Possible utilization of BIM in the production phase of construction projects

BIM in work preparations at Skanska Sweden AB

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Abstract

Construction organizations have had to increase their productivity and make the project process, from conceptual design to handing over, more efficient in order to increase their profit margins. The Information Technology (IT) industry has developed new Information and Communication Technology (ICT) solutions and tools which aim to support construction organizations in projects in order for them to achieve their goals of reduced project costs, increased project control and increased productivity. An ICT tool that, during recent years, has grown to potentially create a new paradigm within the construction industry is Building Information Modeling (BIM). But as the construction industry has shown it cannot absorb new technological innovations as fast as the market responds, the entire industry has hereby been perceived as conservative and slow in adoption of BIM throughout the whole project lifecycle.

An interesting contradiction is why there has been such slow adoption of BIM when improved productivity and effectiveness is a prerequisite for increased profit margins. The evaluation of this contradiction formed the basis for this thesis. In compliance with the construction company Skanska Sweden AB, for which this research has been conducted, a decision was made to evaluate this problem with focus on how BIM can be used in the production phase of con-
struction projects and how it can be aligned to production processes to increase productivity. A specific production process, work preparations, was chosen to be evaluated as an example of what obstacles there are of implementing BIM and how BIM can be of value in the production phase.

To answer this questions a literature study in combination with empirical observations through qualitative interviews was performed. The literature study was conducted in the areas of communication, ICT and BIM. The qualitative study consisted of interviews with personnel from the central organization of Skanska and with production personnel from four different projects.

The findings revealed that there are several obstacles with implementing BIM in the production phase and that an organizational induced iterative improvement process is imperative to assure effective BIM diffusion and hence an increased BIM maturity level in the production environment. Furthermore, the research shows that the BIM maturity level will set the standard for how well BIM can be used as a tool to support production processes. Moreover, our research has resulted in a three-step model which provides recommendations how Skanska and other construction organizations gradually can increase their BIM maturity level in the production phase and thereby utilize BIM in production processes such as work preparations.
Preface

This master thesis within the subject of BIM in the production phase of construction is the final part of our education at the Royal Institution of Technology (KTH) and the Department of Real Estate and Construction Management in Stockholm. The thesis, which comprises 30 credits, has been produced in collaboration with the construction company Skanska Sweden AB and the region of Residential building Stockholm.

The idea of the thesis’s subject was presented by Skanska whereas the delimitation of the work was formulated by us in accordance with our supervisor from KTH, Väino Tarandi, and our supervisor from Skanska, Johan Ekstrand. Our ambitions with this work were to provide Skanska with an insight in what obstacles and benefits there are if implementing BIM in the production phase by illustrating how the work preparation process could be made more effective by the use of BIM.

We would like to thank all the interviewees from Skanska for their participation and the valuable input that they have given to our research. We would also like to express gratitude towards Johan Ekstrand and Väino Tarandi for the guidance, support and feedback that they have given us throughout our research.

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Abbreviations

AEC Architecture, Engineering, Construction
AGC Associated General Constructors
AIA American Institute of Architects
BC BIM Coordinator
BIM Building Information Modeling
CAD Computer Aided Design
DM Development Manager
DM-EP Project Manager in Effective Production
DM-HES Project Manager in Health, Environment, Safety
HVAC Heating, Ventilation and Air conditioning
ICT Information and Communication Technology
IFC Industry Foundation Classes
LEED Leadership in Energy and Environmental Design
MEP Mechanical, Engineering and Plumbing
PA Project Administrators (SM, SE, PE)
PrE Production Engineer
PE Project Engineer
PM Project Manager
PM-BIM BIM Project Manager
PrM Production Managers (SM, SE)
ROI Return on Investment
SE Supervising Engineer
SM Site Manager
SO Safety Officer
SW Skilled Worker
2D Two dimensions: x, y
<table>
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<th>Three dimensions: x, y, z</th>
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1. Introduction

The introduction to this thesis provides an insight of why the research has been conducted on the subject of BIM in the production phase of construction. It further explains and clarifies the research question and its relevance and delimitation. Moreover the introduction provides a reading guide which explains the context of upcoming chapters.

1.1 Background

The construction industry is known to be conservative and slow in adopting new innovations and technology (Hjertquist and Elmqvist, 2006). As the competition to exploit available land in urban areas increases, the profit margins in the industry are decreasing (Lutz and Gabrielsson, 2002). This has put pressure on construction companies to make their production process more effective, decrease costs and at the same time produce high quality facilities.

The construction industry is characterized by temporary organizations where many different actors are involved and where a high level of collaboration is necessary, but far from achieved (Alshawi and Ingirige, 2003). Due to the dynamic nature of construction projects a complex communication pattern is created which makes the interaction between different teams and professions hard to manage (Wikforss and Löfgren, 2007). In addition, all actors are driven by financial incentives where gains for one actor easily end up being costs for another. These construction industry traits have made the aforementioned goal of making the production process more effective hard to achieve.

The development of ICT and BIM has provided construction companies with tools that can be used for planning and managing construction projects with less effort and greater accuracy. But still the implementation of these technological solutions have been made in a slow rate (Eastman, Teicholz, Sacks and Liston, 2008; Fisher and Kunz, 2004).

Skanska, which is an international construction company with a wide range of expertise in areas of construction and development operations, is an example of a company with high ambitions to introduce new BIM solutions in their business. But due to the complexity of the organization, the hierarchical order and implementation obstacles, effective use of this technology has become hard to accomplish. Even if they have introduced BIM in the detailed design phase they still have a long way to go before fully attaining and experiencing project related benefits. A first step in developing the use of BIM in Skanska is to implement it in the
production phase to a higher extent than is being implemented presently. Skanska have shown great interest in trying to introduce BIM in work preparations as an initial step to extend the permeation of BIM into the production environment.

Work preparations are an important part of the quality, environment and work conditions assurance of a construction project and are performed for activities that have significant impact on the project in these areas (Skanska, 2010). If project activities are well prepared, the chance of having a successful project increases. The implementation of BIM in this process could enhance its effectiveness and thereby cut production costs, save time and honor the client’s quality and economical requirements.

1.2 Problem statement

This research evaluates the possibilities of aligning BIM in the production phase of construction projects. This evaluation consists of finding a solution for how BIM can be used in a specific production process: work preparations.

In order for us to generate such solution we have considered what implementation obstacles there are with implementing BIM in the production phase and thereafter gone into depth of what inhibitors there are for an effective work preparation process. Further we have considered what positive aspects of BIM that can aid inhibiting factors in the work preparation process and hence make this process more effective.

The research question to be answered is:

What obstacles are there in implementing BIM in work preparations and what possible benefits can be attained by utilization of BIM in this process?

There are several factors contributing to the relevance of our research question:

- The Swedish construction industry has in general been slow in adapting to new technology, such as BIM, due to implementation barriers. Therefore it is imperative to overcome such barriers in order to experience benefits. Our research provides a framework of implementation obstacles for BIM in the production environment.
- Our research evaluates how BIM can be used in a specific production process and pinpoints what benefits that can be attained through implementation. Our research can
herby be seen as a project with the intent to increase the knowledge about BIM possibilities in the production environment.

- The research can advantageously be a driver to increase the BIM usage within the production environment when the added value of implementing such technology can be made more explicit.

1.3 Purpose and aim

The main purpose with the thesis is to help Skanska increase the usage of BIM in the production phase of construction by providing a solution for how this technology can be applied in the production environment and into the process of work preparations. An important purpose of our study is also to provide Skanska and other construction companies with a framework of general BIM implementation obstacles present when adopting BIM in the production environment.

1.4 Delimitation

In discussions with our research supervisor at Skanska, Johan Ekstrand, the scope of our research was determined. The initial delimitation was to evaluate how BIM could make the work preparation process more effective.

Early on in the research process it was concluded that the scope had to be widened to include general BIM implementation obstacles in the production environment to adequately answer the research question. This decision was made in order for us to evaluate how the level of BIM maturity affects the possibilities to align production processes and BIM.

In compliance with Skanska and our research supervisor it was determined that a more general perspective of BIM implementation in the production environment should be taken but still evaluate the initial question, i.e. what obstacles are there in implementing BIM in work preparations and what possible benefits that can be attained by the utilization of BIM in this process.

1.5 Reading guide

Before starting to read this thesis we believe that a brief explanation of the layout will facilitate the understanding of our research and our findings.

- 3 -
The *theoretical framework* in this thesis consists of two sections: communication theory and ICT/BIM.

The communication theory provides an understanding how the information transfer between two or more individuals work and what possible barriers there are which can hinder an effective communication process. Communication is a fundamental part of the information exchange between people in work preparations, why an understanding of possible obstacles related to communication are necessary to consider.

The theoretical part of ICT and BIM in construction provides the reader with information regarding new technological innovations and applications that can make the information transfer more effective. These tools can provide new communication channels and mediums, which can enhance the communication process in work preparations. This section also provides an insight of BIM implementation barriers that affects the BIM maturity level in the production environment and the possibility to effectively implement BIM in work preparations.

In the *empirical section* the results from our study regarding Skanska’s work preparation process and BIM usage are presented. The focus in this section lies in illustrating the identified obstacles in work preparations which hinder an effective process and also to clarify implementation obstacles of BIM in the production environment and what level of BIM maturity Skanska have. This information further sets the framework for the analysis and suggestions on how work preparations can be made more effective by the implementation of BIM.

In the *analysis* we connect the empirical results with relevant theory to verify:

- What identified implementation obstacles that need to be considered in assuring effective BIM implementation in the production environment.
- What identified obstacles there are in the work preparation process and the value of implementing BIM in this process to overcome some of the identified inhibitors.

The analysis is conducted in two steps:

- An analysis of identified BIM implementation obstacles and the BIM maturity level in the production environment.
- An analysis of the identified barriers in work preparations, where main focus lies on the communication and visualization aspect.
In the section of *recommendations for Skanska* we provide an in depth analysis of:

- What specific BIM implementation barriers that need to be considered in supporting effective BIM usage in the production environment.
- A specific three step solution for how BIM can be implemented in work preparations and hence make this process more effective.
2. Method

In this chapter an explanation is made of how the research has been conducted and what research method that has been used. It also provides an insight in what reasoning that has been applied and what research techniques that have been used in order to gather relevant data. Further a justification to why these different approaches have been taken towards answering the research question is presented.

2.1 The research design

There are several ways to go about in regards to what research design that should be used in a research. The research design is the overall plan to collect relevant information on the subject studied. It is chosen in relation to if the problem to be examined is structured or unstructured (Ghauri and Grønhaug, 2010).

The research design used in this research can be explained as being of an exploratory nature. The reason for choosing such design has to do with the fact that our research problem is somewhat unstructured. Although we know what areas that we need to consider in our research to adequately give an answer to our research problem we do not know:

- What the main barriers are for effectively implementing BIM in work preparations.
- The general BIM implementation obstacles that are present in the production environment.
- What obstacles there are in the production environment regarding effective work preparations.

These topics set the frame for what kind of reasoning that should be applied and what kind of research method and techniques that should be used.

2.2 Reasoning - Deductive and Inductive

An inductive research implies that empirical observations are the basis for theory building. In contrast, a deductive research refers to that observations and hypotheses are derived from existing knowledge or theory which then are verified through empirical studies. Furthermore, deductive reasoning is usually connected to a quantitative type of research and inductive to qualitative methods. In most research cases the use of inductive and deductive research rea-
soning are used in different proportions (Ghauri and Grønhaug, 2010). In fig 2.1 the two types of reasoning are illustrated (Skinner, 2010, p.1-2):

**Deductive**

Theory

- Hypothesis

- Observation

- Confirmation or Rejection

**Inductive**

Theory

- Tentative Hypothesis

- Pattern

- Observation

![Fig. 2.1 Deductive and Inductive reasoning](image)

As shown by the process, seen in fig 2.2, we used an inductive research approach. This type of approach was chosen since we had an unstructured problem to study and where hypotheses and questions regarding the subject were relatively unknown. In fig. 2.2 our research process is illustrated.

![Fig. 2.2 Our research process](image)
2.3 Literature review

A literature review was performed as a second step in our research with the aim to verify the relevance of our empirical findings with relevant theory. The literature also provided a base for logical understanding of concepts and theories relevant for the subject to be studied. In our research we found it necessary to perform literature reviews on communication, BIM and ICT theory. The sources used were e-journals, printed books, articles and some dissertations.

2.4 Research methods - Qualitative and Quantitative

There are two basic groups of research methods that can be used in a research: quantitative and qualitative. The methods refer to what techniques that are used in order to gather research information and are based on the research design chosen. The relation between quantitative and qualitative methods and techniques are illustrated in fig 2.3 (Ghauri and Grønhaug, 2010, p. 107):

![Fig. 2.3 Qualitative and quantitative research methods and techniques](image)

As mentioned earlier we used an exploratory research. In this type of research, qualitative methods are preferable to use. In order to answer our research question we used four case studies. This method is useful when the subject to be considered is hard to study outside its natural setting and is suited for exploratory research (Ghauri and Grønhaug, 2010). Further we used semi-structured interviews as a qualitative technique. The purpose of using semi-structured interviews was related to do the fact that:

- We had research areas that were exploratory in nature which made it hard to formulate and isolate specific questions related to the research areas.
In contrast to structured interviews, we believe that they could capture relevant ideas, thoughts and attitudes related to our research subjects in a more efficient manner.

2.4.1 Interviews - population and sample size

In order to obtain satisfying results and be able to make generalizations based on the results, researchers carefully need to select sample populations (Ekmekci, 1997). In our research we used three different population samples in order to get relevant answers to questions related to the subjects of communication, BIM and work preparations. The interviewing guide and interview questions are found in appendix 1 and 2. In fig. 2.4 our different populations and sample sizes are presented.

As illustrated in the figure above we performed interviews in two different construction processes: the detailed design and the production phase. The purpose of choice had to do with the fact that BIM knowledge and related process are usually owned by the detailed design and the line organization. Work preparations are, on the other hand, a production process performed in the project environment and hence in the temporary organization. The figures within the brackets illustrate the sample size in each population.

Furthermore, the production population consisted of two subpopulations: project administrators (PA) and skilled workers (SW). These interviewees were gathered from four different projects at Skanska: two housing projects and two commercial projects. The reason for inter-
viewing people from two different types of construction facility areas was that we wanted to widen the research input.

2.5 Reliability and validity

The value of the study performed is determined by the reliability and validity of the research. Reliability refers to the quality and accuracy of the qualitative or quantitative study and whether the results can be reproduced using the same methodical approach (Joppe, 2000 in Golafshani, 2003).

Validity refers to that correct methods have been used to find adequate answers that are relevant to the study and research question at hand, and whether the research measures truly measure what was intended from the beginning (Joppe, 2000 in Golafshani, 2003).

These two important aspects have been taken into consideration through the whole research process and will be discussed in the analysis chapter.
3. Theory

This theory chapter consists of two sections. The first section provides a background of communication theory from a general perspective. It aims to illustrate the essential elements of communication in information transfer and the importance of effective communication in construction projects. Furthermore barriers for effective communication are presented in order to give an insight in what obstacles that may be present for achieving effective communication.

The second section provides an introduction to ICT and a deeper insight in BIM technology, which has become a prominent ICT tool in the construction industry. It this section emphasis is put on what possible beneficial aspects there are if construction organizations effectively can implement various BIM applications. It further pinpoints what obstacles that need to be considered and overcome in order for construction organizations to benefit from BIM adoption.

3.1 Communication in construction

Effective communication between individuals, teams and organizations is an important factor for success in construction projects (Dainty, More and Murray, 2006). Clampitt and Downs (1993) in Kulvisaechana (2001) support this statement and demonstrate that effective communication and productivity are highly correlated. It is not only essential for collaborating human activity, but also a fundamental element on organizational level where communication contributes to a learning organization (Barker and Camarata, 1998 in Kulvisaechana, 2001). Although the construction industry relies on effective communication settings, it is hard to accomplish such environment in a project-based industry (Albino, Garavelli and Gorgoglione, 2004). This because the project setting is characterized by being people intense with vast information flows and where the communication patterns are dynamic, spontaneous and informal (Wikforss and Löfgren, 2007). Problems in the project setting related to noise, distraction and other forms of barriers that affect the information flow and inhibit effective communication between individuals (Dainty, More and Murray, 2006).

Theories about communication dates back many hundreds of years, but it is not until the twentieth century that theorists have defined what we today now know as communication theory (Dainty, More and Murray, 2006). Before going deeper into communication theories, a
definition of communication is necessary. Torrington and Hall (1998) define communication as “transmitting messages from one person and the receiving (and successful understanding) of those messages by another” (Dainty, More and Murray, 2006, p.55).

This definition of communication consists of three features. The first is the transmission and reception of a message. This could either be verbal or non-verbal depending on what channels and mediums that are used in the process. The messages that are transmitted are representations of a person’s thoughts, feelings, beliefs and attitudes, which is why the messages are not always easy to interpret by another person (Agarwal, 2010).

The second feature is that communication involves at least two persons, one that is transmitting the message (the sender) and one that is receiving it (the receiver). The role of these two is essential for effective communication since the encoding and decoding of the messages is dependent on the sender’s and receiver’s communication skills (Baguley, 1994 in Dainty, Moore and Murray, 2006).

The last feature of the definition deals with the communication process and how the message is sent between individuals. According to Stohl (1995) in Kulvisaechana (2001) communication can be either directional (one-way) or bidirectional (two-way), where directional communication is transfer of information from one person to another. The first does not allow information to be sent back to the sender. Bidirectional communication on the other hand allows information to be sent back and forth between the sender and receiver and is more dynamic to its nature than directional communication. This is also why bidirectional communication is preferable in the construction industry and in a project-based settings (Dainty, More and Murray, 2006).

3.1.1 The communication processes

This section provides a deeper insight in the bidirectional process since it is more preferable in the project setting.

A model that explains the two-way communication process is shown in fig. 3.1 (Philip Bagulay, 1994, p.57). This model shows an iterative process where at least two persons share information back and forth through different channels and mediums. The channel refers to the conduit through which the message passes, such as a telephone, a letter, a meeting etc, while
the medium refers how the message is transferred, e.g. through writing, speaking, illustrating etc. (Dainty, More and Murray, 2006).

The model illustrates three essential parts of the communication process (Dainty, More and Murray, 2006):

- The internal process of encoding/decoding the message by the sender and receiver.
- The manner in which the information is transferred.
- The actual transfer of the information through the channel.

Notable is that “noise”, which is any kind of distraction in communication or distortion of the message, is present in all processes. This means that effective communication is not only dependent on the channel and medium, but also on the individuals themselves during the process of encoding and decoding a concept.

![Diagram of the bidirectional communication process]

**Fig. 3.1** The bidirectional communication process

As mentioned in the beginning of this chapter the project setting is characterized by complex and dynamic communication patterns, which is why effective communication often fail. This has made it essential to find new approaches towards improving communication. In order to do so it is necessary to identify what factors that lead to less successful communication and where improvement efforts have to be made. Dainty, More and Murray (2006) describe that effective communication in the model above rests upon four essential factors:

- The effectiveness of encoding and transmitting the information through systems, channels and networks.
- The appropriateness of communication channels and mediums used to transfer the information.
The “receivers” ability to decode, interpret and act on the information.

The ability of those communicating to minimize the noise in all processes.

The effectiveness of encoding information has been a problem in the construction industry for many years. As described by Moore and Dainty (2000) in Dainty, More and Murray, 2006 many of these problems originate from differences in culture, education, language, professions etc, which make it hard for people to understand and interpret each others’ messages. Further, a possible obstacle in the encoding and decoding process is posed by Agarwal (2010) who reasons about the semantics, i.e. the meaning of words, saying that a reason for misinterpretations and failure in successful decoding of messages lie in the different meanings of words. The words that the sender uses might not have the same meaning to the receiver, which is why a distortion of the message occurs (Agarwal, 2010).

As the construction industry is non-isolated with many actors involved, the choice of effective communication channels and mediums is also a wide spread challenge (Dainty, More and Murray, 2006). As expressed by Shelby (1998) in Kulvisaechana (2001, p.19-20) “appropriate choices of channel communication’ are those most likely to result in communication effectiveness and efficiency”. Looking at the information transfer within the project organization, the choice of channel and medium has an important bearing of the empowerment process since it influences whether the communication is one-way or two-way, where the one-way tend to undermine involvement and empowerment (Dainty, More and Murray, 2006). In an organization where employees are empowered, i.e. given control and have the ability to make their own decisions, set goals, accomplish results and receive rewards, they tend to be more productive, proactive, intrinsically motivated and more committed than employees that are not empowered (Whetten and Cameron, 2001).

As stated earlier, effective communication is dependent on the individuals themselves and how they perceive and handle the information. Depending on the characteristics of the concept that is to be transferred, the choice of channel and medium plays an important part in the receiver’s ability to decode and interpret the information. A study by Westmyer, DiCioccio and Rubin (1998) showed that people perceived oral communication in form of open discussions and conversations to be the most effective medium for communicating since it allows immediate feedback from the receiver. Armstrong (2001) in Dainty, More and Murray (2006) support this theory by stating that non-verbal communication can lead to misinterpretations. In the project setting the communication process is characterized by conveying detailed in-
formation about project variables such as design intent, economical feasibility and time schedule etc. The need for alternative mediums to be used in the communication process is therefore important in order to secure successful information transfer between the sender and the messenger (Torrington and Hall, 1998:121 in Dainty, More and Murray, 2006)

Moreover, the decoding and interpretation of the message is dependent on more factors than just the channels and mediums. As explained by Armstrong (2001) in Dainty, More and Murray (2006) factors like personal perceptions and preconditions, people hearing what they want to hear, difference in business language, emotions, noise etc. are factors that affect the interpretation and can inhibit effective communication

3.1.2 Additional barriers to effective communication

Even though factors for effective communication, such as previous presented, are identified it inevitably fails on some occasions due to a number of different barriers. Several barriers for effective communication have been presented by authors with different perspectives on its origin, such as the individual’s and the organization’s perspective (Dainty, Moore and Murray, 2006). In relation to these perspectives, barriers of effective communication will be presented.

3.1.2.1 The individual’s perspective

As stated earlier, successful understanding of the message is a prerequisite for effective communication. This means that the receiver has an important role in the communication, which is why Sheldrick-Ross and Dewdney (1998) in Dainty, Moore and Murray (2006) have identified barriers from the listeners’ perspective. They found that listeners have a selective perception, which means that they only hear and accept information that corresponds to their model of the world. Another problem is that listeners, instead of actually listening, are making their own assumptions of what the sender intend to communicate. Agarwal (2010) refer to this phenomenon as psycho-sociological where the receiver has a selective perception. He further states that the reason for difference in perception can be a cause of inadequate data, limitation of past experience and own believes and values. This means that information ‘gets lost’ the first time it is transmitted and that the decoding is based on wrong information.

Torrington and Hall (1998) in Dainty, Moore and Murray (2006) present factors such as stereotyping, cognitive dissonance and not paying attention as possible barriers for effective communication. The theory of stereotyping is closely correlated to Agarwal’s theory of selec-
tive perception and means that people tend to stereotype others based on socio-economic backgrounds, professions and perceived dispositions. Rather than listening to what others’ have to say they will hear what they expect the other person to say, which can lead to courses of actions that do not correspond with the needs of a particular situation.

In situations when barriers of cognitive dissonance are apparent, the individuals receive information that conflicts with their established believes, which leads to difficulties in understanding or responding positively to that information. In such situations the individuals will challenge or disbelieve the information (Torrington and Hall, 1998 in Dainty, Moore and Murray, 2006).

Not paying attention is another barrier that can cause disruptions in the communication process and may depend on many different factors, such as stress, lack of motivation and engagement and other types of noise. Being distracted and not paying attention often leads to individuals forgetting information soon after it has been communicated (Torrington and Hall, 1998 in Dainty, Moore and Murray, 2006). According to Agarwal (2010) the ability to deal with noise is the most common barrier in communication and also very difficult to control, which is why effective communication often fails due to these noise related barriers.

3.1.2.2 The organization’s perspective

Huczynski and Buchanan (2001) in Dainty, Moore and Murray (2006) have identified barriers that have their roots on the organizational level and these are inter alia power differences as well as the physical surroundings. Power differences refers to employees avoiding to communicate upward in the organization because they believe that superiors do not fully understand their needs. The physical surrounding, such as room layout, technical equipment etc, can have essential impact on the noise which then becomes a distraction for the people participating in the communication process (Agarwal, 2010).

3.1.2.3 Summary

Effective communication is reliant on effective listening skills as much as it is on communication skills according to Baugley (1994) in Dainty, Moore and Murray (2006). In order to have a successful information transfer it is essential that both the sender and the receiver are willing to listen, receive and process the information. But effective communication goes beyond just successful information transfer. It also involves successful ‘translation’ of the transmitted information into useful knowledge for the receiver. As Torrington and Hall (1998) stated in
Dainty, Moore and Murray (2006) the combination of several channels and mediums increases the chance of successful communication, since it enhances the sender’s possibility to choose an appropriate channel that helps the receiver in the process of decoding and interpreting the message.

The development of ICT has provided new possibilities to encode, transfer and decode information in such way that the receiver’s possibilities to interpret the information is more consistent, which helps to minimize the misinterpretations without reducing important information (Albino, Garavelli and Gorgoglione, 2004).

3.2 ICT and BIM in construction

In an increasingly global and competitive market and with pressure from clients and internal organizations to increase the return on investment (ROI) in performed projects, state of the art technological aids have emerged in order to minimize project costs, increase project control and amplify the construction industry’s productivity (Chelson, 2010; Eastman, Teicholz, Sacks and Liston, 2008; Lurey and Raisinghani, 2001 in Dainty, Moore and Murray, 2006).

According to Lutz and Gabrielsson (2002) one of the reasons for low productivity within the construction industry is due to an insufficiently competitive environment where the level of innovation is low. The importance of having construction organizations investing in modern technologies is a prerequisite in order to increase the competitiveness within the construction industry (Marcusson, 2000 in Lutz and Gabrielsson 2002). It is also a precondition for the organizations economical growth (Olander and Widén, 2010).

In the spirit of increasing productivity in the construction process, improving information and communication support via ICT implementation has become a strategic challenge for construction companies (Samuelsson, 2003 in Wikforss and Löfgren, 2007). ICT implementation requires careful and strategic planning at both the organizational and the project level in order to realize its full potential (Whyte, Bouchlaghem and Thorpe in Dainty, Moore and Murray, 2006; Ahmad, Russel and Abou-Zeid, 1994). Furthermore, the implementation and use of ICT in construction has made it possible for companies to gain a competitive advantage (Peansupap, Walker, Goldsmith and Wilson, 200-; Jacobsson and Linderoth, 2008, Dainty, Moore and Murray, 2006).
In recent years, BIM technology has develop to be one of the most promising ICT tools in the construction industry. In the following chapter a thorough description of the opportunities, benefits and obstacles of BIM implementation will be presented.

3.2.1 Building information modeling

This part gives a definition of what BIM is and an insight of what possibilities BIM enables when it comes to positively affecting important project variables. Both tangible benefits and intangible benefits will be presented. In addition, implementation and adoption obstacles with this state of the art technology are presented. These obstacles are separated into three different categories related to work processes, social context and technology. It should be noted that many aspects of the possible obstacles with BIM strongly correlate with the obstacles that ICT induces in construction organizations. The theory presenting obstacles will therefore include integrated aspects from both.

3.2.1.1 Introduction of BIM

BIM is an interrelated and interacting set of principles, processes and technologies producing a “methodology to manage the essential building design and project data in digital format throughout the building’s life-cycle” (Pentillä, 2006, p.403).

A BIM model is a virtual model which represents the future facilities physical and functional appearance (Azhar, Nadeem, Mok and Leun, 2008). BIM is one form of Computer Aided Design (CAD) that offers the opportunity to use n-dimensional models to enhance project deliverables. This by providing technical functions such as clash controls, diverse analysis opportunities, 4D and 5D applications meaning that models are connected to time schedules and cost calculations (Eastman, Teicholz, Sacks and Liston, 2008).

BIM tools provide opportunities for project members to control important project variables such as cost, time and quality in a more efficient and timely manner and early in the project make value creating decisions (Azhar, Nadeem, Mok and Leun, 2008; Fisher and Kunz, 2004). This is made available due to the increased information availability and the amplified information management that BIM provides (Ahuja, Yang and Shankar, 2009; Dainty, Moore and Murray, 2006). Moreover, BIM also offers extended visualization opportunities which advantageously can enhance communication and collaboration between project participants and hereby reduce any project process related problems (Peansupap, Walker, Goldsmith and Wilson, 2007; Wikforss and Löfgren, 2007; Ahmad, Russel and Abou-Zeid, 1994). From this
perspective, the benefits made available by the use of BIM have provided the construction industry with the opportunity to increase the productivity and take a step towards a more efficient production (Chelson, 2010; Love, Edwards, Han and Goh, 2010; Azhar, Nadeem, Mok and Leun, 2008).

Although the use of BIM is sought to represent a new paradigm of handling low productivity levels within the construction industry there are challenges and risks that have made the adoption of BIM much slower than anticipated (Eastman, Teicholz, Sacks and Liston, 2008; Fisher and Kunz, 2004). A prominent risk is the construction industry’s reluctance towards new innovations (Wikforss and Löfgren, 2007). Reasons for such reluctance are the lack of knowledge of how to use BIM and understand what benefits that can be attained (Singh, Gu and Wang, 2011). A great challenge is also to cope with the disturbances caused by BIM from a social context perspective (Love, Edwards, Han and Goh, 2010; Gu and London, 2010). In addition, management challenges involve that there are no clear guidelines or agreements on how to implement and utilize BIM within construction organizations (Azhar, Nadeem, Mok and Leun, 2008). In contrast to normally used delivery methods there are still no clear contractual agreements which can support the changes that BIM brings in regards to risk sharing, ownership of information and financial incentives (Sieminski, 2007; Wikforss and Löfgren, 2007). Furthermore technical constraints related to problems of interoperability between different BIM tools and exchange formats are obstacles to be considered (Eastman, Teicholz, Sacks and Liston, 2008).

3.2.1.2 Possible benefits of BIM adoption

Understanding the benefits that BIM provides is an essential driver for effective adoption (Ahuja, Yang and Shankar, 2009). Both tangible and intangible benefits are of interest in ensuring effective diffusion. Tangible benefits mean that they can be measured and quantified, e.g. decreased cost due to evaluation of building performance and cost estimation capabilities. In contrast, intangible benefits refers to that it is hard to estimate the actual benefit in quantitative terms, such as improved product quality, better decision-making capabilities and increased availability of information (Becerik-Gerber and Rice, 2010). In the following section possible benefits will be presented.
**Tangible benefits of BIM**

When a construction project is initiated the architect will perform the conceptual design according to the clients’ requirements. If a BIM model, with the right level of detail, is designed the client and the contractor can get an indication on the *feasibility to perform a project* according to given size, quality, budget and program requirements (Eastman, Teicholz, Sacks and Liston, 2008). This feature is made available since the BIM model is a virtual representation of the future facilities physical and functional appearance (Azhar, Nadeem, Mok and Leun, 2008). This beneficial aspect can be referred to what Winch (2010) describes as minimizing the client surprise by performing value engineering which is “a conscious and explicit set of disciplined procedures designed to seek out optimum value for both initial and long-term investment” (Cullen, 2010). From this perspective BIM is used as a strategic business tool in estimating feasibility and possible economical benefits for the contractor and the client.

Further, BIM tools not only provide a framework for evaluating the feasibility of a project. It also provides the possibility to *evaluate the building’s performance* according to regulations regarding functionality and constructability (Eastman, Teicholz, Sacks and Liston, 2008; Azhar, Nadeem, Mok and Leun, 2008). In addition, the possibilities to perform alternative analysis, e.g. energy analysis and life cycle analysis of the virtual model, can be especially valuable if the project scope includes designing a building according to certain environmental certificate standards such as Leadership in Energy and Environmental Design (LEED). To perform an extensive sustainable analysis early on in the design stage is a feature that a traditional design approach has not been able to provide (Azhar, Carlton, Olsen, Ahmad, 2011). In accordance with aforementioned, BIM provides the opportunity to perform value engineering in an early stage and during the production phase which enables the design team and PA to ensure the design intent (Azhar, Nadeem, Mok and Leun, 2008).

Moreover, having a digital representation of the physical building enables the design team and PA to evaluate the design performance and to *detect design errors* before and in the production phase, see fig. 3.2 (Veidekke, 2012). This refers to ensuring constructability by detection of clashes between different building components and installation systems (Chelson, 2010; Eastman, Teicholz, Sacks and Liston, 2008; Fisher and Kunz, 2004; Azhar, Nadeem, Mok and Leun, 2008). This can allow the project team to perform quality control at any given time in the project (Wu and Hsieh, 2011). Clash detection is presently the mostly used metrics for evaluation of economically related benefits of BIM (LeFevre, 2011). The value of detecting
clashes is according to Smith (2009) in Chelson (2010) equivalent to a majority of all the change order expenditures due to deviations in the design. Accordingly, Geil and Issa (2011) state that studies have shown that the use of BIM decreased the amount of change orders by approximately 40%.

![Clash detection](image)

**Fig. 3.2 Clash detection**

In addition, BIM tools provide the opportunity to perform *quantity takeoffs and cost estimations* (Chelson, 2010; Eastman, Teicholz, Sacks and Liston, 2008; Fisher and Kunz, 2004; Azhar, Nadeem, Mok and Leun, 2008). From the BIM model quantities can be extracted and form a basis for a bill of quantities which can be used in the procurement phase of a project. This is of value since traditional approaches of quantity takeoffs often are insufficient (Sabol, 2008). In addition, the quantity takeoffs can be used as foundation early on in the project to control costs. In traditional design approaches rough order of magnitude (ROM) estimates are preformed (Gould and Joyce, 2009). This as the building’s physical and functional appearance according to the client’s demands is not yet determined. There is hence less information of the final design of the facility. BIM provides the opportunity to increase the accuracy of the cost estimation process by increased information availability (Sabol, 2008). The cost estimation capabilities are of value for both the contractor and the client. In a design/build delivery method the contractor can perform cost estimation in early design to establish the cost baseline for the project and to optimize the design to honor the client’s budget (Eastman, Teicholz, Sacks and Liston, 2008). It is hence of internal benefit for the contractor since BIM provides
the opportunity for early cost control and for the client as their quality requirements can be optimized in relation to costs.

Furthermore, the designed BIM model can be of value in *facility management* since it provides a source of information on the physical buildings’ components and installation systems (Eastman, Teicholz, Sacks and Liston, 2008). In the BIM model, important information in terms of manufacturer specifications and maintenance instructions can be attached to building and installation components in order to provide an accurate information base for clients and operators (Sabol, 2008), see fig. 3.3 (Veidekke, 2012). In order for the model to be useful for facility management it is a prerequisite that early design input is performed so that necessary information is incorporated into the model. This means that the client must set clear demands and goals on what is expected in terms of integrated facility management via BIM. Second, manufacturers and suppliers need to provide information on facility component traits so that the design team can evaluate and integrate it into the model (Eastman, Teicholz, Sacks and Liston, 2008).

**Fig. 3.3** Facility management

**Intangible benefits of BIM**

*Benefits related to information availability*

The project setting is characterized by a vast number of related activities and there execution is dependent on project participants making qualified decisions based on project variables such as time, quality, economy and risks. Due to the nature of construction activities there is a
certain level of task uncertainty which has be to put into relation to project participants having appropriate information to make qualified decisions (Maggiolini, 2011).

Moreover the quality of the decision will depend on what information that is available. In traditional projects, the different project participants in the production environment have their own information which is structured and suited for their specialized needs. Hence the amount of information that can be jointly shared is limited due to the lack of a central source of information (Wu and Hsieh, 2011). This makes it hard to mutually decide how a production activity is to be performed. By having a BIM model that works as a central information source the decision making process can be enhanced, which traditional project tools have not offered. Using BIM, core competences can gather to jointly decide and address onsite related problems more effectively (Zeng and Tan, J. 2007; Ahmad, Russel and Abou-Zeid, 1994).

The need for quick access to real-time, updated and reliable information that can be shared among project participants is therefore an essential part of reducing the specific task related uncertainty. This to increase the possibilities of delivering an outcome which is satisfactory (Wu and Hsieh, 2011). This implies that effective information channels and management is a prerequisite to reduce the overall project mission uncertainty (Winch, 2010). From this perspective, BIM and other ICT tools can favorably provide the project participant with the right information at the right time to perform decision making tasks in the production environment (Ahuja, Yang and Shankar, 2009; Dainty, Moore and Murray, 2006). BIM tools hereby provide the possibility to reduce the chance of project participants making poor decisions since the information availability is widened in scope. As a result the amount of design changes in the production environment can be reduced (Chelson, 2010)

Moreover, when looking at the project life cycle of a construction project the mission uncertainty is highest in the beginning and then decreases as the project develops (Winch, 2010). As seen in fig. 3.4 it is in the detailed design where the uncertainty is at its highest (Winch, 2010, p.7).
At the same time, it is in early project stages that the design team has the most favorable possibility to make essential decisions that will affect project outcomes. This is illustrated in fig. 3.5 (Griem, P., 2009).

In early stage of project development, i.e. the detailed design, the level of information available to support essential decisions and perform value engineering is low (Winch, 2010). By performing BIM design in an early stage of a project, the design team can increase the amount of information available and act upon it. The information asymmetry between required information to take a decision and the information available can hereby advantageously be decreased. This is illustrated by the red curve in fig 3.6 where dynamic uncertainty decreases and the certainty increases (Modified, from Winch, 2010, p.7).
This will provide the foundation from which important project goals and variables can be met more effectively (Alshawi and Ingirige, 2002 in Ahuja, Yang and Shankar, 2009). This as the ability to impact cost and functional capabilities will increase.

**BIM as a visualization and communication tool**

According to Fisher and Kunz (2004) the most significant improvement potential in the design and construction of a project lays in the interface between the projects participants. A key challenge is therefore to establish an environment where integration between various participants is possible (Ahmad, Russel and Abou-Zeid, 1994). From aforementioned perspective and in a fragmented project environment it is essential for project participants to share information via effective communication channels (Winch, 2010; Ahmad, Russel and Abou-Zeid, 1994). This due to the fact that construction projects naturally consists of many different stakeholders who are dependent on each other’s performance and hence effective communication is a prerequisite to meet the project goals. Having an effective communication process between project participants can beneficially create a foundation from which important project variables, such as costs and quality, can be improved (Alshawi and Ingirige, 2003).

In the project environment the traditional and primary communication channel to transfer information comprise of 2D paper based documentation and graphics although it is argued to be an insufficient way of communicating (Eastman, Teicholz, Sacks and Liston, 2008; Chelson, 2010; Meyer, 1991 in Ahmad, Russel and Abou-Zeid, 1994; Sacks, Radosavljevic and Barak, 2010). Its insufficiency is related to that this communication channel does not enhance a com-
prehensive understanding of the project scope and the project status. The project participants hereby lack intuitive and user friendly visualization tools to make information explicit (Wu and Hsieh, 2011).

In contrast to 2D based communication channels, BIM supports and provides visualization of design and production processes (Chelson, 2010). The development of 3D visualization through accurate BIM models has pushed the potential of visualizing the physical and implicit functional means of a facility which are of great benefit for project stakeholders (Winch, 2010). This relates to what Sacks, Radosavljevic and Barak (2010) calls process transparency, which is the ability for project participants to visualize production processes in order increase control and understanding. BIM hereby provides the capability to alter the dynamics of communicating design intention and design review (Winch, 2010). BIM helps construction professionals to simulate the future built environment and hereby identify possible design, production and operational issues (Salman, Nadeem, Mok and Leun, 2008), see fig. 3.7 (Veidekke, 2012).

According to Sacks, Radosavljevic and Barak (2010) effectively communicating design intent is one of BIM’s key functionalities and that it provides the opportunity to convey information in dynamic views. This can enhance communication and discussion during project meeting (Wu and Hsieh, 2011). This will further enhance insufficient ways of communicating design objectives to the SW during the production phase of construction (Sacks, Radosavljevic and
Barak, 2010). According to Formoso and Powell (2002) in Sacks, Radosavljevic and Barak (2010) important beneficial aspect of visualization in the production environment include:

- Improved motivation and engagement of SW.
- Increased involvement of SW in improvement efforts.
- Reduced tendency towards making errors since they are made visible.

All these aspects play an essential role in contributing to higher level of quality. Improved motivation and engagement of onsite SW is an important factor contributing to a higher level of performance (Whetten and Cameron, 2011). Increased involvement of construction workers makes it possible to effectively ensure constructability and reduce task associated risks since the construction workers expertise can be taken into consideration. Moreover, reduced tendency towards making errors will diminish the amount of changes that will have to be made and hence contribute to a higher level of quality and save costs (Love, Edwards, Han and Goh, 2010; Chelson, 2010)

3.2.1.3 Obstacles for ICT and BIM adoption

Desirable benefits can never be attained without construction organizations taking into consideration and being aware of what possible pitfalls BIM and ICT adoption may induce at the organizational and the project level. It is therefore important for organizations to understand and comply with the changes that new technology brings, in order to avoid damaging consequences (Dainty, Moore and Murray, 2006).

In recent years research within the area of ICT have focused on technical related issues rather than on inter-organizational, which has repressed factors such as social context and changed business processes (Peansupap and Walker, 2005; Wikforss and Löfgren, 2007). To consider the outcomes of interaction between such factors and technology is important (Monteiro and Hanseth, 1995, Orlikowski and Iacono, 2001 in Jacobsson and Linderoth 2008). Putting efforts into addressing organizational and people centered issues is essential since they pose great challenges for effective BIM implementation and adoption (Love, Edwards, Han and Goh, 2010; Gu and London, 2010). In accordance with aforementioned, Gu and London (2010) divide obstacles related to BIM adoption into three different categories:

- Work practice and process related issues.
- Social context issues.
- Technical issues.
As implied, the adoption of BIM induces vast changes for organizational practice and for employees involved in this process. The adoption of BIM has created several challenges which need to be overcome and appropriately met by construction organizations to benefit from possible opportunities. Above mentioned categorization will be used to, in the following section, present obstacles with BIM adoption.

**Work practice and process related issues**

*Changing and new business processes*

ICT technology is not just a set of technological tools aiming to improve old business processes. It is rather a mediator of innovation that involves re-engineering and creation of new business processes and strategies (Ahmad, Russel and Abou-Zeid, 1994; Jacobsson and Linderoth, 2008; Dainty, Moore and Murray, 2006). New processes will have to be adapted by construction organizations in order to benefit from the advantages provided by ICT and BIM enhancement. A great challenge presented before construction organizations is to handle these ICT mediated change processes which are ambiguous. In addition, consequences of implementation are hard to foresee due to an immature level of the users (Rosenberg, 1982, Ciborra, 1996 and 2000, Orlikowski, 1996, Orlikowski and Hofman, 1997 in Jacobsson and Linderoth 2008).

ICT enhancement will lead to an overall organizational change in routines and practices which requires well thought through strategic planning in the permanent as well as in the temporary organization (Ahmad, Russel and Abou-Zeid, 1994). This includes taking into account changes related to coordination, ensuring quality of the information and changing roles and responsibilities (Wikforss 2006 in Wikforss and Löfgren, 2007). In an environment of change the role of PA becomes even more challenging and more demanding. As mentioned above new technology adoption creates ambiguous and unpredictable changes in organizational processes and social structures, which are to be led by managers of construction organizations (Peansupap and Walker, 2005; Kling, 1980; Markus and Robey, 1988 in Jacobsson and Linderoth 2009). In addition, organizations are designed to create stability and predictable conditions to reduce the ambiguity of changing conditions (Whetton and Cameron, 2011). From this perspective, a crucial and hard task is therefore given to PA who have the responsibility to keep the organization in equilibrium. Therefore, the nature of the organizational structure is contradictory to the PA leading change of new technological enhancement.
A present problem that the PA have to face is that there are no clear guidelines or agreements on how to implement and utilize BIM within construction organizations (Azhar, Nadeem, Mok and Leun, 2008). It is therefore to establish standardized processes to support BIM usage and to define guidelines for its implementation (Azhar, Nadeem, Mok and Leun, 2008; Howard and Björk, 2008).

Lack of integration between the design and production processes regarding ICT and BIM usage

A great obstacle that is present before and during implementation of various ICT tools is the gap between the use of ICT technologies in the permanent and in the temporary organization. ICT applications supporting production processes are less common than ICT support in the permanent organization since they are not suitable or ‘ready packed’ in order to fit the project based organization’s working processes (Jacobsson and Linderoth, 2008; Wikforss and Löfgren, 2007). The majority of ICT systems and tools are often designed to be used in the permanent organization. When pushed out in the project setting it creates ineffective administrative work routines and gives restricted support to the mobile work environment of onsite personnel (Wikforss and Löfgren, 2007). This results in that the expected benefits in the project setting are unattainable.

Above mentioned lack of alignment of technology to production related processes has also caused a digital divide between the design and production phase in construction projects and between individuals that are digitally enriched and those who are not (Dainty, Moore and Murray, 2006). This gap has affected the onsite personnel’s frame of reference and created a reluctant view from the project organization in adapting new technologies.

In order for the project organization to adapt and experience benefits of adoption it is a prerequisite that alignment between current production process and available tools are performed (Hartman, van Meerveld, Vossebeld, Adriaanse, 2012; Wikforss & Löfgren, 2007; Callon, 1986 and Linderoth, 2007 in Linderoth and Jacobsson, 2008). For organizations to ready pack technological solutions for the production environment is essential to ensure effective diffusion (Linderoth and Jacobsson, 2008)

From an integrating and alignment perspective an important aspect to consider is the incorporation of construction knowledge (Eastman, Teicholz, Sacks and Liston, 2008; Ahmad, Russel and Abou-Zeid, 1994). This refers to the personnel in the temporary organization having demands on what technological tools that can support the production related processes. Accord-
ingly, Gu and London (2010) state that there is limited articulation of needs of technical requirements for BIM from the temporary organization. From the perspective of BIM, this refers to that there is a need to have an information demand from the project organization in order to align the use of BIM and to create a foundation for satisfactory output in the production environment.

**Contractual changes – economical incentives and ownership of information**

An essential factor for how effectively different project participants can make use of the BIM technology benefits is the chosen delivery method and whether the design is performed by external consultants or by in-house staff. A present issue in regards to this matter is to what extent different participants can divide the economical benefits of BIM in-between the different disciplines. In general, the design-build and other forms of collaborative delivery method approaches enable better opportunities for the contractor and the client to benefit from BIM adoption, since the design in performed in-house (Eastman, Teicholz, Sacks and Liston, 2008). It is therefore important to find alternative approaches to deliver a facility that creates a win-win situation for all stakeholders, since economic incentives will create a foundation for the adoption of BIM (Becerik-Gerber and Rice, 2010).

Furthermore, a collaborative project environment where interoperability issues are solved is, in accordance with aforementioned, a prerequisite for effective BIM adoption. In this environment, processes of mutual information sharing and distribution through BIM contribute to several beneficial aspects (Fisher and Kunz, 2004). At the same time this also poses a challenge upon who owns the right to valuable information such as design input information, simulation, diverse analysis information and the actual BIM model (Azhar, Nadeem, Mok and Leun, 2008).

Moreover, not only are the owner rights of information a possible legal concern. Another present risk is the division of responsibility for maintaining and updating the information in the collaborative designed model (Sieminski, 2007). This posed risk is a challenge since designers and contractors are not willing to take responsibility for the accuracy of information if the contractual establishment are not supportive or understood (Chelson, 2010).

As implied there is a need of establishing guidelines for a contractual agreement in order to cope with such problems as stated above. At the present stage of development, professional groups such as Associated General Constructors (AGC) and American Institute of Architects
AIA) are developing contractual guidelines that can address legal concerns related to collaborative use of BIM (Eastman, Teicholz, Sacks and Liston, 2008).

**Social context issues**

ICT adoption does not only induce a changed technological environment. The employees, regardless if employed in the temporary or permanent organization, will be affected by such innovative change. According to Kling (1980), Markus & Robey (1988) and Orlikowski (1992) in Jacobsson and Linderoth (2009) the importance of the social context of adoption cannot be neglected. Not taking this important factor into consideration in the implementation stage could lead to failure or misaligned usage (Lucas, 1975 in Jacobsson and Linderoth, 2009). The greatest challenge of achieving acceptance among users, and hence effective diffusion, is to understand the socio-technical gap and what challenges it poses on processes of social interaction (Aryici, Aouhad and Ahmed, 2005; Aranda-Mena and Wakefield, 2006 in Gu and London 2010; Peansupap and Walker, 2005). Balancing the social nature and collaborative environment of construction projects with the implanted structure and functionality of technology is hereby crucial (Wikforss & Löfgren, 2007).

**Changing roles and responsibilities**

In a BIM enhanced environment, as a result of new ways of working and new processes to adapt to, interpersonal roles and relationships within the permanent and temporary organization will change (Gu and London, 2010; Eastman, Teicholz, Sacks and Liston, 2008). Traditional roles of project participants will be disturbed (Gu and London, 2010; Wikforss and Löfgren, 2007). Implementation of BIM will require that individuals within the organization gain interdisciplinary knowledge and expertise (Ahmad, Russel and Abou-Zeid, 1994). In addition, new roles will also be introduced into the organization (Eastman, Teicholz, Sacks and Liston, 2008).

The individuals’ roles and responsibilities within the organization play a vital role in the diffusion of technology and will determine what benefits that can be achieved from adoption (Wikforss and Löfgren, 2007). The permeation of BIM and ICT technology will depend on gatekeepers who will act as mediators of information and knowledge from external sources to the project organization (Peansupap, Walker, Goldsmith and Wilson, 200-). These gatekeepers or knowledge workers have been identified as being mostly middle level managers within construction organizations and especially those who run the daily operations in the project
setting (Alshawi and Ingirige, 2003). These individuals will act as intermediate points between the temporary project and permanent organization in adoption and application of technology and will also generate the highest potential ROI by adapting and using available applications (Alshawi and Ingirige, 2003). Identifying those individuals within the project organization is therefore a central task for the top management.

Training and education

According to Gu and London (2010) there is lack of training in how to use BIM applications and lack of awareness of possible benefits of BIM. In compliance Love, Edwards, Han and Goh (2010) express that there is a skill shortage among production personnel on how to use BIM. Further, Pfitzner et.al (2010) has identified that one of the main changes required in enhancing BIM usage at the project level is the training of staff. This view is further verified by Yan and Damian (200-) who in their study of benefits and barriers with BIM found that very few within the Architecture, Engineering and Construction (AEC) industry in UK and USA have knowledge about BIM and its capabilities.

To educate personnel in using new technologies is a primary organizational factor and essential for successful implementation (Peansupap and Walker, 2005; Howard and Björk, 2010). It therefore becomes important to provide adequate employee support and training in regards to motivate them in adopting the new technology (Gu and London, 2010; Young, 2008 in Chelson 2010). It is further essential to increase the lack of awareness since it will create the foundation for understanding the added value provided by BIM. In compliance with Peansupap, Walker, Goldsmith and Wilson (200-), Howard and Björk (2008) state that new roles may be required to spread BIM knowledge within the organization and to assure effective BIM implementation. A key question posed by them is how this role should be built in and represented within the construction process.

Furthermore, to provide sufficient training is an organizational and managerial task. Therefore, managers need to create an environment based on trial and error learning (Fleck, 2002 in Wikforss and Löfgren, 2007). A present problem is that to practice such learning may be hard in the project environment, due to the project traits of a limited timeframe and economical recourses (Alshawi and Ingirige, 2003). The costs associated with relevant training in terms of resources and time wastage has also contributed to a reluctance towards effective implementation (Yan and Damian, 200-). From this perspective it makes it an important task for the organization and managers to evaluate what is the most appropriate way of providing support
and training, as well as to angle the training towards production managers (PrM) that can give the highest ROI.

Technical issues

Problems of interoperability

According to Fisher and Kunz (2004), Ahmad, Russel and Abou-Zeid, (1994) and Alshawi and Ingirige (2003), a great challenge is to ensure effective collaboration between project participants by solving issues of integration. A problem in the project environment is that numerous of the project participants use different information distribution systems, which make the sharing of information and the communication between participants ineffective (Wu and Hsieh, 2011; Eastman, Teicholz, Sacks and Liston, 2008). From a technical perspective this mainly concerns data exchange formats and hardware and software systems used in the project (Alshawi and Ingirige, 2003). In order to attain a desirable level of interoperability and integration for effective BIM adoption it is of great importance that open standards, such as Industry Foundation Classes (IFC) are used (Wu and Hsieh, 2011; Zeng and Tan, J. 2007). Another alternative is to solely trust the software vendors to develop technical interfaces between different BIM tools although this approach is less favorable (Bernstein, 2004 in Chelson 2010). However, this problem is still present since there is a great deal of development needed in regards to technical aspects of information exchange and what contractual changes open standard usage presents.
4. Empirics

The start of this chapter presents a brief introduction to the construction company Skanska Sweden AB. In addition, this chapter consists of two sections in which the empirical results are presented. The first section presents Skanska’s present work preparation process and what obstacles that have been identified that hinder an effective process. The second section provides an insight in the current BIM maturity level within Skanska and further how this is reflected in their practical work. It also pinpoints identified issues in the current BIM work process and what obstacles that need to be overcome to ensure effective BIM adoption in the production environment.

4.1 Presentation of Skanska Sweden AB

Skanska Sweden AB is a part of Skanska Group, which is one of the world’s largest construction companies with a leading position in several home markets in Europe, USA and Latin America. Skanska is, besides construction, also active in project development in selected markets in the residential and commercial property fields, and also in the infrastructure through public-private partnerships (PPP). The Skanska Group has approximately 53 000 employees, of which 10 000 are working at Skanska Sweden. In the year 2011 Skanska Sweden presented revenue of approximately 27 billion SEK in 2011 (Skanska, 2012).

By using the global experience combined with the local presence, Skanska acts as a local company with global strength. Their aim is to be the leader in development and construction of green projects, where all projects shall be performed according to their code of conduct and the five quality targets (five zeros): zero loss-making projects, zero accidents, zero environmental incidents, zero ethical breaches and zero defects.

Skanska’s mission is to “develop, build and maintain the physical environment for the living, traveling and working” and their vision is to be “a leader in its home markets – the customer’s first choice – in construction and project development” (Skanska, 2012).

4.2 Work preparations at Skanska

Before initiating the production phase in a construction project it is important to review what activities that have to be thoroughly prepared in order to avoid disorders during the actual execution of the task on site. These preparations are referred to as ‘work preparations’ and are
often conducted for activities that can have essential impact on the project, environment or personal safety (Skanska, 2010).

Activities that should be prepared are those that inter alia are extensive, technically complicated, economically important, highly resource demanding and risky from a personnel safety and environmental aspect. During a work preparation, which is often performed a few weeks in advance, the activities are analyzed and documented by the PrM together with the SW that are involved in the execution of the task. The purpose is to plan how activates should be performed in order to stay on time, keep within budget and provide the quality that is expected (Skanska, 2010; Skanska interviews, 2012).

In order to fulfill the purpose of a work preparation it is necessary to focus on some milestones such as appropriate working methods, necessary tools and equipments, adequate resource base, working environment, material waste, environmental impact, safety etc. Depending on the activity and its impact on the project, some milestones might be more prioritized than others (Skanska, 2010; Skanska interviews, 2012).

A production activity can be done in numerous ways, and it is hard to tell which is better than the other. Depending on the conditions on site, some methods are to be preferred over others, why it is important to prepare the task in advance together with the relevant SW who are the experts in construction. By involving them in the preparation phase, Skanska is working towards their purpose of “utilize everyone´s competence, secure the working environment, quality and environment and also increasing the predictability of productivity” (Skanska, 2010).

The following section describes Skanska’s standardized work preparation process and what sub-activities there are under each phase.

4.2.1 Process and internal guidelines

Skanska have a well-established work preparation process which consists of four steps, seen in fig. 4.1. One of the main focuses behind this process is to increase the employee involvement and take advantage of the in-house competence provided by the SW to adequately prepare an activity (Skanska, 2010).

Each step consists of sub-activities that have to be carried out before moving to the next step. Below an explanation of the four steps are provided and what responsibilities different people have in each step.
**Fig. 4.1** Skanska’s four-step process for work preparations

### 4.2.1.1 What activities should be prepared?

During the detailed design a risk analysis is made where risks regarding finance, procurement, production, safety, environment etc. are taken into consideration. This document is the basis for an early draft of which activities that should be work prepared. It is foremost the site manager (SM), the project manager (PM) and the project engineer (PE) that are involved in this first draft of what activities that should be prepared (Skanska interviews, 2012).

As the production progresses a continuous dialogue should be held between the PrM and the SW, subcontractors and side contractors in order to identify additional activities that should be work prepared. The purpose of involving the SW and other production personnel is to set the level of which activities that should be prepared and which should not (Skanska, 2010).

According to our research Skanska is advocating a high employee involvement in the beginning of the process since it is important to get the input from the SW who are important knowledge carriers of the production environment. If they have their say, they get more involved in the activity and become more motivated to improve the outcome (Skanska interviews, 2012).

### 4.2.1.2 Preparation time

The preparation time is the time from when the SW and subcontractors are informed that a work preparation meeting is going to be held until the point at where it is held. This information should be communicated out in advance in order to give the workers sufficient time to prepare. There is no guideline for how long in advance this information should be sent out since it depends on the complexity of the activity (Skanska, 2010).

By informing relevant SW that a work preparation is going to be held, they have time to reflect over the work and how it can be done. Moreover, they have time to review drawings and other documents for the activity. The more time the workers have to prepare for the meeting, the greater are the chances to get a successful meeting where everybody contributes with their knowledge (Skanska interviews, 2012).
But the preparation time also give the PrM, who are responsible for the meeting, time to prepare additional documents and drawings that have to be considered. As Skanska work with standardized construction solutions the PrM have time to review those solutions and get good input on how the work preparation can be improved. Other documents that are of interest during the meetings are time schedule, prior work preparations, financial plan etc, which preferably also should be distributed in advance (Skanska, 2010).

4.2.1.3 Work preparation meeting

During the work preparation meeting the PrM, together with the SW and/or subcontractors, plan and coordinate the activity. In some cases, where the activity involves high safety risks and/or are more complicated, a safety officer (SO) or other expert should attend the meeting with the purpose to assure personal safety and to anticipate hazardous and unsafe situations (Skanska, 2010).

The time the participants have to prepare for the meeting during the preparation time should result in an active and communicative meeting where the SW’s ideas and thoughts are brought up. The PrM has a moderator role where he or she needs to make sure that the SW get their chance to speak. Skanska have also developed a standardized agenda, which is used for the meetings. This agenda treats demarcations of the work preparation, requirements and risk identification regarding safety and environment and how these are prevented. Focus also lies on the required resource base, financial situation, time schedule etc. If this agenda is followed during the meeting, the chances of having a successful work preparation and execution on site increases (Skanska interviews, 2012).

4.2.1.4 Follow-up

After completion of an activity, a follow-up meeting is held with the purpose to highlight what went good and where improvement have to be made. Deviations from the work preparation are noted and should be discussed during the meeting. Participating in these meetings are the PrM and the SW that have performed the task. Sometimes it is enough to have a representative from the SW-team who has gathered the other workers’ thoughts (Skanska, 2010).

The idea with the follow-up meeting is to improve the choice of methods by documenting possible pitfalls, which then can be used in future projects. This means that the documentation is an important part of the meeting, especially when knowledge transfer is advocated in Skanska. By having an up-to-date work preparation with actual information regarding time,
resources, costs etc, it can not only be used as inspiration and support for future projects, but also for invoicing (Skanska, 2010).

4.2.2 Identified obstacles in the work preparation process

Our research has shown that the way work preparations are conducted in the production phase deviate from Skanska’s four-step model and guidelines. These deviations often lead to an ineffective process where the result of the work preparation is not always optimal for the current project. In addition to these deviations our study has shown that there are communication barriers between SW and PrM, which make effective information transfer difficult to accomplish. As a result of our study, we have gathered the deviations and barriers that hinder an effective work preparation process in table 4.1. The result is based on interviewees from two categories; PrM and SW. The table illustrates the number of people from each category that has pointed out inhibitory factors based on their experience from work preparations.

Table 4.1 Factors that inhibit an effective work preparation process

<table>
<thead>
<tr>
<th>Factors hindering effective work preparations</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Temporary organization</td>
</tr>
<tr>
<td></td>
<td>Production managers, number of persons and percentage of group (7 interviewees)</td>
</tr>
<tr>
<td>Insufficient information distribution from production managers to skilled workers</td>
<td></td>
</tr>
<tr>
<td>Short preparation time</td>
<td></td>
</tr>
<tr>
<td>Communication barriers:</td>
<td></td>
</tr>
<tr>
<td>• Misunderstandings in verbal communication</td>
<td></td>
</tr>
<tr>
<td>• Difficulties in interpreting 2D-drawings</td>
<td></td>
</tr>
<tr>
<td>• Inability to visualize 2D-drawing into 3D-thinking</td>
<td></td>
</tr>
<tr>
<td>• Few or inappropriate use of communication channels/mediums</td>
<td></td>
</tr>
<tr>
<td>• Information overload/inability to handle ‘future’ information</td>
<td></td>
</tr>
<tr>
<td>Lack of motivation and engagement in meetings</td>
<td></td>
</tr>
</tbody>
</table>

- 38 -
Insufficient information distribution from production managers to skilled workers refers to a deviation in the second step in the four-step model by Skanska. The information distribution is fundamental in order to give the SW the possibility to prepare for the meeting. This factor refers to people who recognize that they have provided, or have been provided with, less information than the activity have required in order to thoroughly prepare for the meeting.

Short preparation time is close connected to the above mentioned factor and refers to the actual time the SW have to prepare for the meeting from the moment they have been provided with necessary information until the meeting.

During the work preparation meetings there are communication barriers that hinder an effective communication:

- **Misunderstandings in verbal communication** refer to language barriers between PrM and SW through verbal communication.
- **Difficulties in interpreting 2D-drawing** deals foremost with the SW varying ability to interpret and understand 2D-drawing.
- **Inability to visualize 2D-drawing into 3D-thinking** refers to the difficulties in imagining a third dimension to a 2D-drawing and the thereby visualize the end result in advance.
- **Few or inappropriate use of communication channels/mediums** deals foremost with the resources the PrM use during the work preparation and the lack of additional tools to enhance the communication process.
- **Information overload/inability to handle ‘future’ information** is the SW’s lack of ability to disconnect their thoughts from the current work and focus on the work preparation and its activity.

The result in lack of motivation and engagement during meetings refers to how many of the interviewees that have recognized low motivation and engagement with themselves and others
during the meetings. Low motivation and engagement implies that they are inactive during meetings and do not contribute with their competence, nor showing any interest of participating.

Poor knowledge transfer and reuse of knowledge/experience from previous projects is based on that there is no good strategy of how to take advantage of each other’s competences besides verbally sharing knowledge during work preparation meetings.

Inconsistency in documentation strategy means that the quality of work preparations vary from being very illustrative with drawings and qualitative text documents, to hand written documents that are barely readable.

Poor effort in follow-ups and gathering of experiences refers to lack of knowledge transfer where experiences from the work are gathered in order to be used in future projects.

4.3 Building information modeling within Skanska’s organization

Following section will describe Skanska’s current BIM working process and further pinpoint what obstacle that we have identified in the BIM implementation process in the production environment.

4.3.1 Skanska’s vision of Building Information Modeling

As Sweden’s largest construction company, Skanska have expectations and pressure on them from the public, the industry and other external stakeholders to be a role model in the construction industry. Skanska are determined to increase their ROI in performed projects and to gain a competitive edge against other construction companies on the Swedish market.

A step towards fulfilling the expectations from external parties and to gain a competitive edge is for Skanska to enhance the benefits and tackle the obstacles induced by BIM adoption. The President and CEO of Skanska, Johan Karlström, further made the positive aspects of BIM adoption explicit when he stated that:

"We are confident that our expanded expertise and use of BIM will give us both competitive advantages and increased profitability in the projects" (Karlström, 2009)

The decision to do strategic investments in adoption of BIM was taken already in September 2008, which was the starting point for Skanska in their effort in adapting to BIM as a technical aid to increase productivity. In 2009 new guidelines was set to increase the BIM usage
within the organization (Skanska, 2010). The demand was set that every Skanska owned and developed project, commercial and residential, with a contracting sum of larger than 50 million SEK would use BIM as the basis for the detailed design (Skanska interviews, 2012). The main objective of Skanska is to implement BIM in the whole building process, from tendering to facility management and hereby increase productivity in each project phase although this requires a step-by-step implementation (Skanska interviews, 2012).

4.3.2 BIM maturity

At present stage Skanska have twelve different BIM application development areas which they have decided to incorporate in their business strategy. These are illustrated in fig. 4.2 (Skanska, 2010). The aim is to gradually incorporate these areas in different implementation stages. The different levels in the figure represent in what sequence Skanska intend to incorporate BIM applications in their projects and working processes. The green area is the core in representing the basic level of BIM implementation in a project and the other areas are complementary add-on applications.

The focus since 2009 has been to integrate 3D detailed design, collision control, visualization and production planning (the marked area in fig. 4.2). A great effort has therefore been taken in adopting BIM in the detailed design phase of performed projects (Skanska interviews, 2012). It should be noted that each of these BIM applications can be used on their own to a certain level depending on what guidelines that are set. The level of maturity is determined not explicitly if each application is used or not but rather to what extent the application area is implemented. From this perspective, Skanska have put a lot of effort and work in order to fully experience pre-construction benefits in the detailed design. Also, the level of BIM usage is project specific and to what extent a certain project uses BIM varies from project to project. Although this is true, the fact is that few projects have fully integrated BIM applications neither in the detailed design nor in the production phase of construction. The diffusion of BIM throughout the organization is therefore still limited to a certain extent (Skanska interviews, 2012).
An important step is according to the BIM project managers (PM-BIM) to further put focus on getting the BIM model out into the production phase. Exactly how the implementation stages are going to look like is still a question to be solved since there are no established guidelines yet. At the moment this journey is being defined and an intensive work will continue from 2012-2015 to realize production usage and benefits. This will represent a movement in fig. 4.2 from the core area to the outer circle where production application areas are illustrated.

4.3.3 The current BIM work process in Skanska

"The implementation of BIM induces changes which includes new processes and working procedures. We are redefining our processes and trying to make it explicit that a change does not only include processes and tools. It is the people...that make the changes possible" (Skanska interviews, 2012)

As stated in the previous section, the current level of BIM maturity at Skanska is to use BIM in the detailed design to experience pre-construction benefits. It is in this project phase where BIM adoption primarily has made an impact in terms of new and changed working process and new roles and relationships.
4.3.3.1 The BIM-coordinator – role and responsibilities

The BIM coordinator (BC) is a relative new role within Skanska Sweden which emerged as a result of the need of support in implementing BIM in the detailed design phase. The primary responsibility of the BC is to handle and support the change processes and new working procedures related to BIM adoption. The supportive function of the BC enables Skanska to secure a unified approach to BIM implementation. The BC has an essential role in developing and managing not only technical aspects of BIM adoption, but also social related aspects.

4.3.3.2 The BIM process within Skanska

The illustration below, fig. 4.3, briefly describes the identified work process of Skanska regarding BIM (Skanska interviews, 2012; Skanska, 2012).

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**Construction processes timeline**

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**Fig. 4.3 BIM process in Skanska**

**3D detailed design**

The initial step in this process is for the BC to set the guidelines for how BIM should be used in the project. This is done by establishing a *BIM manual* for the specific project. The manual is established in order to define and describe working procedures and provide support in handling CAD related information in a project. This includes:
- Establishing a structure for who is responsible for what regarding the BIM usage, i.e. roles and responsibilities.
- Specify demands on software usage and exchange formats of files between project participants to handle interoperability issues.
- Specify the level of detail of the 3D model to fit the application areas.

The BIM manual provides a mutual framework for the consultants to collaboratively design the BIM model. The model is gradually developed through an iterative process where the BC integrates the design consultants’ work into a complete model with all physical functions incorporated. The finished version of the model will create a foundation for further analysis such as collision control and provide the opportunity to be used as a production planning and visualization tool.

**Collision control**

To perform the actual collision control is the responsibility of the BC. This is done when the integrated model is finished and has an appropriate level of detail. The BC will thereafter gather consultants and preferably onsite personnel to attend collision control meetings where possible clashes between building components and different installation systems are visualized. In this interactive environment alternative solutions are discussed hence providing the opportunity to ensure constructability. After the meeting each consultant will update their separate models according to what has been agreed. The versioned model will then be sent to the BC who will integrate the new models from each design consult to a new versioned BIM model. This process is approximately repeated 4-6 times before most clashes are detected and corrected (Skanska interviews, 2012).

**Production planning and visualization**

At present stage of development, Skanska is using the BIM model as basis to create construction site plans, which describe the disposition of resources on the building site. The model is also used in the production environment by onsite personnel by printing snapshots of the model. These snapshots of different sections are used to visualize and communicate the building design and to clarify how certain difficult parts are to be built.

As a visualization tool the BIM model can also be used in sales purpose. The model is then adapted to conditions necessary to be effective in this purpose. This includes making the inte-
rior and exterior of the building more detailed to give the buyer an insight in the future facility’s physical appearance.

4.3.4 Identified obstacles of BIM implementation in the production phase

As described in the previous section, production benefits of BIM are yet to be realized. Through our qualitative research we have identified factors which hinder effective implementation of BIM in the production phase. In table 4.2 these factors are presented. The table also illustrates in which interview group specific factors have been identified and number of persons who share the same point of view. The representatives from the permanent organization consist of BIM and other line personnel: PM-BIM, BC and development managers in health, environment and safety (DM-HES) and development managers in effective production (DM-EP). The representatives from the temporary organization consist of PrM.

Table 4.2 Factors hindering effective BIM implementation in the production phase from different perspectives

<table>
<thead>
<tr>
<th>Factors hindering effective BIM implementation in the production phase</th>
<th>Permanent organization</th>
<th>Temporary organization</th>
<th>Total, number of persons and percentage of group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gap between design and production process regarding BIM usage</td>
<td>60 %</td>
<td>0 %</td>
<td>25 %</td>
</tr>
<tr>
<td>Lack of guidelines of how BIM should be implemented in production phase</td>
<td>60 %</td>
<td>0 %</td>
<td>25 %</td>
</tr>
<tr>
<td>Not suitable support or training for onsite personnel to use BIM in the projects</td>
<td>80</td>
<td>71 %</td>
<td>75 %</td>
</tr>
<tr>
<td>Lack of knowledge of production managers in using BIM</td>
<td>80 %</td>
<td>100 %</td>
<td>92 %</td>
</tr>
<tr>
<td>Lack of incentives to use BIM in their projects if added values are not understood</td>
<td>40 %</td>
<td>29 %</td>
<td>33 %</td>
</tr>
<tr>
<td>Lack of demands from production on information needs</td>
<td>80 %</td>
<td>14 %</td>
<td>42 %</td>
</tr>
<tr>
<td>Lack of incorporation of construction knowledge in the detailed design</td>
<td>60 %</td>
<td>0 %</td>
<td>25 %</td>
</tr>
</tbody>
</table>
Interoperability issues/BIM technology not ‘ready packed’ for the production phase needs

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>40 %</td>
<td>Red</td>
<td>14 %</td>
</tr>
</tbody>
</table>

*Gap between design and construction process regarding BIM usage* means that new and changed processes and working procedures have partially been introduced in the detailed design (processes of collision control, visual planning etc. and the change in working procedures they induce). This has not been done in the production phase.

*Lack of guidelines of how BIM should be implemented in the production phase* refers to that there are no clearly defined procedures and there is a lack of standardized process of how BIM should be implemented in the production phase.

*Not suitable support or training for onsite personnel to use BIM in the projects* refers to that there is lack of support from the organization regarding BIM usage in the production environment. Furthermore, lack of suitable training means that the support provided does not create an increased understanding or commitment to use BIM.

*Knowledge gap: lack of knowledge of production managers in using BIM* deals with the fact that the PrM does not have the proper skills to use BIM in the project environment and that the knowledge about BIM is decentralized and primarily visible through the support function of the BC in the detailed design.

*Lack of incentives to use BIM in their projects if added values are not understood* is basically the fundamental view that if the PrM cannot connect potential BIM benefits with increased performance in important project deliverables, they will not advocate BIM as a technical aid.

*Lack of demands from production on information needs* is the fact that there is no pressure from the temporary organization in the BIM detailed design regarding what information that is wanted in order to align the BIM model to current working procedures in the project setting.

*Lack of incorporation of construction knowledge in the detailed design* refers to that there is a shortage of involving PrM in the detailed design to ensure that the BIM model meets the requirements when it comes to constructability onsite. The level of constructability is represented by how well the digital model actually represents the physical facility to be built.
Interoperability issues/BIM technology not ‘ready packed’ for the production phase needs means that the BIM model and related applications are not well suited to fit the production work processes at a certain level of BIM development.
5. Analysis

In this part of the thesis we analyze the results of our empirical work. Under heading 5.1 we present the implementation process of BIM in the production environment. The following part, part one, puts focus on analyzing what obstacles there are in implementing BIM in the production phase from a general perspective and what construction organizations have to consider to achieve effective implementation. In the same way, in part two, we analyze the obstacles regarding work preparations and how BIM can work as a supportive tool to improve this process. The connection of the first and the second part further works as a foundation for recommendations of how BIM can be implemented in work preparations. This is presented in chapter 6.

5.1 Implementing BIM in the production environment

In our research we found that there are several obstacles with BIM implementation in the production phase which will set the BIM maturity level within the project setting. In addition we have found specific process related problems and obstacles in the work preparation process. Having these two perspectives in mind we have created an illustrative model (fig. 5.1) which intend to explain the relationship between the level of diffusion of BIM technology, the level of BIM maturity in the production phase and how this affect the possibilities to implement BIM in work preparations and what benefits that can be attained.

Fig. 5.1 Implementing BIM in the production environment
Looking closer at the model the level of diffusion through the first wall will depend on how well construction organizations can handle identified general obstacles related to people, processes and technology through an iterative improvement process. This is represented in fig. 5.1 by the dotted ‘windows’ which implies that BIM applications are adapted in the production environment as a result of overcoming identified obstacles. This will affect the level of BIM maturity in the production environment, which will set the frame for what production process related benefits and work preparation benefits that can be attained. Further, the level of diffusion through the second wall will depend on how well construction organizations can handle identified obstacles related to people, processes and technology in work preparations and what level of BIM maturity that is present.

Conclusively, fig. 5.1 provides an analysis of how we look at the implementation of BIM in the production environment. In the following sections we will start with analyzing the first wall and the BIM implementation obstacles that we have identified and how these can be overcome. Second, we will look at obstacles related to the second wall representing work preparations and present how BIM can be a beneficial tool in overcoming these obstacles. Thirdly, we will look at the process as a whole to give recommendations on how BIM can be implemented in work preparations to increase the process effectiveness. This will however be presented in chapter 6.

5.2 Identified BIM implementation obstacles and their interdependencies – part 1 – overcoming obstacles for effective BIM diffusion

In the results, an introduction of identified obstacles which hinder effective BIM implementation in the production phase were presented. Although these inhibiting factors have been separately identified throughout the interviews their appearances are interconnected and can hereby not be treated separately if effective BIM implementation in the production phase is to be realized. The correlations between these factors make it important to analyze the interdependencies between these factors and to illustrate this in a more explicit way. Fig. 5.2 provides a basic chart over such analysis where the identified obstacles and their supposed interdependencies are presented.
The different clustered areas represent that the obstacles within the area are internally related to each other. There are also dependencies between each area. This is shown by the arrows between each area.

For construction organizations to increase their BIM maturity level in the production phase an iterative improving process in each area is necessary. By doing so the level of diffusion of BIM usage will increase and the benefits of BIM adoption can be realized. Observe that fig. 5.2 is a more explicit representation of the first wall illustrated in fig. 5.1 and that improvement in this loop will increase the level of diffusion through the first wall.

In the following sections each area of BIM implementation obstacles will be presented and analyzed.
5.2.1 Area 1

As the aforementioned figure illustrates, the intense focus on the detailed design phase has created a gap between the design and production phase regarding BIM knowledge and usage. There is hence a lack of established BIM processes to support the production environment. According to Azhar, Nadeem, Mok and Leun (2008) a present problem is that there are usually are no clear guidelines or unanimous approaches how to implement and utilize BIM within construction organizations. As expressed by one of the BIM interviewees (2012) there have been rather sprawling initiatives when it comes to implementing BIM in the production phase. This was also further made explicit during the interviews where 60 % of the respondents of BIM and other line personnel were aware of this gap. In addition, 60 % of the same group expressed that there is a lack of guidelines of how BIM should be implemented in the production phase, which can be interpreted as a consequence of having above mentioned gap in BIM usage. The fact that the group with PrM did not express an opinion on this subject can be interpreted as that they actually have not yet experienced a need for such framework.

While the detailed design has adapted to the re-engineered and new business process that BIM induces, the production phase has not. In the detailed design explicit guidelines have been developed for how BIM should be implemented in regards to the traits of the process, whereas there is a lack of implementation guidelines for the production phase. As said by one of the BIM personnel (2012) there are no standardized solutions or manuals how to implement BIM in the production phase. From this perspective this has caused, what Dainty, More and Murray (2006) describes as a digital divide between detailed design and production processes, and between those who are technically enriched, e.g. BIM personnel, and those who are less technically enriched, e.g. PrM. According to several BIM and other line personnel (2012) the maturity level of using BIM in the production environment is lower than in the detailed design. This was further explicitly supported by the fact that 100 % of the PrM felt that they lacked proper knowledge of hands-on BIM and that 80 % of the BIM and other line personnel group thought that this was the case. To minimize this gap has proven important for technological enhancement in the production environment according to Jacobsson and Linderoth (2008).

According to Hartman, van Meerveld, Vossebeld and Adriaanse (2012) it is essential to develop a framework for implementation in the production phase and to align available technical tools to current and new business processes in order to experience benefits. Further, to develop guidelines and implementation strategies construction organizations must take into consid-
eration the social, the technological and the changed process factors, which are essential to ensure effective implementation and acceptance among users. In accordance with aforementioned, one of the PM-BIM (2012) expressed that the change BIM induces includes not only redefinition of working processes and introduction of new technology, but a great part deals with the individuals within the organization and getting everybody on track. During the interviews with the PM-BIM, they uttered that at the moment they are trying to establish guidelines for implementation of BIM in the production phase but that there are still uncertainties and problems to be solved.

However, establishing guidelines for implementation is not enough. A sufficient amount of resources, in terms of adequate support and training etc, also needs to be put in to fulfill the implementation objectives and to give suitable support in the project environment. As expressed by Peansupap and Walker (2005) and Young in Chelson (2010), a primary interest of organizations is to educate personnel in the implementation stage to ensure effective diffusion. In addition and according to Young (2008) in Chelson (2010) there is an imperative need for adequate employee support and training in order to motivate them into adopting new technology. Accordingly, one of the BIM interviewees (2012) said that it is important for Skanska to put resources in educating personnel in order to create a more unified approach on how BIM can be of value in the production phase and that they need to improve in this aspect.

In our research, the interviews revealed that there was a lack of suitable support or training for the onsite personnel to use BIM related applications. According to the interview results a total of 75 % shared this view. An interesting and contradictory observation was made regarding this fact. According to 80 % of the BIM and other line personnel interviewees they had acknowledged the lack of suitable support and training for PrM. At the same time 71 % of the PrM experienced the same thing. The contradiction lies in that it is in the interest of the BIM personnel to provide suitable support in order to increase the knowledge of BIM and how to use it in the production environment. Conclusively, there is a possibility that although support is provided from the central organization it is still not provided through appropriate channels or in the most suitable way.

As expressed by one of the BIM interviewees (2012) training is provided for those who want it. The interviewee pointed out that there are several courses available, but that they often get cancelled due to lack of participants. In interviews with two PrM they said that it is too time consuming to go away on courses to learn about BIM and to get hands on experience. In addi-
tion, they expressed that there is no value in practicing hands on if it is not related to their specific project since it will not motivate or engage them to really learn about the benefits of using BIM. Further, they thought that a one day course is not support enough since continuous support from a BC or equivalent is necessary in the production environment to increase their knowledge and to find BIM application areas. This is supported by the view of Gu and London (2010) and Young (2008) in Chelson (2010) that having adequate support is important for effective BIM diffusion. The need of having a continuous supportive function in the production environment may be motivated by that it is a need for establishing an environment for trial and error learning (Fleck, 2002 in Wikforss and Löfgren, 2007).

The aforementioned implies that it is a prerequisite to have a supportive function in the production environment to attain effective BIM diffusion. Although this is true it may be hard to economically motivate having such function as a permanent solution in the production environment. This due to project traits of having limited economical resources (Alshawi and Ingirige, 2003). As expressed by one of the PrM (2012) there are already too many administrators in some projects, which in the end will affect the competitiveness in the tendering phase. Also, a risk in totally handing over the responsibility for BIM support to a single entity is that it may take away motivation and engagement from the PrM to use BIM. As uttered by one of the interviewed BIM personnel it is an important question to create a local engagement of BIM usage in the production environment.

Furthermore, one of the BIM interviewees expressed that it is hard to provide adequate support to production personnel due to that there is a lack of contact between the BIM personnel in the detailed design and PrM in the production phase. The interviewee expressed that the extent to which they can give support in the production environment depends on the social relationship with key PrM. The main contact regarding BIM usage is with the detailed design manager, whose involvement in the project basically ends as the detailed design finishes. Hereby a contact point or bridge of BIM establishment between the detailed design and the production is no longer available. Another BIM interviewee stated that to ease up the contact points between the detailed design and the production is essential. Also, having a person that work as mediator of BIM knowledge by following the model out into the production is one of the most important questions for embedding BIM in the production.
5.2.2 Area 2

As showed throughout the interviews there was an almost unanimous view that there was a lack of knowledge of the PrM in using BIM applications. As stated earlier, 100% of the PrM felt that they lacked knowledge on how to use BIM tools although they, to a less or greater extent, knew what BIM was and what possibilities it made available. Although there undoubtedly is a lack of knowledge among PrM in BIM usage, many of the interviewees expressed that they were positive to use BIM in general and expressed that they were open to gain knowledge about how to use it in the production environment and to learn how to attain BIM benefits.

As stated before, and according to Wikforss and Löfgren (2007), a problem of implementing new technology in the production environment is the reluctance towards new innovations. This may be true but the reasons why are seldom explained or elaborated further on. Based on our research we argue that a vast part of this reluctance can be explained by a lack of knowledge in how to use new technology, such as BIM, in the production environment and that the added values therefore are not understood.

According to the BIM personnel (2012) the reason for this lack of knowledge can partially be explained by the fact that there has been an extensive focus on implementing BIM in the detailed design, which has caused aforementioned digital divide. In compliance with what has been stated above another reason that contributes to this knowledge gap is the lack of guidelines on how to use and align BIM in production processes. This has resulted in that the support and training available is not suited for the traits of the production environment and the PrM.

In interviews with BIM personnel (2012) they said that it is important to increase both the general knowledge about BIM and hands on usage by the production personnel. Especially since it will provide the basis of the understanding what possible benefits that can be attained and what added values that BIM can provide. If the added values are not understood then effective implementation of BIM in the production environment is unattainable. As expressed by one of the PrM (2012) he always needs to perform value engineering in order to meet economical objectives in the project. If the added values cannot be shown in an explicit way, it does not provide any incentives for PrM to consider more extensive BIM applications.

Furthermore, as expressed by some of the PrM, the use of new technology in the production environment is generation related and younger personnel are keener on using such tools since
they are usually more digitally enriched. As expressed by one of the more experienced PrM it is valuable having younger professionals in the production environment who can handle the BIM model since this provides the opportunity for others to increase their knowledge through an interactive and continuous contact. As said by Alshawi and Ingririge (2003) gatekeepers of knowledge have been identified being mostly middle level managers that run the daily operations in the project setting. These individuals are important for the diffusion and the knowledge spreading of BIM in the production environment. The younger professionals can provide an extra contact point in BIM usage and can work as a complementary supportive function along with the BC in aligning BIM applications with production working processes.

From a knowledge transfer perspective a mutual sharing of knowledge and experience between these younger digitally enriched and older experienced PrM is valuable. The actual mutual knowledge sharing is valuable not only for the PrM in increasing their knowledge in hands on BIM usage. Their construction knowledge can be channeled and put in relation to the capabilities of what the BIM model can provide in terms of construction benefits.

5.2.3 Area 3

As mentioned in the previous section it is preferable to have a gatekeeper of knowledge, i.e. younger professionals, to increase the knowledge about BIM and to support the more experienced PrM in finding BIM application areas in the production phase. Although this way of working will help the permeation of BIM in the production phase other aspects of knowledge sharing and knowledge transfer that can contribute to an increased diffusion are essential.

An aspect, which has been identified throughout the interviews, is that there is a lack of demands from the production environment on how they want to use the model and what information they require in this usage to fit the indented purpose. Implicitly this is a knowledge transfer chain, since the PrM needs to use their gathered construction knowledge to articulate information demands to the detailed design personnel so that the model can provide satisfactory output when used in the production environment.

During the interviews it became evident that there are no clear requirements or demands from the production environment in what information that is needed from the BIM model. In the group of BIM and other line personnel (2012), 80% said that they lack demands from the production of information needed. Several people of this group expressed that it is essential to
take into consideration construction knowledge of PrM to ensure constructability but even more importantly to specify what information that is of value for the production.

Surprisingly, only one of seven of the PrM gave input on that he felt a lack from his side in having demands on the BIM detailed design. Two of the PrM (2012) expressed that they early in the detailed design had a meeting with the BC to discuss what level of BIM that should be used in their specific project. A situation where the PrM will give their input in the BIM detailed design is valuable and preferable. We do believe that, at current stage, this process needs to be done to a greater extent and that this is a present obstacle for effective BIM implementation. Especially when taking into account the identified lack of knowledge of onsite personnel in using BIM and understanding BIM capabilities. This can also explain why so few PrM experienced that they lacked in giving input on BIM usage and information needed in the detailed design.

These aspects are of central importance since it is in the detailed design the basics of the project are set. As stated by Winch (2010) the magnitude to which one can affect important project parameters such as quality, time and economy will decrease as the project time increases. This implies that important decisions regarding the BIM model and further usage in the production environment are imperative to perform in the detailed design phase.

From this perspective, it becomes even more evident that it is essential to have an increased demand from the production and thereby incorporate construction knowledge in the detailed design and into the BIM model. This will also provide the basis for which BIM guidelines that can be set up to support BIM usage in the production environment. As uttered by Jacobsson and Linderoth (2008) and Wikforss and Löfgren (2007) technology pushed out in the production environment is often not suitable or ready packed to fit working processes. Having clear guidelines will preferably diminish interoperability issues between BIM technology and construction processes and alignment can thereby be done more effectively.

A gradual increase of information demand from the production side on the BIM design will hence create a foundation from which PrM can experience BIM benefits, and thereby the added values provided by different BIM applications. As expressed by one of the BIM personnel (2012), this will hopefully result in an increased engagement of PrM in contributing with valuable input to the detailed design phase regarding BIM usage.
The results from our study show that there are several obstacles that hinder an effective work preparation process. The obstacles are not only founded in the production as a cause of the PrM effort in work preparations, but can also be traced back to the central organization of Skanska and the poor strategy they have provided on how to handle and store information in the production phase. In the results we presented obstacles that are hindering an effective work preparation process. Some of these obstacles are connected to each other, which is why we have categorized them into four groups, see table 5.1. This section will provide an insight into each group and explain possible causes to why they occur and what has to be done in order to overcome them in the future. However, our main focus lies within the first and second group: communication/visualization and motivation/engagement. A deeper analysis of these groups is therefore presented.

Table 5.1 Grouping of obstacles that hinder effective work preparations

<table>
<thead>
<tr>
<th>Group</th>
<th>Inhibitory factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Misunderstandings in verbal communication</td>
</tr>
<tr>
<td></td>
<td>Difficulties in interpreting 2D-drawings</td>
</tr>
<tr>
<td></td>
<td>Inability to visualize 2D-drawing into 3D-thinking</td>
</tr>
<tr>
<td></td>
<td>Few or inappropriate use of communication channels/mediums</td>
</tr>
<tr>
<td>2</td>
<td>Lack of motivation and engagement in meetings</td>
</tr>
<tr>
<td>3</td>
<td>Insufficient information distribution from project administrators to SW</td>
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<tr>
<td></td>
<td>Short preparation time</td>
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<tr>
<td>4</td>
<td>Poor knowledge transfer and reuse of knowledge/experience from previous projects</td>
</tr>
<tr>
<td></td>
<td>Inconsistent documentation strategy</td>
</tr>
<tr>
<td></td>
<td>Poor effort in follow-ups and gathering of experiences</td>
</tr>
<tr>
<td></td>
<td>Information overload/inability to handle ‘future’ information</td>
</tr>
</tbody>
</table>
5.3.1 Group 1

As stated in the beginning of the thesis, the communication aspects are of great importance in work preparations. This statement is confirmed by our study, which has shown that there are several obstacles in the work preparation process that correlate with communication barriers.

Looking back at table 4.1 we can see that 86 % of the interviewed PrM recognized that the SW have misunderstood the message that has been sent, while the SW themselves are not aware of that considering that only 33 % recognized this issue. This recognition primarily occurs as the work already has started and deviations from the work preparation are made (Skanska interviews, 2012). The phenomenon that unaware misunderstandings occur can be explained by theory of the semantics in Agarwal (2010), i.e. different meanings of words. But parallels could also be drawn to stereotyping where the SW’s professional background and own perceptions overtake their ability to interpret the message. One cannot only put the entire responsibility for misinterpretations on the receiver. The sender, PrM, also have an important part in this process since they are choosing what information to transfer and what channels and mediums to use. The skill of choosing the right information to encode and transfer via a channel is not the easiest task. Especially in the construction industry which is characterized by a vast collection of information and complex activities. In order to reduce the possibility for misunderstandings 2D-drawings are used as communication tool in the work preparation process. The intention of this communication channel is to help the SW to more easily interpret and understand what is to be done. But as expressed by Eastman, Teicholz, Sacks and Liston (2008), Chelson (2010) and Sacks, Radosavljevic and Barak (2010) 2D-drawings are insufficient in visualizing the design intent. In compliance, our study shows there are two communication barriers related to this fact: the ability to interpret the drawings and the ability to visualize the 2D-drawings in three dimensions.

The receivers’, in this case the SW, ability to decode and interpret the message from drawings is a matter of skill, experience and ability to translate geometry from paper to real construction components. Drawings can be very complicated and consist of many layers from different heights in the same level. This means that the reader of the drawing has to be able to separate the different layers and imagine them arising from the drawing, i.e. create a third dimension in the mind, and out of that connect the lines and flat surfaces into volumes and shapes. This is a skill that far from all production personnel has and this often causes confusion. Our study has shown that experienced SW tends to be more effective in interpreting drawings and creating a picture of the end product. Agarwal (2010) explains that this is caused by their ex-
perience which is used as a reference in the interpretation process. Their ability to sort and categorize information in the drawings is a result of previous practice, which is why younger SW often experiences more difficulties in interpreting 2D-drawings.

Difficulties in interpreting a message can be traced back to one of the four essential factors for effective communication by Dainty, More and Murray (2006); the receiver’s ability to decode, interpret and act on the information, which is crucial in the information exchange. As stated earlier an individual’s ability to translate a message rests upon the cognitive characteristics, which means that every individual uses their own preferences when translating a message. This phenomenon is very hard to have an impact on since it is entirely dependent on the individual. However, there are ways of increasing the possibilities to successfully translate a message. By having effectively encoded messages and by using appropriate communication channels, the chances of misinterpreting the message decreases. But this leads to an important question: what is an appropriate communication channel? This is impossible to give a direct answer to since it is dependent on the characteristics of the task as well on the person receiving the message. However, three of the interviewees in our study had earlier experience of 3D-visualization in production, which they claimed to be a very effective tool that increased their understanding of the activity that was to be performed. This supports Torrington’s and Hall’s (1998) statement that the use of diverse communication channels and mediums enhances the communication and information exchange and leads to a more successful communication process.

As a result of the study and with relevant theory supporting the importance of effective communication, there is an obvious need of improving the communication channels and mediums in the work preparation process. As previously mentioned, the dominant channel that is used in work preparations are 2D-drawings, which is why barriers, such as misinterpretations and difficulties in understanding the message often occur. In order to overcome these issues additional options have to be introduced in the process. Adding another dimension to the communication medium of visualization by incorporating 3D-illustrations and digital 3D-models could favorably enhance the communication process. As expressed by Torrington and Hall (1998) the chance of communicating a message with less noise can be achieved if more channels are used. The visualization opportunities that BIM provides can help the SW in their process of decoding 2D-drawings since they can actually see the end product in 3D without making their own assumptions. This reduces the possibility of having SW who’s own perceptions get mixed up with actual facts which leads to distortion of the message. This relates to what
Formoso and Powell (2002) in Sacks, Radosavljevic and Barak (2010) calls project transparency and the ability to more easily visualize the production process and increase the control and understanding of the project. By having 3D-illustrations the message becomes more specific and does not leave as much room for own assumptions as with e.g. 2D-drawings, which thereby helps minimizing misinterpretations.

5.3.2 Group 2

Based on our study we saw that there is a general positive attitude towards work preparations among employees, but still 67% of the interviewed SW and 71% of the PrM recognized that others lack motivation and engagement when it comes to participating in meetings. Poor motivation and engagement means that they are not willing to neither absorb nor share knowledge with their colleagues, which lead to an inactive work preparation process. We have not been able to identify the exact reasons why some are less motivated, but according to Whetten and Cameron (2011) a possible reason may perhaps originate in poor management where no clear goals or requirements are set by the PrM. They also state that low motivation can originate in lack of empowerment where the SW are not entrusted and their ideas and thoughts are ignored. Another possible reason for employees not being motivated is simply lack of interest to plan for the future. As expressed by one of the SM (2012), many of the SW are ‘practical workers’ who have great interest in producing physical objects and less interest in administrative work, such as planning an activity. Even if thorough planning can enhance their own work they tend to solve problems as they arise instead of trying to avoid them from the beginning. This is a behavior that can affect the entire project and jeopardize the time schedule, budget or worse colleagues’ safety.

There are many possible factors that can be the basis of an employee’s lack of motivation, and it is not always easy for managers to understand the underlying factors. According to our study, PrM rarely put any effort in trying to identify the reason of the behavior and do not take any specific actions in order to create a more active group. It might be very hard to know what actions to take in those situations, but as Thompson (1978) said “the best way to change an individual’s behavior in a work setting is to change his or her manager’s behavior” in (Whetten and Cameron, 2011 p. 360). This implies that the managers can take simple actions such as asking questions that require a more explanatory answer in order to invite the SW into the discussions.
Our study showed that the PrM have a positive attitude towards SW’s suggestions and they strive to have everyone active during the meetings. This is confirmed by the SW themselves whose experience is that they have an important role in the work preparation. By having this result confirmed we can disregard the possibility that the SW are not given the opportunity to affect the outcome of the work preparation, i.e. being empowered to certain extent. Rather it is a matter of them not taking advantage of the opportunity that they are provided with to affect the process.

Although none of the interviewees (2012) expressed a negative attitude towards work preparations themselves, their experience was that colleagues who have shown reluctance in participating in meetings base their thoughts on lack of interest and meetings being a waste of time. This is a behavior which easily can rub off on other coworkers, why it is essential to change these impressions. Visualization of 3D-models could create an interest and thereby increase the motivation and engagement of construction workers. This conclusion is supported by Formoso and Powell (2002) who in Sacks, Radosavljevic and Barak (2010) stated that one of three important beneficial aspect of visualization in the production environment include increased engagement and motivation of SW. This point of view was also supported by Skanska’s DM-HES and the interviewed SW (2012). The DM-HES said that SW need an interactive process where they can work with more senses than just hearing and speaking. By improved visualization opportunities the meetings can become more dynamic and the participants would become more engaged and motivated.

5.3.3 Group 3

A fundamental purpose with the work preparation process is to involve the SW and encourage them to be active during the meetings and propose new ideas and thoughts on how an activity can be performed. But in order to achieve such purpose the SW need information regarding the task, which they seldom have. Our study has shown that insufficient information distribution is one of the factors that too often occur, where 67 % of the SW and 57 % of the PrM recognized this issue. Based on our study and the information received from the PrM, a reason why this happens is due to that the they do not believe that the SW use the information that has been distributed, i.e. that they do not review drawings or documents provided. This conclusion is founded in the belief that SW are too occupied to take their time to review the information (Skanska interviews, 2012). This statement is confirmed by some SW that participated in our study. They stated that there is no need to prepare in advance since the work
preparation meeting per se is a preparation (Skanska interviews, 2012). This attitude reveals that there is a lack of understanding why preparation in advance is important among the SW. Even if the SW implicitly are given the opportunity to affect the production and their own working conditions, they ignore these possibilities. This attitude reflects on the PrM who becomes sloppier in distributing the information.

But not all of the SW reason the same way. There are several examples of SW from our study who realize the importance of being involved early in the work preparation process. Our study has shown that younger people with less experience are those who are most willing to participate and contribute during the meetings. This could be due to their ambitions to learn more from seniors and become better in their work. However, many of those who have a positive attitude towards having work preparations and see the benefits of having them do not think that they are provided with enough information in order to prepare for the meetings. Sometimes the PrM simply ignore distributing the information because they expect the SW to, by their own, find drawings and other necessary preparation material that often is available in a binder onsite. Other times there simply is no information available to distribute due to incomplete drawings and documentation.

In situations where PrM rely on the SW to find relevant information by their own, they must consider two important aspects. First they have to realize if the SW are engaged and motivated in having work preparations or not. Individuals that have positive attitude towards work preparations will have incentives to find information they need to be able to prepare for the meeting given that the information is available onsite. On the other hand, SW who are not motivated or have no interest in work preparations will not put an extra effort to gather relevant information.

The second part is the reliability of the information. As conditions constantly change in construction projects, drawings also change, which is why right information has to be available at right time. The PrM have to update the binder with drawings in order to be sure that the information the SW receive is up to date. Otherwise they will, as Agarwal (2010) said, base their solutions and ideas on inadequate data and the purpose of having preparation time goes to waste.

Our study also showed that the SW have too short time, if any, to prepare for the meetings. In many cases the information is distributed when they arrived at the work preparation meetings. Referring to Skanska’s process how to conduct work preparations, this is not a way to in-
crease employee involvement, but rather eliminating it. Some PrM rely on that it is enough to inform the SW about the meeting date and what the characteristics of the activity are. No requirements or details are provided which gives the SW very little to base their ideas and reflections on. As said earlier this is a matter of providing insufficient information from which wrong assumptions can occur.

5.3.4 Group 4
In Skanska’s four step model (see fig. 4.1) the last step in the process is the follow-up. The purpose is, as we mentioned earlier, to gather the experiences and reflections from the SW and document positive and negative aspects for use in future projects. This is a good initiative and a step towards advocating knowledge transfer and a learning organization. However, our study revealed that none of the PrM worked with follow-ups after the work prepared activity had been completed. What they did instead was having follow-ups a few weeks after the start of the activity in order to make changes in the working method and thereby make it more effective. By having follow-up meetings soon after the activity has started it is possible to make beneficial changes, which hopefully cuts time and costs and increases the quality of the work. Although this an initiative that is not in line with Skanska’s guidelines, it certainly improves the choice of method and leads to a more effective process.

But there is a problem in how these follow-ups are performed. According to the interviewees (2012) the follow-up meetings do not include any kind of documentation or update of the initial work preparation documents. This means that no matter how good the change was and what positive effects it brought to the project, the knowledge would stay within those who were involved in the work preparation and not be transferred to others in the organization.

Though the majority of our interviewees thought that better follow-ups should be made, no one did perform a final follow-up where experiences and lessons learned were documented. They did not even update the work preparation document as new solutions had been worked out. This leads to the question: why?

According to the DM-HES and DM-EP (2012), the reason is most likely dependent on a poor documentation strategy. All the documents from work preparations, e.g. drawings, pictures, texts etc, are uploaded in a project folder on a common server from where employees can access it. It might sound as a good way of storing the documents, but as there are folders from thousands of projects it is almost impossible to find old work preparation documents that can
be reused as an inspiration in new projects. This has lead to poor reuse of work preparations, which is why knowledge and other experiences hardly ever get transferred this way.

Furthermore, the nonuse of old work preparations does not give the PrM any incentives to improve the quality of them. This can be related to as Whetten and Cameron (2011) say, that poor guidelines and strategies lead to decrease in motivation to perform certain tasks, such as writing qualitative work preparations. According to our study we have seen that the quality varies a lot, both in content and in format, which the DM-HES and DM-EP agree on. The inconsistency of the documents makes it hard for someone who has not been involved in the process to interpret and understand the content of a work preparation. From what is stated above, an improvement in the IT-strategy to enhance the information reuse and facilitate the knowledge transfer among employees within the organization is needed.
6.  Recommendations for Skanska

Based on our empirical study and the analysis of the results, this chapter will provide recommendations how Skanska can increase their BIM maturity level in the production and hereby use BIM in work preparations. We will also present a three step model for a gradual implementation of BIM in work preparations.

Looking at the result from our research it becomes evident that Skanska have a low BIM maturity level in the production phase. This limits the possibility to adopt BIM in production activities such as work preparations. To be able to introduce BIM in work preparations the obstacles related to BIM implementation in the production have to first be overcome. Through an iterative improvement process, the maturity level in production can increase and hence amplify the possibilities of using BIM as a supportive tool in work preparations.

6.1 How to handle general implementation barriers to ensure diffusion of BIM to support work preparations

The result in table 4.2 indicates that Skanska need to put greater effort in several areas in order to enhance BIM diffusion into the production environment. Improvement efforts are especially important in the second area in fig 5.2. This section provides suggestions how Skanska can go about in the iterative improvement process to support usage of BIM in work preparations. Moreover this relates to the first part in fig 5.1 and is illustrated in fig 6.1.
6.1.1 Increased scope of responsibility for the Production Engineers

As shown by our study it is important to have a permanent function to support BIM usage in the production environment. Presently this role probably has to be taken by the BC since there is a lack of knowledge among PrM. But we do not believe that this is a sustainable solution since there are not enough BC to support all projects on fulltime. Even if there were, it might not be economical favorable. The responsibility of establishing BIM processes in the production progressively needs to be taken over by a role that is steadfast in the production. To have such a role has shown itself to be positive for the permeation of BIM.

One way to accomplish this is to increase the scope of responsibility of the production engineers (PrE). As this role is mainly occupied by young professionals in Skanska it makes a perfect gateway for channeling BIM into the production environment. As mentioned earlier, younger professionals have proven to be more eager to learn about new technologies, and can thereby work as gatekeepers and knowledge carriers of BIM. As expressed by one of the BIM personnel it is important for Skanska’s managers to identify young professionals with the potential to take on this increased role of responsibility. It is also important that Skanska’s managers provide adequate support to assure that the PrE effectively can bridge BIM knowledge from the detailed design into the production environment.
As stated in the analysis we believe that the support and training provided by the BC is channeled in an insufficient way today. In accordance with this and above mentioned increased role responsibility, we suggest that education and training provided by Skanska in hands on BIM usage and knowhow primary should be aimed towards the PE.

Another reason for this implementation approach is that it would not be reasonable to put the responsibility of BIM adoption into production on the BC. As the BIM maturity level increases in Skanska, we believe that the BC will have to put more focus on establishing new BIM processes and handling more general BIM implementation obstacles, rather than working in the project setting. But they still will have an important role as a support to the PrE in their work to find new BIM application areas and help them in the implementation of these.

It should also be noted that the scope of responsibility of the PrE is not supposed to be at the level of today’s BC. The PrE role should rather be expanded to a minimum where he/she acts as a bridge between the line organization and the project with regards to BIM usage and provides support in the production environment.

6.1.2 Increased involvement of production managers in the BIM design

A prerequisite to increase the use of BIM in the construction phase is to have a model that contains information that is useful for the PrM. The only way to incorporate this information is by getting input from the PrM of what information they need in order to make their work more efficient. Having them provide demands of what information that is desirable from the model, is from a work preparation perspective equally important. In terms of what kind of demands and knowledge that can give valuable output in work preparations is hard for us to explicitly state, since it depends on the characteristics of the activity.

As the PrM provides the BC with input of desired information in the model we enter a loop where we believe that the BC will increase their understanding of what information that is valuable for effective BIM use in the production. The same goes the other way around where the PrM most likely will realize the potential benefits with BIM and thereby have incentives to increase their use of BIM in their daily work. Looking back at fig. 5.2 we can see that the connection between area 2 and 3 is created.

Regardless of what information that is necessary we have identified two approaches that can be applied regarding when and how this input should be incorporated into model. These are presented below.
6.1.2.1 Alternative 1

In this alternative the production demands are incorporated early in the detailed design to support usage of BIM in work preparations. The model will hereby be adapted to fit the needs of work preparations early in the project setting. But since the information is incorporated this early there are some possible constraints, which might affect the ability to use the model in work preparations:

- Since the production team may not be established this early in the project it might be hard to determine who will give adequate input of what should be incorporated into the model.
- It might not be possible to determine all activities that should be work prepared in advance, which is why inadequate information may be provided.
- PrM have different routines on what activities that should be work prepared and what information that is needed, which might call for a supplement later during the production phase.

6.1.2.2 Alternative 2

In contrast to the first alternative, the PrM provides additional information input into the BIM model as the production already has started. In accordance with Skanska’s four step model of how work preparations should be performed this information can preferably be incorporated in the BIM model when it has been decided what activities that are to be work prepared.

As with the first alternative there are possible constraints:

- The model is not ‘ready packed’ or initially suited to fit work preparations. It is somewhat unknown what level of detail that is needed.
- The collaboration between the PrM and BC must be effective in order to have the required information as the work preparation is initiated.
- The chance of falling back to the nonuse of BIM exists as additional work with setting up the demands is required for each work preparation.

In both alternatives it is necessary to establish what level of detail that is required for the specific work preparation. Moreover it requires that a more cooperative environment is established between the design team and the PrM. We believe that this cooperation, in the long term, will benefit the overall productivity of performed construction projects.
Comparing the two alternatives above it becomes obvious that they both have inherited process related constraints. But due to the uncertainty and risk of having wrong information in early stages of detailed design, we believe that the second alternative is preferable.

6.2 Implementing BIM in work preparations - the three step model

The three step implementation plan refers to part 2 in fig. 5.1 and is illustrated in fig. 6.2.

![Fig. 6.2 The second part of BIM in the production phase](image)

We believe that the identified barriers for an effective work preparation process can be overcome gradually by implementing BIM. To what extent these barrier can be treated are dependent on what the level of BIM maturity and available BIM capabilities in the production environment. We suggest a three steep model of how BIM can be used in work preparations. As fig. 6.3 shows the added value or experienced benefits of implementing BIM in work preparations will increase as new BIM capabilities are adopted in the production environment since the identified obstacles can be handled more efficiently. This improvement process can mainly be connected to factors such as an enlarged number of communication channels, increased number of communication mediums and improved visualization opportunities.

In addition, fig. 6.3 illustrates the gradual implementation process of BIM in work preparations. As uttered by one of the BIM personnel (2012) a step by step method is essential for
effective BIM adoption in the production phase. In compliance with this we also believe that it is an important factor in order to ensure acceptance and reduce reluctance towards an increased BIM usage. Furthermore, as expressed by one of the PM-BIM (2012) it is important to create good reference examples that can work as drivers for others in adopting BIM. We believe that a step by step method will help creating such reference projects and thereby increase the chance of others following the same path.

6.2.1 Step 1

As a first step the BIM model is used to print 3D-snapshots and 3D-drawings to visualize and communicate the design intent during work preparations. These 3D-snapshots and views are used as a complement to ordinary 2D-drawings and are distributed in advance to prepare the SW in accordance with the second step in the work preparation model (fig. 4.1). They are also used as a supportive tool during the work preparation meetings.

**Fig. 6.3** Schematic illustration of the relationship between increased BIM maturity level and experienced benefits of BIM usage.
The model is not used in real-time and thereby the visualization and communication aspect is not realized to its fullest potential. The channel through which information is transferred is still paper based and the 3D-views and snapshots are non-dynamic since they are looked upon from a specific view, which is predetermined by the PrM. From this perspective, we believe that a smaller fraction of the identified communication barriers can be overcome, such as inability to visualize 2D-drawings into 3D-thinking and also difficulties in interpreting 2D-drawings.

6.2.2 Step 2

In this step the BIM model is used in a more interactive way. In addition to printed 2D-drawings and 3D-snapshots and drawings, the digital model is used during work preparation meetings. Real-time navigation is performed and the model is used as the basis for communication and visualization during the meetings. In this process the PrE will have an essential role in supporting the PrM how to navigate and ‘walk inside’ the BIM model.

If comparing step 1 and 2, the vast difference is that the model plays an important role in communicating the constructability and design intent to the SW. In this step the actual model can be seen as an additional communication channel, which increases the visualization possibilities as navigation is performed in real-time. This is also shown in fig. 6.3 where there experienced benefits will increase as additional BIM capabilities are being used in the work preparation process.

Furthermore, we also believe that it could be of value having a smart board since this would provide the opportunity for the PrM and SW to interact in a more convenient way. By letting the SW communicate their thoughts and ideas trough additional mediums (writing, illustration) we also believe that their engagement and motivation of giving valuable input would increase. In addition, this provides the opportunity to quickly save comments and notifications which are valuable for the actual work onsite and when updating the BIM model.

6.2.3 Step 3

As in step 2, the BIM model is used for real-time navigation and also for printing relevant 2D and 3D-drawings. An additional feature in this step is the use of 4D-models during the meetings. This implies that a 3D-model is connected to a time schedule in order to illustrate the assembly order of the section that is being work prepared. We believe that this kind of animation can effectively make the interdependencies between different construction entities explic-
it and also help to avoid having different work teams collide with each other during the actual construction. By doing so, rework and changes due to clashing construction activities and clashes between building components can be minimized.

Additionally, we suggest that guidelines need to be established for what activities that should be developed into 4D-sequences. Preferably 4D-modeling should be used in work preparations where:

1. There are activities that have several and close dependencies between each other, i.e. their outcome will affect other outcomes to a great extent. For example the relationship between inner walls and openings for vertical and horizontal shafts.
2. Activities which are located on the critical path in the production time schedule (activities that will affect the end date of the project) and are of a large scale, e.g. assembly of prefabricated outer walls, assembly of roof construction and reinforcement works in the bottom floor slabs.

Although we believe that it can be of great value using 4D-visualization in work preparations this puts additional demands on the detailing level of the BIM. We do believe that the level of detail does not necessarily need to be highly extensive in order to fulfill the purpose of visualizing interdependencies and work assembly paths.

The above mentioned facts and the possible obstacles of incorporating construction knowledge into the BIM model will need to be put in relation to what extra benefits this extra feature will have in the work preparation process. However, there is an unknown asymmetry in this step regarding what extra input that has to be made and what output the model can deliver in terms of extra benefits. This is also illustrated in the figure 6.3 by the dotted lines.
7. Conclusions and discussions

The purpose of this thesis was to investigate what obstacles that have to be overcome in order to successfully implement BIM in the production environment and in work preparations and what possible benefits that can be attained by this adoption. As our empirical study revealed, Skanska’s BIM maturity level in the production phase is considerable low, which is why a successful implementation of BIM in work preparations is not possible at a current stage. The gap between the design and construction phase has lead to barriers through which BIM applications and knowledge cannot permeate, unless they are broken.

As an initial step towards implementing BIM in work preparations, Skanska must create a ‘bridge’ between the design phase and the production phase in order to transfer BIM knowledge into projects. Our suggestion is to increase the responsibilities of the production engineers who will act as this bridge and have basic knowledge about BIM applications. But in order to make this possible, a better strategy on how to educate and support the production engineers with BIM usage in production has to be developed. Our intention with this thesis was not to provide such strategy, but rather identify what essential obstacles that must be considered when trying to implement BIM in the production phase.

As the BIM maturity level in production increases it enables implementation of BIM in work preparations. We have studied how work preparations are performed in Skanska today and identified several obstacles that hinder an effective process. Many of these deal with communication issues where skilled workers often have difficulties in understanding the design intent and what is to be done. By implementing BIM, where better visualization and communication possibilities are enabled, into this process we believe that many of these obstacles can be overcome and also improve the efficiency of work preparations.

Our study has resulted in a three step model where a gradual implementation of BIM applications is provided. This model should be looked at as a basic guideline, which takes Skanska’s current BIM maturity level into account. We have hereby provided an example of BIM capabilities in the production environment. We have also provided Skanska and other construction companies with a framework of which BIM implementation obstacles that need to be considered to be able to align production related processes and BIM.

An interesting question we asked ourselves was why Skanska, which is one of the largest construction companies in the world, have not put greater effort in implementing BIM technolo-
gies throughout all phases of a project, but only in the design phase? BIM has undeniably been proven to increase productivity which has been considered the main objective in the construction industry for many years.

We believe this is closely correlated with the fact there has been a general lack of understanding of BIM implementation obstacles in the production phase. In addition, we also believe that the benefit and added values of BIM are difficult to measure. As we stated in the theory chapter there are tangible and intangible benefits, where the tangible are mainly found in the design phase and the intangible are primarily found in the production phase. The tangible benefits can be measured and valued in hard parameters, such as costs, energy consumption, time etc, while the intangible are much more complicated to measure. How can one measure the added values of better visualization possibilities or increased information availability? It is possible, but very difficult since it requires a thorough research in what parameters that can reflect those values. We therefore believe that it is imperative that in the future establish such relevant parameters to be able to estimate the added values provided by BIM in a more explicit way.

As Skanska have a vision to become “a leader in its home markets - the customer’s first choice” we think that they must increase their competitiveness and productivity by incorporating BIM into their entire work process. Being able to build ’smarter’, cheaper, faster and with higher quality will not only benefit Skanska’s brand, but also provide more satisfied customers who will have Skanska as a first choice. Skanska is heading in the right direction towards their vision, but we still think that much more intense work has to be put into innovation integration and business strategy improvements in order to be ahead of the competitors.

7.1 Reliability, validity and generalizability

In order to assure reliability in our research we, in the initial step, conducted pilot interviews with relevant Skanska personnel from the BIM department and the production side of construction. In addition, discussions with our research supervisors were held to further get input on how to formulate relevant questions and what sample populations that should be used. This helped us to conduct the qualitative interviews and to get exploratory answers. An interview guide and an interview plan were established early on in the research process with the aim of isolating relevant people who could give valuable answers to our questions. To secure that the interviewees would answer the questions honestly an anonymity option was provided. Fur-
thermore, the interviews were recorded to ensure that analysis could be conducted in a proper way. Although this was done we believe that the interviews could have been performed in a more efficient and consistent manner. Since we used semi-structured interviews the scope of the interviews could sometimes become too extensive.

To verify validity, the method choice was discussed in the initial stage of the research process. The method choice was determined after careful evaluation of alternative methods. To use of an inductive reasoning, an exploratory research method and a qualitative interviewing technique was verified by the nature of our research question and research problem, which were unstructured. In addition to the process of choosing method, valuable input was given from our research supervisors at KTH and Skanska AB. In addition, a thorough literature study was performed and was based on reliable sources, which increased the trustworthiness of our research.

The generalizability of our research can be referred to as being good. The reason for this statement has to do with the fact that:

- The identified obstacles we believe can be observed in other construction organizations that have a low BIM maturity level in the production environment.
- The implementation model can be generalized since the second wall of obstacles can be changed to consider obstacles in other production processes.
- The three step solution can to some degree be used by other construction organizations if integrating and evaluating their own work preparation process to fit each of the implementation stages.

7.2 Recommendations for future research

During our research we encountered several questions that should be looked further into. Even though we identified some obstacles regarding the implementation of BIM in the production phase, we believe that more thorough research should be done in this area. In addition, possible research questions could be:

- What education and support is necessary to provide to the production managers and especially the production engineers in order to transfer knowledge about BIM and increase the usage in the production phase?
• *How can measurements of intangible benefits be established in order to estimate the added value in a more explicit way?*

These questions are not only applicable on Skanska, but any other construction company that have not yet implemented BIM in the production phase.
8. References

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Figures


Veidekke, 2012. BIM model from current project.
9. Appendix
Appendix 1

Interview guide

This interview is a part of the researchers’ master thesis at the Royal Institute of Technology (KTH) and the Department of Real Estate and Construction Management. The master thesis is conducted in collaboration with the construction company *Skanska Sweden AB* and the region of *Residential building Stockholm*.

The purpose with the interview is to map the BIM and work preparation process within Skanska and to pinpoint work preparation related and BIM implementation related obstacles in the production phase of construction. Further the interview aims to evaluate the possibilities to implement BIM in this process.

The interviews will be recorder for the researchers to perform a thorough analysis of the interviewee’s answers. If the respondent does not want to accept this condition a notification should be addresses to the researchers prior to the interview date.

To cope with anonymity the interviewee will not be mentioned by name in this master thesis. The interviewees’ current role within the temporary or the permanent organization will be presented instead.

In attached appendix interview questions that will be used as guidelines for the interview are presented. Observe that these questions only form the foundation for further questioning. We hereby reserve the right to address additional questions during the interview.

Thank you for your participation!

Sincerely,

[Signatures]

Marcus Björk Löf

Ivica Kojadinovic
Appendix 2

Interview questions to BIM and other line personnel

Name: ____________________________________
Role: ____________________________________
Project: ___________________________________
Interview date: ____________________________

1. How does your BIM-department work with the BIM model at current stage of development? Is the main focus on usage in the detailed design or in the production phase of construction?

2. What established guidelines are there to support BIM usage within the permanent as well as in the temporary organization? Is there a developed handbook to support BIM usage?

3. How does the BIM department work with BIM modeling? What different roles are present?

4. How does the overall BIM process appear from the initiation of a project to the final handing over phase?

5. Do the BIM department use standardized product libraries that has been quality assured and that can be used by architects and constructors? Why, Why not?

6. At present stage, in what application areas is the BIM model used? (Clash controls, risk analysis, quantity takeoffs, 4D/5D etc.)?

7. What do you consider to be the most beneficial aspects of using BIM?

8. Do you consider BIM to be an effective communication tool and why?

9. In what project phase do you consider BIM to be of greatest value? Why?

10. What are the most obvious flaws in the current BIM process in the detailed design and in the production phase?

11. Do you think it can be of value to reuse the information that is stored in the BIM model?
12. How often does information from the BIM model and earlier projects get reused?

13. How does the BIM Department work with incorporation of construction knowledge into the BIM model to assure constructability and to assure that the model is “ready packed” to suite the production environment?

14. Do you believe that offering the client different BIM solutions can work as a competitive edge in the procurement phase?

15. What do you believe are the most prominent risks that a construction organization needs to consider when implementing new process that BIM induces?

16. Is it possible to extract specific parts of the BIM model and connect them to 4D or 5D applications?

17. Do you believe that the organization of Skanska has adequate competence to take advantage of the opportunities that BIM provide or do you believe that external recruitment is necessary and/or internal education to increase the competence within the company?

18. Do you believe that the project administrators, without earlier BIM experience, would be able to navigate in a BIM model and to illustrate an animated video? Does this require the competence of a BIM coordinator?

19. What kind of internal education does the organization offers for employees in the temporary as well as in the permanent organization regarding BIM usage?

20. How do you view the BIM development within the organization? What is the next step in this development?

21. How does Skanska work with evaluating the effects of BIM? Are there any measurable parameters that are used?

22. Do you believe BIM, as communication tool, could enhance the effectiveness of work preparations?

23. How do you believe that the current work preparation process will change if BIM is introduced in this process?

24. What do you believe are the biggest obstacles with implementing BIM in the production phase and in work preparations?

25. In what construction phase do you believe that BIM can be of greatest value?
26. From what perspective do you believe that BIM can enhance the effectiveness of work preparations?

27. Do you believe that new roles will have to be established in the production environment to support the usage of BIM? Why?
Interview questions to Production Managers

Name: ____________________________________
Role: _________________________________
Project: ___________________________________
Interview date: ___________________________

1. When should an activity be work prepared and what is the primary purpose?

2. How does the work preparation process appear? Please describe how you work with work preparations in your project?

3. Who determines what activities that should be work prepared and how? Are there any guidelines for what activities that should be work prepared?

4. In what construction phase is it decided what activities that should be work prepared? What documentation is used as basis for this decision (Risk analysis, quality assurance plans etc)?

5. What main roles are involved in the work preparation process? Who is responsible for leading the work preparation meetings?

6. What tools are used to communicate how an activity should be performed?

7. Have you ever experienced difficulties in communicating to the skilled workers how an activity should be performed during a work preparation meeting? Why?

8. How do you view the role of the skilled workers in a work preparation? To what extent do the skilled workers affect the content in a work preparation?

9. Do you believe that the skilled workers have a key role in contributing with valuable knowledge and input to the work preparation? Why?

10. Are there any specific demands from the organization of Skanska that work preparation needs to follow certain guidelines?

11. Do you believe that work preparations minimize the risks for unexpected events to occur that can have essential impact on the quality of performed work? In what way?
12. Do you believe that work preparations eases identification and communication of:

a. Risks involved in the specific activity to be performed?

b. How the activity should be performed?

13. How do you work with follow-ups on performed work preparations?

14. How do you store old work preparations? Digitally or manually?

15. To what extent do you use old work preparations? Do you believe there are any associated risks of doing so?

16. Do you believe that work preparations are an essential part of assuring quality in activities performed in the production? Why?

17. Do you see any flaws in the current work preparation process? If yes, what are they and how do you believe that these can be improved?

18. Have you ever experienced a situation where it is hard to communicate information during a work preparation meeting? Why?

19. Is BIM used in the production phase and in your project? If yes, to what extent and what role do you have in this usage? If no, why do you believe this is the case?

20. Do you believe that that there is a basic knowledge of how to use BIM tools among production leaders?

21. Do you believe that BIM could be an effective visualization tool, which could enhance the effectiveness of work preparations? Why?

22. What associated risks do you think implementing BIM in production process and work preparations could bring up front?
Interview questions to Skilled Workers

Name: 1. ___________________________ 2. _______________________________

Role: 1. _______________________ 2. _______________________________

Project: ___________________________________

Interview date: ___________________________

1. How does a typical work day look like? What preparations are made before starting the work on-site?

2. How do you view the purpose of work preparations? What do you believe is the primary purpose?

3. Please, describe how the work preparation process is performed based on your experience from this production process?
   a. What responsibility areas are present?
   b. How do you prepare before a work preparation meeting?
   c. What tools is used to prepare? (Drawings, specifications, other documents?)
   d. What time is provided for you to prepare for a work preparation meeting?

4. After the activity has been worked performed and the activity executed on site, how does the follow-up look like? Do you have follow-ups where you together with the production leaders document positive and negative aspects of performed work?

5. Do you feel that you are given the opportunity to affect how an activity should be performed during a work preparation? In what way?
   a. Do you feel engaged and motivated, and do other coworkers feel engaged and motivated, to contribute with thoughts and ideas to a work preparation?

6. If more convenient solution appears during execution on site, do you still follow the guidelines provide by the work preparation?

7. Do you participate in work preparations which are not directly connected to your area of responsibility, but may affect your work anyway?

8. How do work preparations help you in your daily work on-site? In what way?
9. Are there any difficulties regarding work preparations during the meetings? If yes, please specify.

10. Do you believe that the communication always works as expected during the work preparation meetings?
    a. Are you given the opportunity to give input?
    b. Have you experienced difficulties in interpreting 2D drawings to understand what should be done?
    c. Have you experienced difficulties of interpreting 2D drawings among colleagues?
    d. Is it always clear what the production leaders or other colleagues are communicating or are there misunderstandings? How do the project leaders deal with this?

11. Do you believe that the current work preparation process is effective?

12. What improvements do you think could be made to make the work preparation process more effective? E.g. more preparation time, involve more persons?

13. Do you know what the term BIM means? Explain?

14. Have you been involved in a project where you have used 3D drawings as a visualization tool?
    a. Do you consider it to be an effective tool?

15. Do you believe that the communication process can be enhanced by using 3D-visualization during the work preparation meetings? Why?