de olika parterna. Man vill ha en närtolk för att få på projektet: Struligt, tappar bort, dumpar på olika ställen, flera leveransadresser vilket leder till att man får leta efter sakerna när man ska använda dem.

Dåligt märkt material, t.ex. armeringen kom fel.

Allt material som ska till ett visst objekt vill man ha på ett och samma ställe

Leverans som inte kommit

Kontakt med leverantören, frågar personal på platsen om de vet någonting om leveransen. Om ingenting dyker upp beställs nytt.

Nu tar en YA hand om ankommande gods

Avvikelse bokförs i avvikelserapporter där det framgår vad som har hänt och hur man löst problemet samt vilken anledningen var.

Våra förslagshandlingar på VA-delen som vi fått från VV (konsult Sweco) var dåliga och det är mycket som han ändrats.

Stora avvikelse upptäcks som regel i förväg, det är inte så att arbetet är igång då man märker de stora felen. De fel som upptäcks när arbetet är igång är i regel små vilket gör att stillstånd är relativt ovanligt.

#### Avvikelse i produktionen:

- små problem som man kan lösa på plats, konstruktören meddelas inte/blandas inte in.
- Större problem så frågas arbetsledaren
- Fel i ritningar så kontaktas konstruktören, och ritningen uppdateras

Det bästa är att få ändringar skriftligt, t.ex. mail då det är svårt att veta vem/vald/när någon sagt någonting.

Vid stora saker så kontakta man beställaren, detta sköts av projektchefen.

Behandlas av mätteknikerna, som makulerar de gamla ritningarna och uppdaterar galgarna, en version av de gamla ritningarna sparas för att ha föregående kvar så man kan följa de olika ändringarna som är gjorda.

Mätteknikern giv nya ritningar till
en inblick i hur de andra har tänkt. Projektchefen har haft möte i mina tidigare projekt men då har inte mätteknikerna varit inblandade.
Förr var det sämre säkerhet för utsättare, nu står utsättarna på sig mer och begär att få den skyddsutrustning som behövs för arbetsuppgiften.

Arbetsledarna som ha som uppgift att samlar in/byta ut de gamla ritningarna.
Köts av mättekniker alternativt arbetsledare, det finns ingen tydlig uppdelning utan en dialog förs mellan arbetsledare och mättekniker (ad-hoc)
Om det inte är allt för komplicerade saker erhålls svar snabbt från konstruktören, är det stora saker måste man blendax i VV och då kan det ta flera veckor att få svar.
Små problem som löses på plats antecknas på ritningen inför relationshandlingen, detta skrivs av mättekniker
| Informant #6 | Förberedelsemöte innan avtal skrivs med hyresgästen/beställaren (ovanligt att ha så gott om tid som i detta fall innan produktionen startar):
- Arbetsmiljöplan diskuteras
- Titta på de saker som behöver arbetsberedas ordentligt
Planeringsmöten innan projektet drar igång:
- Leverantörer medverkar för att man ska kunna planera inköp, dessa uppgifter skrivs in i avtalen (t.ex. leveranstider).
"Jag tycker att man ska kunna begära att handlingar är justa när de kommer ut, det är inte vi som ska vara några granskare på plats; det ska byggas."
Riskhantering/risk-inventering gör vi direkt vid upphandlingen
Det är viktigt att hålla alla informerade (YA, maskinister o.d.) med vad som är nytt, detta genomförs på informationsmöten. Regelbundenhet mellan dessa informationsmöten är viktigt för att hela tiden hålla alla uppdaterade, ofta har man sådana här möten varje vecka. |
| --- | --- |
|  | Om det finns gott om tid så kan man lägga ner mer krut på tidplanen, har man en bra tidplan kan man koppla tidplanen till en inköpstidplan. Inköpstidplanen innehåller vad man ska köpa och när köpprocessen ska påbörjas mht leveranstid och förekomst av ramavtal. Och när man ska skicka ut förfrågningar för offerter på varor där inget ramavtal finns Vissa leveranser är extremt svårt att påverka, t.ex. kinesisk sten som kan bli kvar i hamnen och vara där i några veckor.
Hos ramavtalpartners finns det med i avtal hur lång leveranstiden är. Om man dessutom planerar i god tid har man möjlighet att få ett billigare pris på varorna.
Någon som tar emot och ser att det är rätt saker som kommer samt anvisar leveransen till rätt plats, denna någon är oftast en arbetsledare eller ibland produktionschef (mindre byggarbetspatro) alternativt en utsättare. (APD-plan) |
|  | För att ha en god avvikelsehantering kräver det att man ser felen i handlingarna och det är inte alltid så lätt, oftast är det utsätta som har störst inblick och är de första som får ritningarna samt ser felen.
Ibland finns det tendens att konstruktorerna skjuter över problem i projekteringen in i produktionen, genom så kallad "Löses på plats, LPP". Detta förfarande är vanligast i totalentreprenader.
Det finns olika sätt att lösa avvikelser på, om det är mindre avvikelser kan man via konstruktör/beställare/byggledning få ett snabbt svar i hur man ska lösa problemet, detta tas då upp i dagbok eller avvikelsehantering.
Utförandeentreprenad/generalentreprenad:
- Vid problem så vänder man sig direkt till beställaren för att se vad som gäller
Totalentreprenad:
- Man vänder sig själv till projektören
Logistiken av pappersritningar är ett problem och de kan bli liggande innan de |
kommer ut till arbetsplatsen.

Om man i förväg kan se att det är en risk för problem/avvikelse kan produktionchefen ha en extraplan på vad som kan göras om någonting går fel.

Vid omställning/flytt av resurser är produktioncheferna duktiga på att ha reservplaner. Dock blir det ökade kostnader då förberedelser behöver göras innan arbetet ens kan börja, t.ex. måste utsättare ut på plats. Det är svårt att dokumentera och ta ut vilka faktorer som påverkas vid omställning som ska vara till grund för en åta.

"Ju mer kraft som är nedlagt innan byggstart desto bättre bygghandlingar får man bygga efter"

Det finns olika sätt att se på handlingar allt ifrån:
- De som nästan går att stämpla som relationshandling direkt
- De som är väldigt olika

"Jag skulle säga att man kan tjäna mycket på att planera bättre, det stora problemet är att det ofta inte finns någon tid. Många ute i produktion går från ett projekt direkt in i nästa."
D Untranslated Swedish Quotes [5 pages]

Content:

- Untranslated quotes from the Swedish interviews
[1]: "Jag skulle säga att man kan tjäna mycket på att planera bättre, det stora problemet är att det ofta inte finns någon tid. Många ute i produktion går från ett projekt direkt in i nästa."

[2]: "Om man hade en dag extra att planera så blir det mindre misstag vad gäller vilka material som ska användas. Om det fattas någonting kan man stå där med maskiner och det kostar pengar."

[3]: "Från att konstruktören gjort handlingen är det två månader innan vi har den i produktionen. Stegen är internremiss (5 dagar), extern remiss ”vägverket" (1 månad), mottagningskontroll (5 veckor).”

[4]: "Det är svårt att få alla intresserade av tidplanen, det är ett jättejobb att sätta sig in i tidplanen. Vår tidplan består av tusentals aktiviteter och då är det ingen som orkar ta tag i det."

[5]: "Planeringen och en tidplan är några av de viktigaste styrmedlen för att få en bra ekonomi och effektivitet på jobben samt en säker arbetsplats.”

[6]: "Vi har även fått in mycket ändringar efter vi byggt saker och ting och fått göra om, bilat betong och lagt nya rör. Detta blir äta-arbeten som faktureras separat. Trots att vi får betalt så blir det ett orosmoment då vi måste revidera tidplanen och skjuta på andra arbeten."

[7]: "Det spelar ingen roll om du är världens bästa hantverkare, missförstår du en sak så blir det jävligt fel”

[8]: "Vi har även haft mycket problem med förslagshandlingar, förslagshandlingarna på betongkonstruktionen har vi varit tvungna att ändra på många ställen. Detta kan till viss del bero på att vi har olika syn på byggandet, vi ser på det ur ett produktionsperspektiv och arkitekten ur ett estetiskt perspektiv.”
[9]: "Vid totalentreprenad har man ett närmare samarbete och dialog med konstruktören. Detta samarbete gör att projektet fungerar bättre relativt generalentreprenad."

[10]: "En klassisk avvikelse är gjutfogarna, i en totalentreprenad har du rett ut problemet redan innan handlingarna tas fram medan man i en generalentreprenad ofta får göra större eller mindre avvikelser från handlingarn, så kallade 'produktionsanpassningar'."

[11]: "Vi försöker hela tiden tänka på vart vi ska göra av massorna, så fort vi gräver en grop tar vi beslut om vi ska körta bort det eller om vi kan köra det inom området."

[12]: "På andra projekt där man har sprängt bort berg och sedan krossat det har man ibland haft det krossade berget på arbetsområdet vilket resulterat i att man fällt flytta massorna flera gånger trots att man trodde att det var en bra plats man la dem på. Därför är bra att ha upplagsytor utanför arbetsområdet."

[13]: "På APD-planen kommer vi märka upp de olika byggnafarterna och sedan dela ut ritningen till leverantörerna så de vet till vilken byggnafart de ska leverera varorna. På ritningen skall det även vara anvisat vart leverantörerna ska stå och vänta innan de får tillträde till arbetsplatsen. Förrådskillen öppnar grindarna in till arbetsplatsen via sin mobiltelefon."

[14]: "Det är ganskan svårt att planera eftersom de har svårt att hålla leveranstiderna. Då får man ringa upp och tjata. Detta är en av de största punktorna att få logistiken när det gäller material i rätt tid."

[15]: "Generellt sett så är det ganska ofta fel på ritningarna."

[16]: "VA-handlingarna är under all kritik, det finns inte ett rör som stämmer i princip."

[17]: "Jag tycker att man ska kunna begära att handlingar är justa när de kommer ut, det är inte vi som ska vara några granskare på plats; det ska byggas."
[18]: "Jag har inte varit med så länge men de säger att ritningarna inte blir bättre och det är konstigt med tanke på att vi får bättre och bättre hjälpmedel”

[19]: "Handlingarna i generalentreprenad är inte gjorda enbart så att man kan bygga efter dem, de är kanske gjorda så att de kan funka kontraktssmässigt.”

[20]: "Ofta blir det mycket mindre skillnader mellan bygghandlingar och relationshandlingar när man har en totalentreprenad, då har en entreprenör som ska bygga fått varit med och påverka projekteringen i ett tidigt läge.”

[21]: "Min erfarenhet av bygghandlingar i en generalentreprenad är att de har en lägre kvalitet relativt handlingar i en totalentreprenad. Handlingarna i en generalentreprenad är inte lika igenomtänkta, de har inte koll på hur vi ska utföra arbetet... Det kan ibland vara uppenbara fel, som när vi fick en handling där en ledning var placerad genom en pålgrupp. Detta ledde till att vi var tvungna att schakta 3 meter i en pålgrupp när man kunde placera ledningen bredvik pålgruppen men ändå fått en fullgod funktion.”

[22]: "Stora avvikelser upptäcks som regel i förväg, det är inte så att arbetet är igång då man märker de stora fel. De fel som upptäckts när arbetet är igång är i regel små vilket gör att stillastånd är relativt ovanligt.”

[23]: "Mycket av avvikelserna kan man lösa på plats och sedan föra in det i dagboken. De flesta avvikelserna behöver man inte få ut nya handlingar på.”

[24]: "Nu ska vi gjuta här och då ska man ha en transportväg där, man kan inte köra där o.s.v.”

[25]: "Det är svårt att få alla intresserade av tidplanen, det är ett jättejobb att sätta sig in i tidplanen. Vår tidplan består av tusentals aktiviteter och då är det ingen som orkar ta tag i det.”
[26]: "Nu får ju vi en platt ritning och en utsättare sitta och höjdsätta och göra sektioner för alla vägsmutter, detta arbete kommer underlättas mycket om man använder mer 3D-projektering."
E Interview Responses USA [19 pages]

Content:

- Summary of the interviews conducted in:
  - Croton Filtration Plant
  - The New Meadowlands Stadium
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<tr>
<th>Interview with experience of BIM in USA</th>
<th>Workingprogress</th>
<th>Logistics</th>
<th>Deviations</th>
<th>Future of BIM</th>
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<tr>
<td>“coding”</td>
<td>a) Workplaning</td>
<td>f) Materials handling</td>
<td>l) Deviations handling</td>
<td>q) Focusing on the I in BIM</td>
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<td></td>
<td>b) Risk handling</td>
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<td>h) Excavation masses</td>
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<td>o) Plannig</td>
<td>s) Benefits</td>
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<td></td>
<td>e) Use of model</td>
<td>j)</td>
<td>p) As built document – contract drawings</td>
<td>t) Owner/Contract</td>
</tr>
</tbody>
</table>
Informant #7

What the 3D-model allows us to do is that we can sit down and analyze all the positions of the actuators and match them to the information that the manufactures give us. For example there are different options how to install the valves and the model gives us opportunity to optimize the installation angle of the valves.

There is times when I sit down with the guys and I show them the model on the screen and they get a very good visual of the type of valve that they are going to put in, which angle and size on the valve.

A lot of guys don’t look at the 2D-drawings out on the site or get involved in the 4D-model they just get the equipment and install the valve. But if I show them the model they know what to expect and what they are up to.

The model also helps the guys in the field to get a picture of how big some of the valves actually are.

The model can help communication with subcontractors. For example one of our subcontractors designed a valve which didn’t fit the pipe support. When I talk to them over the phone I can send them a snapshot from the model showing them exactly the situation instead of sending them mechanical-drawings. The model includes the

A lot of times the design changes during the project, the model helps us to drastically minimize the human errors on site due to the ability to analyze the geometry more precisely.

You can implement the changes live, in the model, during meetings and thereby you can visualize the effects from changes made by some designer. You can actually see that that change is going to affect that specific valve, or if you e.g. move a pipe you have to move the equipments that are attached to the pipe and there may clashes occur.

One thing that you have to consider when designing is the future maintenance, and the model can be used as a tool to make good decisions when it comes to the layouts of the valves.

Thanks to the model I can easily visualize where the major components are, you have to make sure that the components are not interfered by a wall or such so that the component can be properly maintained.

Something that would help me in my work would be if the model featured some FEA-program.
actual valve, not just a symbol, as well as the pipe support, which makes it easier for them to understand the problem.

“The model makes you a time saver, because you make less mistakes. You make parts that you are going to assemble in the field and it makes you think ahead. It is a time saver, big time.”
**Informant #8**

If the coordination work had been done in 2D it would have taken three times as long. We would never been able to get the project done in time.

When we talk about how layered our systems are, without the model you could maybe look at two drawings on top of each other because there are so many lines. But since we have six different subcontractors it is almost impossible to overlaying those. But in the model you can actually fly through the space and the program has collision control which you can tailor.

One of the things we tried to do on this project was to make sure that everyone had access to a website where they could pick up the latest information. We didn’t have a specific entity that managed this process (that everyone had the latest information). Instead we used an alert system which informed the user about updates.

A problem that occurred during the project was that a few subcontractors didn’t have in-house expertise in 3D-moduling. Instead they hired firms from outside to help them, and they delivered a good product but they were behind and not fully up to date with what was going on. This sometimes made their model

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“**If you do the process right it is all planned in advance. If it is one, two or three drafter but when you get out on the field it are 30 guys working in five or six different areas. If you have one conflict in each of the areas which takes two or three hours to solve, this makes it 60-90 man-hours, how many drafting hours does it take to save this lost time?”**

It would be helpful if I could use a barcode-scanner to scan objects that has been installed. This would be a good and quick tool for me to evaluate progress; it would be great for billings and productivity.

It is a substantial investment on 20-40.000 dollar per workstation. If you don’t have all the objects you have to create them. It would be very helpful if the manufactures could create a 3D-model of every part that they sell, so we don’t need to model it ourselves.

The subcontractors didn’t have enough time to coordinate with eachother due to the pace of the project. This resulted in many clashes which had to be worked out during the coordination meetings, the meetings then could take a whole day. When the changes that was decided during the meeting were to be implemented the people responsible for updating the model were already working on the next area, therefore the model wouldn’t get updated. The drawings issued to the field are created from the 3D-model, if the model was not updated the field drawings weren’t updated. This caused problems in the field.
inaccurate. We allowed one of the subcontractors to use 2D-drawings for his coordination because he had so many problems with embracing the process properly. But this was problematic, when there was a change he took twice as long to turn around the new drawings.

We would identify the area that everyone was to work on during the course of one week. First the sheet metal contractor uploads his model to the website, and then the piping contractor downloads this model and fits his system to the model and then uploads the new model to the website. This process was repeated for all the subcontractors in the following order, plumbing, fire protection and electrical.

The model is used as a 3D-coordination tool.
**Informant #9**

Another thing to keep in mind is that everybody’s (the different contractors) schedule is not tied together. We have our own schedule which ties to our own activities and the other contractors have the same thing. Since the other contractors activities is not tied to our activities the model with our activities cannot be used for coordination.

"The coordination occurs basically on a communication level not so much from the schedule, computer model, it would certainly be better if it would."

The 4D-model came in late in the project. The development of it occurred a little bit later in the project it would have been more beneficial if it started earlier.

The model does not contain enough details to be used in the coordination work.

There is information in the model from the HVAC, plumbing, mechanical, structural but the electrical contractor has none of his information in there.

The reason that the electrical contract drawings is not in the model is that the contractor is late with submitting lot of his stuff.

We have used the 4D-model in some extent to get a preliminary view of what we are up against.

The solving of deviation is usually done the old fashioned way by each contractor puts together their own drawing and then the drawings is brought to our office. We put all the layers together and check it for hits. We really don’t use the 4D-model for that.

Most of the hits have been with electrical. The plumbing has also been a little of a problem since the design has been changed substantially (from the owner) during the project. Fortunately the plumbing contractor have updated both their drawings accordingly.

As a superintendent I would like to see a 4D-model containing information about the objects. E.g. if you scroll over a wall you would see dates for installation of formwork, reinforcement and pouring. Quantities and a hyperlink to your budget so you could see what your estimate was. Another thing that can be included in the model is fire rating on a wall, type of finish on the slab.

I think the problem with BIM, at least at this point, is that it takes a lot of work and a lot of effort to build the model and put all the information together. And all the work with the model should be done before the project starts.

"Also a lot of the coordination efforts will be resolved a head of people actually going to work it is going to be solved on paper... there is definitely savings to be found."

They tend to be traditional in what they expect or want. Off course on private jobs the owners are willing to try something that they think will be cost saving in the long run. The private owners is directly going to be effected by the outcome from the project, it is not public money. (25:30)
For example where we have to install double wall containment pipes as well as HVAC duct work and drain lines and it is all crammed into a little spot. By looking at the model we could see kind of what it would look like so we could at least plan how we should get the double wall containment pipe in.
**Informant #10**

The model was very useful for steel fabricators and for us at times to see what was done. I used the model for the structural work. The model came in use when I and the Project Manager solved some issues or trying to figure out why we had slight variations or problems in some area.

“I was actually surprised at some of the things you could learn from it, it was insightful.”

The model even provided dimensions, if you had some problems with dimensions you could go to the model and focus on some area and get an answer, not always an exact answer but it would lead you in the right direction.

As a field superintendent I wasn’t directly involved in the prefabrication of concrete. But when we had a problem with an element e.g. some time the element was fabricated but not delivered or even loaded on a truck. In these cases I looked in the model to check the status of the element and then I could take necessary action, e.g. call the fabricator and tell them to deliver the element as soon as possible. I think that this was a good way to keep track of stuff.

We used snapshots from the model a lot of times, e.g. when we worked

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Occasionally we had problems of a repetitive nature with some of the precast concrete elements; sometimes the error could repeat itself for about 20 times.

In the coordination meetings I contributed with, among other things, help regarding constructability issues. Sometimes things work in the model but not necessarily in the field.

Information that could be useful to have in the model would be dimensions, connection types, weld types and finish.

When it comes to deviations and changes, sometimes it takes so much longer to get something pulled out of design than it takes to build it. Aside from doing that actual task you will have to coordinate many things around that because you weren’t able to install that particular piece of work.

I think the model is a definite plus for the steelwork, the pieces fit better together.

In my opinion the software could be more user-friendly. Especially for the guys that don’t use the software a lot of time.

In this project we had so many piece drawings and erection drawings sometimes you couldn’t be sure that you had the most up to date drawing. But the fabricator was very good at updating the model so you go to that with confidence and know you have the most current information in the model, but perhaps not on paper.
on the foundation. Just to be able to have the different colors in different parts is a helpful when explaining the work to the workers.
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<th>Informant #11</th>
<th>We first receive the 3D-renderings in cad, dwg-files, from the owner. Usually the drawings are broken down into quadrants of the plant; they are not broken down into smaller parts as our activity schedule. We transfer our files to SCULP (Skansa Teknik) in Sweden via a FTP-server, they in turn send the files to a company in India. The company in India breaks down the objects into smaller parts which correspond to our schedule. The new 3D-model is then uploaded on the FTP-server where we can download them. After that we can export nwd-files from AutoCAD and then import these files into a master file in Navis. Once we have imported the files in Navis we import the schedule into Navis from Primavera. After the schedule is imported to the Navis you are able to link the activities from Primavera to the elements in the drawing-files. This process is the hardest part due to the amount of activities in a big project. Once you have linked the activities, including the specific dates, to the elements you are able to simulate the construction process. Now you have a 4D-model.</th>
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<td>Regarding change orders: After we have inserted all the changes into our schedule we do a critical-path-analysis. With a critical-path-analysis we try to find the activities that affect the end date of the project. This analysis will help us to decide when the new activity will be executed so the negative float is minimized.</td>
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**Informant #12**

When we have finished our coordination for an area we bring in our superintendents and foremen to run through the construction installation sequence. They contribute with their experience from construction and can help with constructability issues.

Our structural engineer used Revit to model the steel structure. The model was then turned over to our steel fabricator that uses Tekla. When we got the model back from the steel fabricator it was very accurate (1/16 inch). We then combined all the fabrication models into sidewalks and end zones section. After that we handed over the model to SCUP and they used the architectural drawings to create a model and combined that with the structural models. This combined model served as the background for coordination.

The database that recorded the status of the precast elements is tied to the model. We had a company that integrated and adapter the pulled information from the Tekla model, and they had a database on their server with information of the precast concrete elements. And then they tied their server information with

We tracked the 2700 precast elements with RFID-technology, which was something that we wanted to experiment with. We did consider it for the steel, but there is too much steel to track; you don’t want to make your first attempt at something when it is really hard. We wanted to look at a smaller entity that we could track with relative ease, just to see how we could plug this technology into future projects.

**Then most important thing is that your subcontractors have the same information and everybody is on the same page. We don’t withhold any information; there is no reason why everyone should not have the same information as we. This openness with information served us very well because we had everybody on the same page, one subcontractor could not turn around and say ‘You didn’t tell me that’.

It is important to update the model by getting feedback from the guys out on the field. This includes all the subcontractors and we don’t want changes to the plans because changes means that we have to go into the model and layout what the change was and how it will affect the project (and then alert the subcontractors about the change). It is just something you got to keep on top off, once that ball gets going you really got to go with it during the entire project.

All our mechanical trades were submitting 3D-models to us, some companies had that capability in-house others had to hire outside help. Most of the models were pretty detailed; they contained a lot of information in terms of piece numbers, hangers and stuff like that. This information was benefitting us throughout the whole process; the more details like that the easier the job becomes.
This work made it possible for us to track the precast elements via their RFID-chips. The chips contained information about the status of the element. There were five statuses; manufactured, in transit, installed, erected, damaged or not.

The status of the elements was illustrated with colors in the model. If you would want more information regarding the elements than just its present status you will have to go to the database.

The status of the precast elements is updated automatically; the only thing we had to do is to scan the element with a RFID-scanner. As it is scanned the information is uploaded to a server and then the information is integrated to the Tekla model which now shows the status of the precast concrete element.

Every time you upload a new version of a file there is an alert, and we could back that up with an email for example saying we have changed the ceiling here and you should be aware of that.

For the purpose of this project having one subcontractor working with the model at a time and then we pass it over to the following subcontractor is that they update the 3D-model just as they would have made hand notes on a 2D-drawing. We are holding them to the 3D-model.
subcontractor. This gives us a much better control over the process in general and allows us to put a stop in whenever we feel it is necessary. You are not dealing with five subcontractors every day, you are dealing with one. You identify this subcontractor’s problem and resolve them, and you get everything in place to go to the next subcontractor.

During the project we were trying to turn over one area every other week (the project was divided into 117 areas). Each subcontractor got to work for two days with the area. The sheet contractor would go first (all he had to respect was the architectural elements and the steel), plumbing was next (had to respect the same thing as the sheet metal plus his work) this work process continues for the remaining subcontractors which are mechanical and then fire protection and last electric. On the final day we have everybody get together under one roof on site, we load up a projector and the model with everybody’s stuff integrated in to it. At this point any collisions that remain we needed to look at. At the end of the meeting we want to be able to sign off on drawings so we can start the construction work of that area.
When all the coordination is under one roof it is a lot easier than it is to manage the subcontractors if they are working in different places throughout the tri-state area.

On the coordination meetings there would be a VDC-guy who manage the model and schedule the meetings and then there would be a Project Manager who could make decisions when our subcontractors could not reach an agreement. The subcontractor’s representatives should be able to make design decisions that is a Project Manager or a high level detailer; someone who is liable. “The last thing we want to have is a person who can draw in 3D but he cannot tell you if you can move that pipe up or down”

First we only required our subcontractors to have the freedom-viewer which is free and then we provided them nwd-files that showed everybody’s collisions. But we found out that our subcontractors started to upload pretty much their best guess. This because they could not take measurements from the nwd-file, they could just see it. Since this didn’t work out very well a bit into the process we required them to purchase NavisWork software and do collision control in-house.
| This cut the number of collisions with almost 75 %.

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E-16
| Informant #13 | Out on the site there are posters showing different aspects of the job in 3D. Out on the field the work crew is interested in seeing the 3D-pictures, they are used to just seeing 2D black and white drawings.  
All the foremen have been able to see the simulation of the construction process.  
They have used the 4D-model to show us the progress and dates to see where we should be and where we were. And then on another occasion they showed us the overall step-by-step process of the job being built from start to finish.  
It is very helpful to see what we are going to build. We see it from an informative standpoint more than a building standpoint. We just look at it and see what we are going to build and what it will look like in the different levels.  
One some tricky part of the job a couple of guys did do some 3D-pictures to help us visualize this parts. | Some people can look at 2D-drawings and see the building built in their mind, not everybody can do that and this where the visualization really helps. |
**Interview Responses USA [19 pages]**

| Informant #14 | After training the young people in the BIM-software they will act like mentors for one older employee. Somehow you need to communicate that he (Foremen or Production Manager) is late, you can send him a print of a p3-primavera file. By the time that he understands the activities in this print and realizes what the dates are you need to support him if he is not familiar with activity descriptions, date classifications, relationships, etc. It will probably take a couple of hours to explain to him the software. Then his going to question the input to figure out why he is late. With the 4D-model you visually show him the structure that he is building. You can easily explain which parts that is late and which effect this will have on other parts of the structure. The data is more user-friendly which makes the communication easier.

“Imagine someone trying to explain a problem to you and you can’t comprehend it, so he sketches it on the back of a napkin but it is too complex to visualize so you turn to a person sitting on the other side of the table. He has a laptop with BIM on it and says here this is it...Boom it’s right there.”

If it too hard to figure out how to I think BIM is very helpful in making early decisions, or changes, that you need to make to be more profitable or safer. You are able to see the project from many different perspectives in a short time, not just one or two. One example in this is when we decided where to place the tower cranes; these cranes can’t be placed too farther out from the structure due to their reach, capacity and limited space of the construction site. We looked at the model to see where the cranes would be placed. Some of the criteria that we considered were the capability to dismantle during demobilization, not being on the way of other prime construction work, and swing radii of other cranes that we will be utilizing. If we wouldn’t use the model we would have to make copies of drawings on transparent paper and superimpose these drawings to visualize different scenarios. We would have come up with the same decision but it would have taken much longer. Using the model we were able to make the decision within half a day instead of several days.

Another area where an intelligent model will be useful is the prebid quantity take-off process; this kind of information makes us more competitive.

The information that will help the mechanical is for example the specifications of a motor or a pump, type of pipe and information regarding the valves. This kind of information makes the BIM-model intelligent.

Just having the information in the model doesn’t really help you; you need to know why you want that information.

The software (Navisworks) cost us about 6,000$ per license and then you need to upgrade the hardware. At the very least you would spend $100,000 to create a 4D-model which 15 people will use excluding costs for their initial training.

There is no template software which you can plug in to a project and it gives you BIM. We need a lot of effort to create a BIM-model. We need to make an assessment whether it is worth it or not, such that large complex projects with big budgets vs. small simple projects with limited budgets will be one of the differentiation factors.

For young very technological capable people, the learning period is almost nothing. Within a few weeks they are
construct in 2D-drawing you are going to create a 3D-model which will help you to understand the complexity of the job. Necessity is mother of all inventions. E.g. in this job the estimators built a scale model of the plant just to visualize it. If we had the BIM-model it would have helped immensely. Now that we have the 4D-model we don’t look at the old model because we have it electronically.

up and running.

“In our contract (lowest qualified bid wins the contract), the owner does not require us to generate a BIM, we chose to become a BIM user to evaluate its benefits without any reimbursement from the client. However, if we can find value in BIM to fulfill our contractual requirements, we can use it and budget that in our bid prices”
F Untranslated Questionnaire Responses [7 pages]

Content:

- Responses from the questionnaire regarding BIM expectations in Sweden
Enkätundersökning angående BIM i produktionsfasen

**FRÅGA 1.** Jobbar du eller har du jobbat på en byggarbetsplats (ute i produktionen) som nyttjat någon form av byggnadsinformationsmodell (åtminstone en 3D representation av byggnaden)?

*Om svaret är nej på denna fråga hoppa till fråga 2*

#16 - Ja, Tunnelinklädnad NL11

#17 - Nej, har inte kommit i kontakt med BIM tidigare.

#18 - Nej inte tidigare men vi tar fram en BIM för NL52 just nu.

#19 - Partihallsslänken

**FRÅGA 1a.** Vilken information ingick i modellen?

*Geometriska data, tidplan, kalkylering, maskinstyrning etc.*

#16 - Geometriska data och underlag för maskinstyrning

#18 - Kommer innehålla i startläget geometrisk data, konfliktprobl samt tidplan

#19 - 3D Tidplan, maskinstyrning

**FRÅGA 1b.** På vilket sätt har modellen underlättat arbetet i produktionsskedet?

*Visualisering, kommunikation, avvikelsehantering, koordinering, logistik etc.*

#16 - Visualisering, kommunikation, undvika projekteringskrockar och förenkling av utförande.

#18 - Vet ej än men syftet är visualisering, konfliktdetektor, logistik

**FRÅGA 1c.** Hur är modellen uppbyggd?

*Mjukvara (Tekla, Revit, Navisworks)*

#16 - Vet ej.

#18 - Tror det är Naviswork
FRÅGA 1d. Erfarenheter från arbetet med modellen?
Vad har gått bra, mindre bra i arbetet med modellen, vilka erfarenheter tar du med dig från arbetet

#16 - Modellen är inte klar så den är ännu inte använd i produktionen.

#18 - Inga än.

#19 - För det löpande arbetet på arbetsplats har vi tyvärr ingen rutinerad medarbetare som behärskar Planeringsprogrammet och dessutom 3 D modellen vilket måste ske succesivt för att ha någon

Större nytta av detta för det dagliga arbetet

FRÅGA 2. Vilka förväntningar har du på byggnadsinformationsmodeller som hjälpmedel i produktionen med hänsyn till...
...logistik?

#15 - Stora förväntningar. Här finns stor potential att utnyttja BIM-modeller för att t.ex. utnyttja arbetsplatsens ytor på optimerat sätt mm. Kräver mycket av modellen och är inte det första som implementeras av oss.

#16 - Komplett APD-plan i modellen, i och med att höjderna är med så kan provisoriska vägar och liknande planeras med större exakthet.

#17 - Vet ej.

#18 - Kunna planera transpvägar, informera vilka vägar är stängda/blockerade/upptagna när

#19 - Stort
...koordinering?

#15 - Samgranskning och samhörning av olika discipliners modeller är grundläggande men bör vara gjort under projekteringen och i liten mån ute i produktionen om det är detta ni menar med koordinering. Att t.ex. koordinera arbetsmoment/arbetslag osv. så att dessa i minsta möjliga mån stör varandra ser jag stor potential i att utnyttja BIM-modeller till. Detta kräver också en större projekteringsinsats för att fungera men det finns stora tids- och ekonomiska vinster att göra.

#16 - Involvera tidplanen i modellen för att undvika krockar i projektens olika skeden.

#17 - Vet ej.

#19 - Stort

...arbetsplanering?

#15 - Stora förväntningar. Stora komplexa projekt har alla möjligheter i världen att med BIM-modeller som stöd förbättra tids- och arbetsplaneringen och på så vis spara tid och i slutändan pengar. Detta på kort sikt.

#16 - Undvika krockar och andra störningar då planeringen kan göras mera exakt och byggdelarna produceras i rätt ordning.

#17 - Vet ej.

#18 - Höja samordningsnivån, Schaktområden, begränsade arbetsomr. Framförallt optimera produktionsprocessen- vilken är den bästa arbetsåganen!

#19 - Den måste vara gjord tidigare men man bör kunna se störningar
...avvikelsehantering?

#15 - Stor potential här. Vi har dock alldeles för liten erfarenhet av användning av BIM modellerna ute i produktionen för att ha något konkret att peka på just nu. Jag ser dock stora möjligheter att t.ex. jämföra teoretiska mängder med faktiskt utförda mängder osv. och på så vis få god koll och goda erfarenhetsvärden för olika typer av projekt på ett annat sätt än idag.

#16 - Vet ej.

#17 - Vet ej.

#18 - Nja, inte högsta prio

#19 - Ingen

...ritningshantering (snabb tillgång till senaste informationen i modellen, måttavtagning)?

#15 - Lätt att tillämpa och goda vinster på kort sikt. Vi ser enorm potential i att systematiskt använda modellinformation för maskinstyrning och utsättning vilket kanske kommer in under denna rubrik.

#16 - En stor hjälp för utsättning.

#17 - Vet ej.

#18 - Nja, inte högsta prio

...någonting annat än ovanämnda områden?

#19 - Stora fördelen måste vara när man visar 3D för personalen
**FRÅGA 3. Vilka problem tror du finns med användningen av byggnadsinformationsmodeller i produktionen?**

#15 - I dagsläget, för lite kunskap om vad BIM är och hur det kan användas för att ge fördelar i produktionen. Ett annat problem i dagsläget är att modeller från olika delar av projektet är olika väl anpassat för BIM-hantering. Modellerna behöver vara projekterade i 3D och i viss mån vara anpassade för att kunna nyttjas på bästa sätt och få projektörer vet hur detta uppnås.

#15 - Det saknas ännu så länge konkreta, goda exempel som visar på faktiska vinster med att använda BIM. De är dock nära förestående och då kommer efterfrågan på BIM-modeller att explodera tror vi. Då kommer problemet istället att övergå till att ha tillräckligt med kunniga projektörer för att möta efterfrågan från projekten.

#16 - Att få fram modellen i tid och att underhålla modellen efter hur projekten fortskriver.

#17 - Vet ej.

#18 - Dagens byggproduktionskultur är långt ifrån detta dagsläget. Låg datavana

Ser inta alla fördelarna i uppstarten så man tycker inte det är värt besväret.

#18 - Krångligt. Detta är ett hjälpmedel men det löser tyvärr inga problem man måste fortfarande

Läsa ritningar och handlingar

#20 - Ett problem är att få fram den projekterade modellen i tid. Inte sällan påbörjas idag produktionen på förhandsbeked/ preliminära handlingar.

För att lyckas krävs nog att arbetet med att ta fram modellen påbörjas i tidigt skede (redan i anbudsfasen).
FRÅGA 4. I vilken del av produktionen tror du det är enklast att börja använda en byggnadsinformationsmodell?

Arbetsplanering, koordinering, logistikhantering, tidplanering, ritningshantering etc.

#15 - Ritningshantering (såsom detta specificerats under fråga 2 ovan). Alla andra användningsområden ställer mer eller mindre stora krav på hur modellen anpassats för just det användningsområdet. Därefter i rangordning: arbetsplanering, koordinering, tidsplanering, logistikhantering.

OBS! Jag arbetar uteslutande med anläggningsprojekt och svaren ovan baseras enbart på erfarenheter vi hittills har av BIM på anläggningssidan. 3D och BIM modellering har ännu inte riktigt slagit igenom på anläggningssidan mycket på grund av de komplexa geometrier vi har att göra med och att varje projekt i många och mycket består av unika byggnadsdelar. Dessutom har vi beställarkrav som hemmar utvecklingen när det gäller CAD. De senaste åren har det dock hänt mycket, inte minst när det gäller programvaror och vi står inför en mycket ljus framtid när det gäller detta. Inom kort tror jag att vi har många konkreta exempel på hur BIM kan användas med framgång och då kommer också nya användningsområden att framkomma. Det här är bara början…

#16 - Arbetsplanering

#17 - Vet ej.

#18 - Arbetsplanering/tidsplanering och enkel 3D-visualisering.

#20 - Jag jobbar i skrivande stund med en 4D-modell i projektet.

Modellen innehåller temporära förstärkningsåtgärder samt grundförstärkning och grundläggning (för en bro).

Modellen togs fram som ett stöd för planeringen. Har dock fler tänkbara användningsområden tex APD-plan, arbetsberedningar, kollisionskontroll mm. Från 3D-målerierna som 4D-modellen är uppbyggd av exporterar vi även data för utsättning och maskinstyrning.