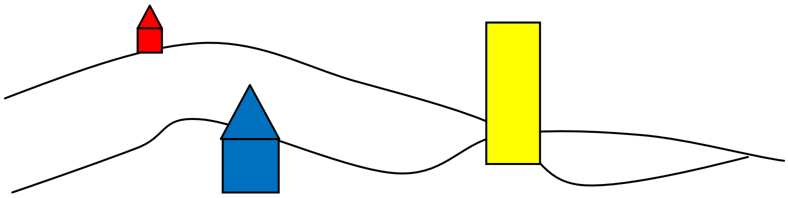

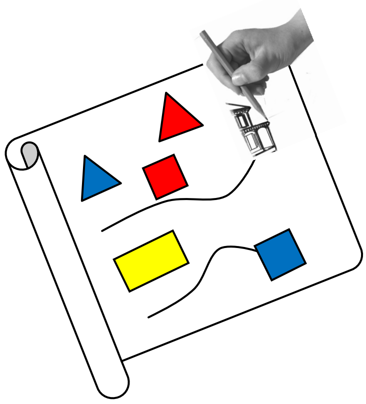

The role and influence of the architect in industrialized building

Master of Science Thesis in the Master Degree Program Design and Construction Project Management

ANNA THOMSEN

Department of Technology Management and Economics
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CHALMERS UNIVERSITY OF TECHNOLOGY
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The role and influence of the architect in industrialized building

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Abstract

An emerging trend within the construction industry is the expectation of the customer to experience and sense the product. The trend would require the building process to incorporate not only function and aesthetics, but also perception and sensation. To meet this trend while at the same time improving productivity, the use of information technology such as BIM and technical platforms have increased in construction projects. Nevertheless, in spite of large investments, the construction industry has not managed to increase the effectiveness and productivity as much as other industries. Evident is that successful use of information technology depends on the integration and collaboration of various experts in a continuous and dynamic process. Such multidisciplinary teams may be organized within a single organization or between business partners.

The purpose of this master thesis is to investigate the use of BIM and technical platforms from an architectural perspective. This is done by evaluating the influence and impact of BIM and technical platforms on the architects' role and work process, evaluating how BIM and technical platforms affect the collaboration and communication between architects and other actors within a construction project, and evaluating how architects use BIM and technical platforms to attain architectural values, style and design quality.

Thirteen interviews with participants in the design phase of two Skanska Xchange projects and five interviews with experts in construction-related information technology have been conducted. The results show that a multidisciplinary development organization, initial education, former experience and how much a participant is encouraged to share professional knowledge are factors that have a large effect on the success of the end result of the construction project. In addition, the technical platform limits the choice of solutions possible, provides other requirements than traditional projects and changes the roles in the design phase.

The risk of relying too much on technology may contribute to decreased quality due to less questioning. Since a building is created and designed to experience and live in, participants in every phase of the construction project have to attain an active role to assure that the end result has a high quality. The influence and professional knowledge of each participant is important in the design phase. It is suggested that a straight forward and simple structured communication plan would minimize misunderstandings and provide each participant with clear responsibilities. In addition, a work plan for each role explaining how the technical platform system and BIM should be used, as well as why and what the expected outcome is, would facilitate the understanding of the Skanska Xchange manual.

Keywords: Building Information Modeling, technical platform, architect, multidisciplinary, construction industry, industrialized building.

Arkitektens roll i industrialiserat byggande

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Sammanfattning

En växande trend inom byggbranschen är att kunden ska ha en möjlighet att uppleva och tycka till om den färdiga produkten, till och med innan den är producerad. Detta kräver att byggprocessen införlivar inte bara funktion och estetik utan även upplevelse och känsla i marknadsföringen av en produkt. För att möta denna utveckling och samtidigt öka produktiviteten i byggbranschen har användningen av informationsteknologi såsom Building Information Modeling, BIM och tekniska plattformar ökat. Trots stora investeringar har effektiviteten och produktiviteten inte ökat i samma utsträckning som i andra branscher. Detta kan förklaras av att en framgångsrik användning av informationsteknologi är beroende av integrationen och samarbetet mellan olika professioner i en fortgående och ständigt dynamisk process. Denna typ av tvärdisciplinära grupper kan verka inom en organisation eller genom samarbete mellan organisationer.

Syftet med denna masteruppsats är att undersöka användningen av BIM och tekniska plattformar ur arkitektens perspektiv. Detta görs genom att utvärdera hur BIM och tekniska plattformars påverkar arkitektens roll och arbetsprocesser, undersöka hur BIM och tekniska plattformar påverkar samarbetet och kommunikationen mellan arkitekten och andra aktörer i designfasen av ett byggprojekt, samt undersöka hur arkitekten använder BIM och tekniska plattformar för att uppnå arkitektoniska värden, design och kvalitet.

Den empiriska studien består av totalt arton intervjuer, tretton med aktörer i designfasen i två Skanska Xchange projekt och fem intervjuer med experter inom informationsteknologi. Resultatet av den empiriska studien visar att en tvärdisciplinär utvecklingsorganisation, förberedande utbildning, tidigare erfarenheter av informationsteknologi och hur mycket de olika aktörerna uppmuntras att dela kunskap är faktorer som har en stor betydelse för hur lyckat slutresultatet blir. Därtill begränsar tekniska plattformar valen av lösningar, ställer andra krav än i andra projekt, och förändrar rollerna i projekteringsfasen av ett projekt.

Slutligen finns det en risk att kvaliteten på slutprodukten försämras vid användningen av BIM och tekniska plattformar då projektgruppen förlitar sig för mycket på tekniken och slutar ifrågasätta vad som syns på dataskärmen. Eftersom en byggnad är skapad och designad för att upplevas och leva i, måste varje aktör i alla faser av projektet inta en aktiv roll och försäkra sig om att slutresultatet ger möjlighet till hög livskvalitet. Influenser och kunskaper från varje aktör i designfasen är nödvändiga för att uppnå detta. För att minska missförstånd och ge varje aktör tydliga ansvarsområden bör en enkelt strukturerad kommunikationsplan upprättas. För att tydligt förklara hur BIM och tekniska plattformar ska användas i varje projekt, varför de ska användas och vilket resultat som förväntas bör också en arbetsplan för varje aktör upprättas. Dessa två dokument underlättar även användningen av och förståelsen av manualen för Skanska Xchange projekt.

Nyckelord: Building Information Modeling, tekniska plattformar, arkitekt, tvärdisciplinär, byggbranschen, industrialiserat byggande.

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Acknowledgements

This thesis is a result of five years of landscape architecture studies at the Swedish University of Agriculture Life and Sciences and two years of design and construction project management studies at Chalmers University of Technology. The master thesis has been conducted at Skanska during the Fall of 2009. I would like to thank everyone who has contributed to the thesis work.

The background to the choice of topic lays in my interest in the communication and interaction between the architect and other participants in the construction project. For my future professional role within construction projects I hope to further deepen this commitment.

Many persons have in different ways contributed to this master thesis, even though some are not mentioned by name I’m grateful for your involvement. Firstly I would like to thank Martin Svahn and Lars Björklund at Skanska, who introduced me to Skanska and gave me the opportunity to do my master thesis at Skanska. Further I would like to thank my supervisor at Skanska, Rikard Espling for giving me the opportunity to study the program of Skanska Xchange and for his comments, engagement and attitude. I also would like to thank the persons who let me interview them and openly shared their thoughts and knowledge about the topic of this thesis. Mårten Sandell should have an extra thank you for reading through and given useful comments.

A would like to bring forward a great thank you to my supervisor at Chalmers University of Technology, Anna Kadefors, who have given me fruitful comments, new perspectives and ideas to make this thesis better. I also would like to thank my supervisor at the Swedish University of Agriculture Life and Sciences, Tim Delshammar, who has provided me with useful comments to improve this thesis.

Last I would like to thank my father for his reading and comments and Magnus for his patience, support and love.

1. Introduction

This chapter will provide an introduction to the topic by presenting an overview of the area, aiming at describing the underlying concept of technical platform and Building Information Modeling (BIM) and the approach of architects. A background to the choice of study and a discussion of the problem area of interest will follow, which will be narrowed down to the purpose of the thesis and the research questions. Further, the research process used and its limitations will be explained in detail in order to develop an understanding of how the problem formulation, selection of methods, data collection and analysis have been performed. Finally, some of the terms and concept that will be used throughout the study will be introduced by providing their definitions.

1.1. Background

Through the history the words efficiency and productivity has seldom been used in the same sentence as the expression good architecture. Consequently the quest for increased productivity has created a more systemized way of working. Lately this has awoken discussions about the role and influence of the architect in the construction industry. For many decades there has been a development and an increased use of information technology in the construction industry (Samuelson 2003). Nevertheless, in spite of large investments, the construction industry has not managed to increase the effectiveness and productivity as much as other industries. The building industry consists of many actors with different educational backgrounds working in different phases of the life-cycle of a construction project. This diversity together with the development of industrialized buildings has contributed to modified work processes, shifts in roles and new ways of communicating. According to Day (1996), both the capacity of the new technology and the organizational change are important in order to implement the technology successfully. In addition, in 1998 the Swedish government approved a national action program to strengthen the cultural, historical and the aesthetic values so that the quality and beauty aspect of the built environment does not become subordinated to the short-term economical aspects.

It is often said that each construction project is unique, nevertheless customers and contractors require increased effectiveness and productivity in construction projects, using standardized methods and components. In an effort to meet the customers' requirements and be able to compete on the global market, many companies, Skanska among them, are utilizing platform-based product development to shorten lead time, decrease variety and reduce cost. Meanwhile, architects and designers emphasize the importance of space for creative development and diversity in graphical expression (Jespersen, 2008).

Whereas the traditional industrial sector is characterized by standardization, the service sector emphasizes customer orientation and delivery on demand. An emerging trend is the expectation of the customer to experience and sense the product, maybe even in a customized manner. The latter trend would extend the necessity of incorporating not only function and aesthetics, but also perception and sensation. It is therefore assumed that the expertise from architects, designers and possibly other experts, e.g. on environment and sustainability, could have important, future roles in platform-based construction development. An important part of the present thesis is therefore to consider the role of the architect today, specifically in construction processes where technical platforms and BIM are employed.

The topic of this master thesis is connected to the author's interest in the communication and interaction between the architect and other participants in the construction project. What makes the concept of technical platform and BIM particularly interesting from a research perspective is the availability and use of 3D modeling technology (Kalay, 2006; Jongeling, 2008). Further, media has given considerable attention to technical platforms and BIM. Finally, major investments in these systems have been made by the major construction companies in Sweden.

It is hypothesized that the successful use of platform-based product development is dependent on the integration and collaboration of various experts in a continuous and dynamic process. Such multidisciplinary teams may be organized within a single organization or between business partners. If the interactions and responsiveness among the participants in a construction project are sub-optimal, the project is not ideally implemented despite the technical platform and BIM (Tweed, 2001).

In this thesis, 18 interviews were conducted with persons having varying experience in using technical platforms and BIM. Thirteen of the interviews have been with participants using the SXC Multi platform in two Skanska Xchange projects. The other five interviews were done with researchers and experts in technical platforms and BIM in design.

1.2. Purpose

The purpose of this master thesis is to investigate the use of BIM and technical platforms from an architectural perspective.
More specifically, the following research questions are addressed:

- How does the use of BIM and a technical platform impact on the architect's role and work processes?

- How does BIM and technical platforms affect the collaboration and communication between architects and other participants within the project?

- Which is the perceived influence and impact of BIM and a technical platform on architectural values, style and design quality? Which management is needed to be successful?

- How can the Skanska SXC system be improved to better support design processes (suggestions/recommendations)?

1.3. Limitations

The two concepts of technical platforms and BIM are often used interchangeably, although they have different meanings and exist independently of each other. In this thesis, they will be considered as two systems, that are coexisting and facilitating each other, see Definitions below. The focus will be on the role, work processes and experience of the architect using technical platforms and BIM. However, to provide a broad view of the matter, both architects and engineers have been interviewed in the empirical study. To limit the study, a decision to focus on the design phase was made. The design phase in Skanska Xchange projects consists of the Premarketing & Design phase and the Reservations and the Detailed Design & Preconstruction phase.

The evolving use of technical platforms and BIM to increase the quality, shorten the project time and come up with cheaper solutions (Tweed, 2001) is, as before mentioned, a driving force for my interest in this subject. Because Skanska Xchange is in an early stage of implementing a technical platform system and BIM tools in Skanska projects, the choice of projects available for this study was limited. None of the projects selected used the SXC Multi platform and BIM from the beginning.

Concepts of time, quality and cost are mentioned as parameters that will be improved by the implementation of BIM and use of technical platform. Whether and how much these factors increase or decrease is discussed in this thesis, but not objectively measured. Since the SXC Multi platform and use of BIM are recently implemented in Skanska, the aim with this study is not to benchmark if the system is profitable and should continue to be used. Instead this thesis will provide recommendations to how the Skanska SXC system can be improved to better support design processes.

1.4. Research process

Figure 1.1 provides a visual overview of the research process adopted in this thesis. The research process has been deliberately dynamic to maintain a flexible work flow and be prepared for changes that are necessary in order to get the best result. Throughout this master thesis each heading in the figure and its subheadings will be explained and motivated.

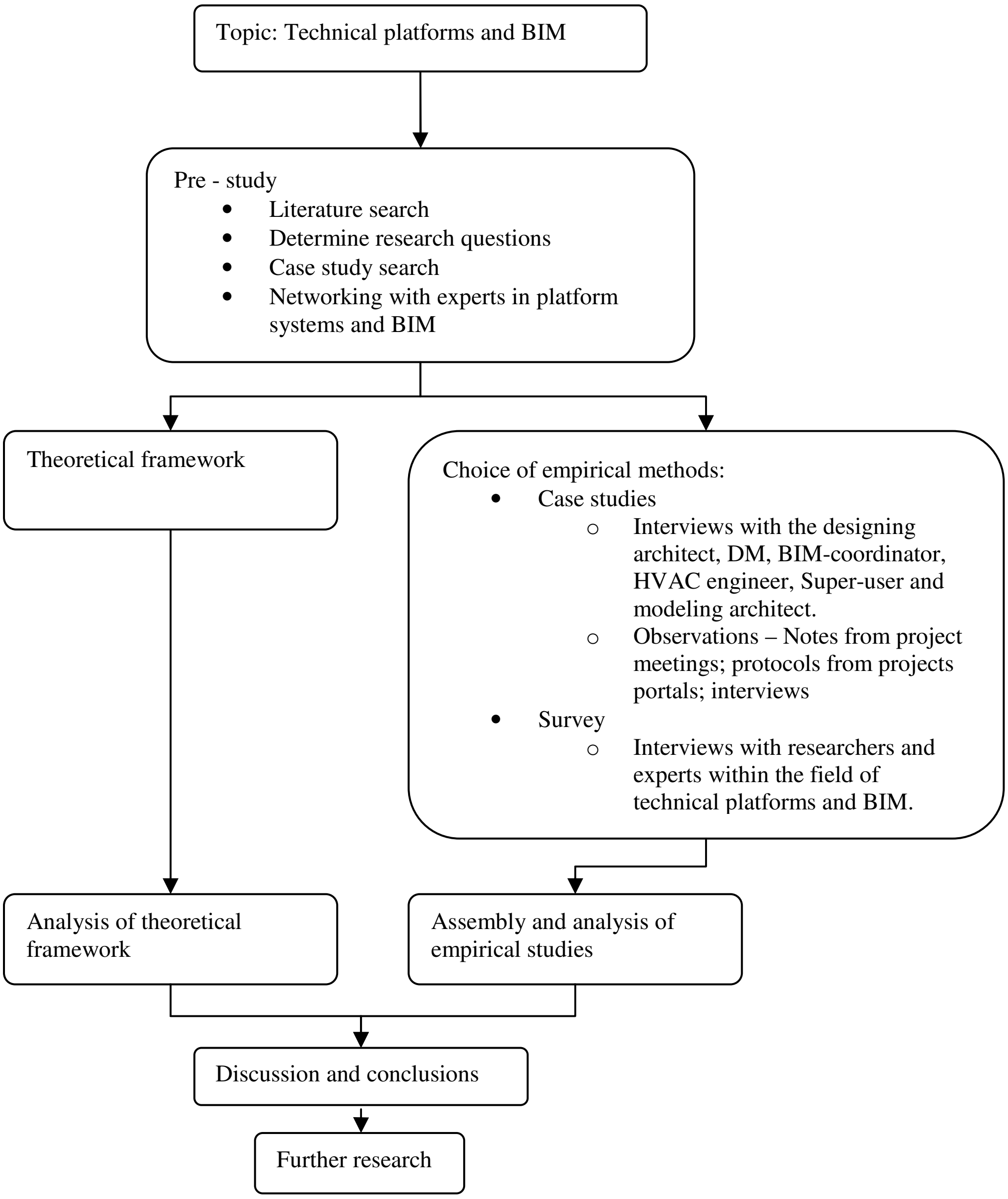


Figure 1.1: Description of the Research Process

1.5. Pre-study

A pre-study was initiated in order to get an indication of how much research has been done in the area of modular design and BIM. Key ingredients of the pre-study were also to identify and contact key organizations and experts, possible case study projects and potential survey objects. The goal of the pre-study was to identify research questions. The keywords used to gain research information about technical platforms and BIM were initially very broad and general e.g. *BIM, platform systems, systematic design*. However, as the research progressed the keywords were narrowed down to address the explicit areas of interest e.g. *technical platform+the architects role, BIM+construction projects, modular architecture*. Merriam (1994) recommends initiating the study by researching the area of interest closely but broadly and then, as the research proceeds, to narrow the focus.

1.6. Gathering of theoretical framework

The theoretical framework forms the foundation for the research and is therefore a very important part of the master thesis. The assessment of theoretical data was mainly done through the electronic library and databases at Chalmers University of Technology (CTH) and Gothenburg University (GU). The electronic library mainly at CTH has enabled the search in databases such as Emerald. From quotations and references in articles in Emerald additional databases, journals and books have been explored.

The theoretical framework is mainly built upon published articles from well renowned journals. Initially and for the most part the database Emerald has been used for searching for journals. In addition, papers, masters theses, debate articles from Swedish journals and written material from electronic sources have been studied. The literature review and gathering of data have been done separately yet closely with the empirical studies to support and try to get the most out of the empirical studies. Furthermore, a high degree of flexibility has been kept during the whole master thesis, in order to encourage a dynamic working process.

The data used in this thesis have been derived from both primary and secondary sources. Repstad (1993) explains the difference between the two by stating that primary sources of data are closer to the main source than secondary sources, hence being considered to have a higher reliability. However, Repstad (1993) makes sure to emphasize that the secondary sources are essential in the sense that they provide the researcher with the necessary background and context needed to carry out academic studies. In this thesis the introduction to Skanska Xchange is considered as a secondary source, while the data from the research articles are primary sources.

1.7. Structure of the Thesis

This thesis consists of eight chapters, which together create a knowledge base for how the use of platform systems and the implementation of BIM affect the architects' role in construction projects.

Chapter two– Theoretical framework - consists of the theoretical framework covering a literature review found within the field of technical platform and BIM in construction, as well as of discussions on how the role of the architect has changed with the implementation of both these systems. The theoretical framework will be acting as a complementary point of reference when discussing the empirical findings in the subsequent discussion and conclusion.

Chapter three - Empirical methodology - In this chapter the applied scientific research method is be presented and motivated. The structure of the interviews and the process of the empirical data selection will be explained in detail.

Chapter four - Results - describes the empirical study that forms the basis of the analysis. Firstly, an overview of the two projects is presented, followed by findings of the two case studies and survey. The Case studies contain; a) notes and observations from project meetings, b) protocols from the web based project portals and c) the results from interviews with the participants of the projects. To make it easier to compare the results of the two case studies, they are described separately. So are also the interviews with the researchers (the Survey study).

Chapter five – Discussion - This chapter contains the analysis of the empirical study supported by the theoretical framework.

Chapter six – Conclusions and recommendations – contains observations and comments from this thesis. Also recommendations to improve the SXC Design system are provided.

Chapter seven – Further research – proposes further research and discussion/debate items about the architects' role in the field of platform systems and BIM.

1.8. Definitions

BIM

BIM is sometimes referred to as Building Information Model, seeing BIM as a 3D model, while other times BIM is considered as a process and then called Building Information Modeling. This thesis uses the latest adaption and encapsulates BIM as a process rich in data that supports communication, collaboration and optimization (Laiserin, 2007). For more information, see chapter 3, BIM in Skanska.

Technical platform

The concept of technical platform is in this master thesis used to describe, well defined platforms containing predefined groups, based on well-tested standardized components and processes. These standardized elements, components and material are put together to optimize the building process (Skanska Xchange, 091012).

Skanska Xchange

Skanska Xchange is a Nordic program where technical platforms, BIM and other tools are used to improve the residential construction processes. The program is based on best practice from the Nordic countries and the task is to evaluate the best way of working in construction projects. (http://info.sxc.skanska.com)

3D Modeling

The concept of 3D modeling is used to visualize and describe physical phenomena. 3D models contain geometry of physical objects providing choices to best explain the dynamic physical environment we live in (Smith 2009). 3D modeling is one minor part of BIM and should not be considered that same as BIM.

2. Theoretical framework

This chapter will present a theoretical framework acting as a complementary point of reference when discussing the empirical findings in the subsequent discussion and conclusion.

2.1. Technical platforms in the architects work process

In this first section of the theoretical framework the literature behind technical platform and the architects' role in, as well as approach to will be introduced. This section begins with an introduction to how the technical platforms are used in construction project, followed by a brief history, which in turn will end with the architects' experience of technical platforms systems.

The words *platform* and *technical platform* are often used interchangeably. Before reading this theoretical framework I recommend the reader to study the glossary on page 5 and 6 for an explanation to how the vocabulary is practiced in this thesis.

Architectural design and the construction of buildings have always been collaborative efforts that involve several individuals representing many different skills and abilities. To manage such a highly complex organization in order to produce a desired result is a challenging task (Kalay, 2006). As a comment to what is important in the construction industry today, Simpson (2004) writes on p.4: "The imperative today is to understand and fulfil each individual customer's increasingly diverse wants and needs while meeting the coequal imperative for achieving low cost." This has caused a progressive use of systematic ways of working. According to Simpson (2004), the use of technical platform can maintain the economy of scale while offering a variety of products to the customer. However, as Martinez et al., (2008) states, the variety of products that can be offered are limited and the role of an architect as a designing participant in the construction project is discussed. Martinez, et al., (2008) further claims that examination and understanding of the organizational, technical and economical implications will decide the success of the use of platform systems in construction projects. Hence, Kalay (2006) suggests that a technological revolution that impacts on information processing has the potential of affecting the core processes and products of architecture and has a major effect on the role of the architect.

Furthermore, Kalay (2006) says that by including interrelated events both in the building components themselves and the benefits of bringing them together, the process of construction and its products can become more intelligent, meaning that they are able to respond to the changing needs of the customers without re-design. This affects what can and needs to be designed in the first place.

2.1.1. Understanding technical platforms

What does the concept of technical platform system really mean and what is it that makes the architects reluctant to lower costs while maintaining product quality is something that construction companies and contractors in Sweden have a hard time understanding. The explanations aiming at describing the concept of technical platform are many (Jongeling, 2008). A technical platform system can be either narrowly or broadly described. Meyer and Lehnerd (1997); McGrath (2001) and Robertson and Ullrich (1998) all have their own definition: Meyer and Lehnerd (1997) describe it as "a set of common components, modules, or parts from which a stream of derivate products can be efficiently developed and launched". While McGrath (2001) states it is "a collection of common elements, especially the underlying sore technology, implemented across a range of products". Robertson and Ullrich (1998) define technical platform as the collection of assets [i.e., components, processes, knowledge, people and relationship] that are shared by a set of products" Seeing an organization as a metaphor to a car, Simpson (2004) adds more information to this debate by stating that in order for an organization to be successful with any of these definitions careful attention to "the customers' needs and underlying product architecture in the family" is needed. He classifies the architecture of a product as either "*modular, if there is one to one or many to one mapping of functional elements to physical structures, or integral, if a complex or coupled mapping of functional elements to physical structures and/ or interfaces exists".*

Approaches for developing modular product architecture and module-based product families increase in the engineering design literature. The confidence in improving the scope and economies of scale as well as to facilitate customization by enabling a variety of products to be quickly and easily developed triggers this development (Simpson, 1994; Tweed, 2001). Nonetheless, as Simpson (2004) points out, does variety provide choices for customers but does not enable the customer to specify the product, yet variety is not customization. He instead emphasizes that a customized product is designed to meet the specific needs of a particular customer, and therefore, Simpson (2004) says, the customer must be involved in the realization of the product in order to be called customized. Almost ten years earlier, Day (1996) brought about the fact that technical platform in the future would allow the customers to design their own buildings and then alter them continuously, resulting in truly adaptive environments. Further, Day (1996) even suggested that the technical platform would replace the role of the architect and the advance computer intelligence would lead to the development of intelligent CAD systems which would allow the whole design process to become accessible to designers with little or no professional training.

2.1.2. The architect in early industrialization

According to Mitchell (1974) the "classical approach" to architectural design, expressed by the Ecole Polytechnique (School of Engineering) and the Ecole des Beaux-Arts (School of Fine Art) during the nineteenth century, was based upon systematic exploration of alternative ways in which a variety of elements from a fixed glossary could be brought together to generate architectural forms.

In the 1910s Henry Ford developed the concept of mass production. The system was based on standardization of component and systematizing of processes. According to Batchelor (1994 p. 70) the systematic repetitions lead to lower costs through economies of scale[1]. This way of producing became widely accessible and was adopted by other industries (Benros and Duarte, 2009).

In Sweden the man who would become the father of the architectural development for the next 65 years introduced the concept of functionalism. Asplund stated that the aesthetic solution lies in the designs placement in the landscape (Qvarnström, 2004). For many years to come would Gunnar Asplund's belief in architecture as a functional form be dominating the role of architecture all over Europe (Qvarnström, 2004). In France and Germany Le Corbusier's Domino houses at Pessac (see figure 2.1) and the Torten housing development by Walter Gropius represent two well-known examples, designed around 1926. In both cases there was a desire to visualize a form that could generate affordable housing using industrialization to lower the costs. The strategy was to design a few model houses that were prefabricated and then repeat them on a larger scale. According to Batchelor (1994) and Benros and Duarte (2009), Le Corbusier was concerned with diversity. This brings us back to the negative attitude that Day (1996) and Simpson (2004) had towards technical platform stating that variety provide choices for the customer but do not enable the customer to specify the product. Simpson (2004) continued by stating that variety does not guarantee customization and customization is what every construction company is striving for.

Figure 2.1: The Domino houses at Pessac by Le Corbusier. Source: http://boiteaoutils.blogspot.com

In the 1960s, as a result of people being dissatisfied with monotony and the impersonality of mass-produced housing, the development of production methods that would allow user participation, grow strong. (Benros and Duarte, 2009) One of the most expressive and influential examples was the Theory of Supports developed by a Dutch architect, John Habraken. The theory distinguished between "support" and "infill". The support was the rigid part of the building that households agreed not to change and included the structure and the infrastructure. The infill, according to Habraken, was the flexible part that could be modified during and after the project. The design followed a specific method that included a grid and zones, together explaining the architectural hierarchy and design system (Habraken, 1987; 2002). Furthermore, Habraken (2002) claimed that the concept of levels allow the participants to find their role and process. The parties involved are considered and who is responsible for what is established. Also the distribution patterns of how the different projects are structured can be viewed in the system.

In addition, Habraken (2002) distinguished and emphasized the difference between design control and actual control during use, where the architect is responsible for all levels except the choice of furniture. The method provided a set of rules that could be

[1] " Economies of scale are factors that cause the average cost of producing something to fall as the volume of its output increases." Source: http://www.economist.com/businessfinance/management

used in the design of various solutions, thereby allowing a certain degree of customization. This method evolved to become what we today call an open system or open building[2] (Habraken, 2002; Benros and Duarte, 2009). In the meantime, Henry Ford's mass production paradigm became gradually old-fashioned in a society where individual choices increased.

The 1970s introduced Toyota's lean production. The goal of lean production is to reduce production time and costs by avoiding the waste that exists in mass production (Womack & Jones, 1996; Martinez, et al. 2008). One tool for this is just-in-time (JIT) production, which decreases the need for storage spaces as components are produced only when an order has been received. This system created greater diversity, resulting in higher levels of customization as customer satisfaction was no longer dependent on what was stored. Unlike other industries, the building industry has been slow adopting the concept of lean production (Benros and Duarte, 2009).

35 years earlier Mitchell (1974) commented on the pattern of development for architects using technical platform by saying:

> *"It does not appear likely that we will discover some basic, underlying "secret" of effective automated architectural design. Rather, the power of effective systems will reside in their capacity to access exceedingly numerous procedures, each of which efficiently performs some relatively small, well understood, and well bounded task."*

Mitchell (1974) also believed that the future role of an architect would shift from the craft-based skills of drawing, spatial puzzle solving and the experienced-based knowledge of prototype designs, to the capacities to understand and manipulate complex structures of data and procedures, in order to indicate effective problem-solving strategies, and to conceptualize the general principles fundamental to the specific situations. Figure 2.2 show a sketch by the Dutch architect Hamers. According to the NAI (Netherlands Architecture Institute) (2009) is the hand sketched drawings able to capture moments in an instant and empahise ceratin architectural features. This spontanous drawings can not be done in the computer. Meanwhile does the work of the new headquarters for the Chinese state TV channel, designed by the Dutch architect Rem Koolhaas, represent a complexity facilitaed by the computer and 3D modeling.

[2] The concept of Open building "suggests distinguishing different levels of decision making, in order to decouple building parts with different life cycles, controlled by different parties, built by different trades. In order to decouple and yet coordinate, a set of rules for dimensioning, positioning and interfacing was developed." Source: (Cuperus, 24 09 2009)

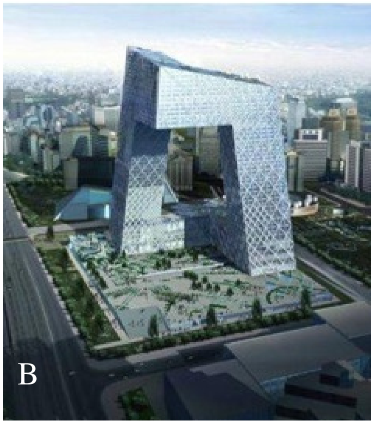


Figure 2.2: A) show one of Hamers spontaneous hand sketches, the church of San Stefano in Rome. (http://en.nai.nl) B) Show the complex work of the headquarters for the Chinese state TV channel (http://oma.edu).

In a report about architectural history, Rudberg (2007) comments on the changing role of architects. She questions if the technological development of today is a threat to the architecture profession? Today it is the architectural team and the entire office - more seldom the individual architect - that almost anonymously stand behind the architecture. Rudberg (2007) states that; to study the participants in a construction project should be highly prioritized if one wants to provide a picture of the conditions and terms of the contemporary architecture. Rudberg (2007) describes the difficulty in the current situation in the distance to the subject and blames the increased usage of computers. The next section presents additional comments to the current role of the architect and what influences this.

2.1.3. The architect's experience of using technical platforms

The role of an architect is to analyze the current state and produce design proposals and give advice for the future based on the information available today. To be able to imagine a new more improved design the architect needs to know relationships between structural elements, stated by laws of physic and logic (Baldwin & Clark, 2000). In order to deliver the best result the architect collects and evaluates information from different sources, re-arranges and produces new information. In addition, the architect evaluates the demands from the customer and simulates the expected impacts that the design will have (Kalay, 2006).

Today, a large amount of information is exchanged between participants within the construction project. In a construction project this information can be found in drawings, tendering documents, project descriptions and other detailed documents. To be able to organize and structure this information and to make it wieldy and lucid requires a lot of work. According to Gustafsson and Schatter (2005) a project platform[3] can facilitate this problem. They further state that the project platform enables the insight of the client in the project and make sure that the participants always work with updated documents. On

[3] A project platform is a system used to facilitate communication and not a technical platform aiming at providing the construction project standardized component and decrease the production time.

the market today there are several platform systems accommodated for the construction industry. Gustafsson and Schatter (2005) therefore push the importance of choosing either a platform that fit that particular project or a platform system that has a regular framework and a flexible part that allows participants to be creative.

Lerthlakkhanakul et al. (2008) and Autodesk (2008) states the dependency between project platforms and technical platforms saying that there is a gap in communication between architects and users, where the architect fails to explain his/her design or built environment so that the user is satisfied. The problem usually is that the users are unable to imagine how the design will be emerged after the construction phase. Users are not, unlike architects trained to understand three-dimensional space, therefore project platforms and technical platforms need to go hand in hand. As a comment to this Habraken (1987) says:

> *"By starting from the concept of theme, which led us to the concept of systems, we begin to see designing as something happening among people. No one designs alone in architecture anyway. We will be less defensive if we can explain the thematic aspects of our work to others because it allows them to think along with us and it makes us free to change the elaboration of the theme or choose a different theme without loss of control"*

Winch and Deeth (1994) mention another communication gap that Lerthlakkhanakul et al. (2008) still claim is a problem, the one between architects and engineers. Hence, Kalay (2006) points out that the technological revolution that impacts on information processing has the potential to affect the core processes and products of the architect and have a "revolutionary" effect on the profession and the discipline of architecture. Broader, the increased use of platform systems has the potential of changing the current strictly hierarchical design process into a network of design, manufacturing, marketing and organizations management, where the responsibility for design is distributed across multiple professions, organizations and geographic locations (Kalay, 2006).

In the early nineties Winch and Deeth (1994) criticized the technical platform system from an architect's perspective and claimed that this form of platform comes to be seen as a technician's tool rather than as a support to creativity for all professionals. Moreover, a recently done study by Israel, (2009) highlights the importance of the architect's preference to use sketches for its creativity in conceptual design. Further, Winch and Deeth (1994) stated that architects easier reject the applications and blame the system when things go wrong, since they feel they have no responsibility for it. This, in the long run affects the architectural quality and value. Even earlier, Little (1988) showed that among all industries in the early seventies, architects were some of the earliest users of CAD, nevertheless the construction industry today lags behind other industries, such as the automobile industry, in how to use platforms and IT systems.

2.2. Digital Modeling

In this section the theoretical framework for the role of architects' in 3D modeling technology and BIM will be presented. The structure of the section is the same as for 2.1 to make it easy following the reasoning and provide a readable yet comprehensive text.

2.2.1. The architect's role in early 3D modeling technology

For several decades discussions about how to make the construction industry more effective have pushed the development of standards and systems. SKETCHPAD was an architectural design system developed in the end of the 1960s, early receiving extensive critique for its content. The system was developed in an engineering environment where design problems, although having a simple graphical content, were described in mathematical terminology. Architects claimed that the design situations differed completely from this way of working as they traditionally arranged volumes in space, selecting materials, constructions and environmental systems which required only very little amount of computerization (Willey, 1975) .

The IMAGE system, a progression of the SKETCHPAD system, was developed at Massachusetts Institute of Technology in the 1970s. This system allowed the architect to explore variations in the designer's image of the design problem. The system also maintained overall the designer's objectives and developed a wide range of alternative designs. The designer specified the spatial design problem by using an idiom which describes both geometric and relational constraints. Then the computer programs automatically generated a three-dimensional spatial design until a configuration satisfied all specific relationships (Johnson, 1970).

Another system was the General Space Planner (GSP), developed by the engineer Charles Eastman. This system mainly focused on equipment and furniture layout, although it came to be applicable to a wider range of architectural design problems. GSP solved the problems with the spatial functions automatically and described it as a set of shapes and the relationship between these shapes. The iterative method used in GSP facilitated not only the architects' work, but that of all the other participants in a construction project. For example, the client used the early sketches to support new relationship that should be satisfied in the design (Eastman, 1971).

As early as in 1975, Willey (1975) pointed out architectural design problems in using systems like SKETCHPAD, IMAGE and GSP and claimed that architects no longer drew when using these early CAD systems: "In c. a. d. systems the ability to learn about possible relationships and solutions through their creation as drawings has been lost and replaced with the manipulation of the relationship themselves."

2.2.2. Understanding BIM

Autodesk (2008) states that the increased use of BIM in construction projects has to do with the customers' ability and need to understand and interpret the future building, moreover the customers' demand for decreased project costs. Further, BIM (BIM) is used as a tool to handle information that is created during the whole construction project, from

concept and design to construction phase and even during maintenance. The Modeling is a structure of how and where project information should be saved. The structure is a database driven by a CAD-system, exclusively a database or a mix of the two. Through the database(s) the project participants can exchange information in a structural way (BIM BIM, 2004). It is the detail expressed in the building information model that ensures that the resulting visualization is a true reflection of the architect's vision. (Autodesk 2008)
As often discussed, today organizations are required to be responsive in order to rapidly react to changing market needs and opportunities. The demand to increase efficiency, decrease costs, reduce time, and increase the turnover are causing construction companies to evaluate and re-think their role in, and way of executing construction projects. According to Aerts et al. (2004), incompatible and inflexible IT systems are no longer suitable and the participants in the construction projects have to quickly respond to the changing needs if caring for architectural quality.

Bergmark (2004) claims the idea of BIM has been used for a long time, even though the information exchange has been more or less automated and developed. Additionally is the concept of BIM often interchanged with the concept of CAD. BIM includes CAD but the information is objectified into tools that can be repeatedly used. BIM can be seen as a development of CAD. Drawings in a BIM system are developed into reports that are generated from a 3D model. The reports contain detailed information about material chosen and room specifications. BIM requires that all the participants use programs that are object-oriented, can handle both 2D and 3D and communicate with other applications to increase the information exchange (Bergmark, 2004).

2.2.3. The architects' role in BIM

Today, the economic benefits of BIM are widely known in industries as the automotive industry, electronics and consumer goods manufactures. They have used "model-based digital design processes" supporting not just production planning, and engineering analysis, but supply-chain integration and visualization of the design (Bernstein & Pittman, 2004). The construction industry however still is just starting to see the benefits and challenges an organization faces when deciding to implement BIM.

One use of BIM is to provide the customer a glance of how the building will be experienced when finished. From an architect's perspective this visualization process is a widely discussed matter and the architect often experiences the BIM structure as limited space for free creativity (Autodesk, 2008). Architects' visualization process traditionally is often based on free thinking with orthogonal drawings, small scale physical models or water colored sketching. This approach creates an unwillingness to structure the design process (Autodesk 2008).

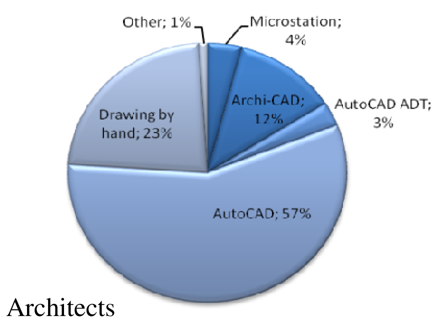
The implementation of BIM requires that the architect handle over a digital 3D model of the design done in a compatible program. All participants in the project use a common database to store drawings and exchange information with each other. (Bergmark, 2004; Norén, 2009)

In a study by Autodesk of the American architect firm RTKL, one employee of RTKL said:

> *"Since we don't have to model the building anymore we use extra time to improve the realism of the visualization. We can spend the time fine-tuning the materials, the textures, the lighting and adding extra details like furniture and accessories, surrounding structures and landscape, even animated 3D people and cars" (Autodesk, 2008, p.7)*

By letting the quick renderings, "plain old" hidden lines views and color settings being done in Revit Architecture and leaving the visualization studio to focus on the high-quality presentation material needed for reviews, approvals and marketing the project save time. One architect in the study expressed the major benefit seen from an architect's perspective as the designers' ability to spend more time brainstorming and discussing ideas in the building information model and the time saved by not having to create, develop or coordinate the model. In addition it is possible to produce higher quality visualizations that truthfully represent the architect's design. Further it is the platform from Revit linked to the visualization of 3D StudioMax that minimizes the time required to coordinate the architectural design and visualization. (Autodesk, 2008)

A study done at the Technical University in Jönköping (Andersson et al. 2008) shows that the transformation to digital 2D planning in the 1980s was an example of a technical revolution and the vision of the work of computer models became more than just geometrical. A study done by Samuelsson (2008) indicates this and adds that CAD was fully implemented in designers work process in 1998. Further, Andersson et al. (2008) claim that the transformation to 2D only concerned the designers, whiles the BIM revolution going on today, concerns all actors in a construction project. Therefore, Andersson et al. (2008) states, the business processes and organization of industries need to be developed before entering the BIM revolution. According to Samuelsson (2008), the use of tools that can handle 3D computer object has doubled by architects and increased with over 30% by technical consultants (figure 2.3).



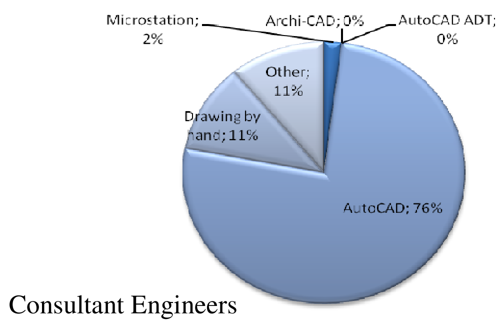


Figure 2.3 Proportion of techniques of the total design time in 2007. Source: Adapted from Samuelsson (2008).

The study by Samuelsson (2008) also reveals that few designers use CAD only for 2D drawings. 60 % of the architects and 70% of the technical consultants use CAD for geometrical data in two or three dimensions (figure 2.3). On the other hand does the study confirm what other studies have shown. Few, only 15% of the architects, technical consultants as well as contractors and facility managers use their CAD databases for object-based data, such as time and economy.

2.2.4. Obstacles to the use and implementation of BIM in the construction industry

Bernstein and Pittman (2004) suggest that the fragmented and solid processes in the construction industry inhibit change such as the one that occurs when BIM is implemented. In addition, the way and the ability that diverse systems and organizations work together in the construction industry need further studies. This is also something that (Martinez, et al. 2008) comments on when they claim that the use of computer techniques has been delayed and obstructed because of the traditional view of old-fashioned techniques, processes and materials in the construction industry. Moreover, the construction industry is labor intensive, site based and constrained by the weather. These factors are causes to why the construction industry lags behind in implementing systems like BIM (Martinez, et al. 2008). Below Bernstein and Pittman (2004) emphasize three other obstacles to the implementation of BIM in the construction industry:

- **The architects' digital background.** The received files on the design development, before used as background files by the architect are not compatible to the format of the used in BIM.

- **Coordination.** The engineer receives the background files for construction from the architect and finds the roof level insufficient, whereby the engineer changes the roof level without consulting the architect, resulting in the different documents not matching, contract breakage and re-work.
- **Disinterest and resistance to change.** The resistance to change is brought up as one fundamental issue to why the construction industry is slow at adopting model-based design. Though, Bernstein and Pittman (2004) believe that there is a broader explanation to this where the designers do not fully grasp the opportunities of extended use of the computer and the limitation of the present systems.

In a seminar initiated by *Svensk Byggtjänst* (2008), Christine Westberg, a building engineer working in the architect firm Krook and Tjäder, emphasizes some factors in order to minimize the cultural chock switching from CAD to BIM. Westberg highlights the competitive advantage in effective information handling and communication. But to be able to witness these positive effects the organization need to consider the following points:

- Question what you want to improve with BIM.
- Management must be committed to its success.

- The size of organization and number of projects affect the way the organization should look at BIM.
- How big is the tolerance with the risks of implementing a new way of working?
- What access to knowledge and resources are available?
- Determine the speed of the transformation together in the organization.

A study done by Samuelsson (2008), shows advantages but also several obstacles to the increased use of IT systems, such as BIM. Below is a selection of what the most and the least positive effects the architects and technical engineers experienced in this study.

- Positive:
- Simpler/faster access to common information
- Possibility of sharing information
- Better quality work
- Better communications
- Easier to handle large amounts of data
- Greater flexibility for satisfying customers
- Possibility of reducing staff

- Negative:
- Continuous demand for upgrading hardware and software
- Overabundance of information
- General attitude that old ways of doing things have worked well throughout the years and changes are unnecessary
- Greater know-how required from staff
- Investment costs too high
- Risk that IT leads to inefficiency
- Non-compatible software
- Preference for manual working because of lack of standards/coordination problems

Consequently Bernstein and Pittman (2004) claims that solving one obstacle does not automatically make the BIM system fit the organization. Although, when all of the barriers are considered and the integration of architectural design, a clearly defined work-flow and facilitating tools in model-based “design-to-build” processes has succeeded, many potential conflicts can be eliminated. Haymaker et al. (2004) stress the fact that even though these systems sometimes successfully do let designers define geometric object and their relations to each other, they are not highly implemented within the construction industry. Haymaker et al. (2004) blame the currently formalized techniques that they claim have not adequately supported the multidisciplinary, constructive, iterative and unique nature of construction projects. The systems do not enable the practitioners to easily construct new representation from and control the integration of information from other representations.

2.3. Future digital concepts

In this last section of the theoretical framework a small selection of future digital concepts will be described. The selection does not by any mean count for a generalization and is aiming at offering the reader a brief introduction and an expanded storage of concepts.

Khemlani (2005) describes the next step for digital 3D technology as a flexible and bidirectional[4] communication between BIM applications such as Revit Building, Revit Structure and ArchiCAD, instead of just the CAD application to which it now connects. Additionally, this would allow better model-based integration between specialized work on a building, such as the architectural design, engineering and construction. It would also allow rule-based automated design to be explored for other aspects of architecture and engineering. Ali and Brebbia (2006) state that the future relationship between architects and digital tools rest with the architects accepting "exemplary architectural design" and further claim that digital thinking is architectural thinking.

2.3.1. Place-making, Virtual Reality and Cyber architecture - towards a virtual architecture

Kalay (2006) declares that the architects' role is the art of making places: *"environments that support and enhance human activities such as living"*. The increased use of computer-based systems has opened up the opportunity to simulate the reality before the construction phase starts. Relph, (2007) and Kalay, (2006) state, that in a virtual world there is a great freedom of choice with no pre-given heritage and local traditions, no planning bureaucracies, no need for sustainability, no budget and no need to make profit. Theoretically, Relph, (2007) states that an identity of a virtual place depends only on the creativity of the designer. Though, in practice this is not the case because imagined places have to accept the conditions of real places if they are to be understood correctly. Virtual Reality is often discussed in indirect opposition to perceived reality and hence is seen to be terrifying, or less meaningful (Champion, 2007). Cyberarchitecture is another concept widely discussed in the world of 3D modeling. The development of cyberarchitecture suggest the architects to abandon the design of the finished products and start developing virtual interfaces for the customer to keep on designing their own objects, spaces and events (Baltazar, 2007). The concept of cyberarchitecture also discusses the possibility of architecture as a continuous and open process, bridging design, construction and use. Baltazar (2007) defines the change in the role of the architect as:

> *"The architect is no longer the author of a finished architectural product, but of a set of instruments with which users can design, build and use their environments simultaneously."*

Champion (2007) explains that a digital simulation of objects will not by themselves give a meaningful content of a real place. Yet by restricting the interface, designers could develop different cultural forms of knowledge, rather than try to express the need of the

[4] - "*moving, or taking place in two usually opposite directions*"

customer in the customer's own words, a worldview the customer already is familiar with. Champion (2007) suggests three major features of places that are often not addressed in virtual environment design. He also discusses how 3D modeling used in construction relates to the techniques used in computer games:

- *Firstly, real world places are dynamic and changeable.* Their boundaries are vague and to simulate this effect in a virtual environment, Champion (2007) suggests the development of fake environmental forces (for example, wind, fog, rain, directional and dynamic lighting, sound).

- *Secondly, places can range from sublime to terrifying.* Scale, detail, atmosphere replication, or phobic triggers, heighten the experiential realism and are often used in computer games. Unfortunately, Champion (2007) says, what scares one person may not scare another. The possibility of simulating a real environment increases the designer's chance of creating a safe place.

- *Thirdly, a place is full of references and associations from by the customer before visited places.* Related activities, emotions and images of environments can be replicated in a virtual environment. Champion (2007) sees this is as one of the most challenging yet interesting of place making, how to create place-associations.

Both Champion (2007) and Bouchlaghem, (2005) are concerned with that CAD is designed to get buildings built, to massproduce rather than qualify the architectural experience. A software program shows static views of the environment, rather than environmental changes acting and interacting over time, as is the case in reality (figure 2.4). "*Yet the real world experiencing of architecture is always mediated through a dynamic and imperfect sensory interface: our minds and our bodies.*" (Champion, 2007). Furthermore, Baltazar (2007) emphasizes an experience of a place and the possibility of a virtual model to realize this experience. She also states that the final result is not necessarily the product; the final result is always the individual experience of the product. Unfortunately, Baltazar (2007) concludes that most designs see the product as the final result, and the event, the actualization of the virtual, becomes consequence rather than part of the design and the architect's work.

Figure 2.4: Shows an archaeological visualization of a 19th Century mining town with real-time rendering. Without people or dynamic environmental forces, the place lacks human scale and seems to float. Source: (Champion 2007, p. 10).

2.3.2. Rule-based design and Smart materials

Rule-based design is often referred to as "generative systems," and have been developed by researchers for different aspects of design such as space layouts, material selection and façade treatments. The rules are generating alternatives for an actual design based on specified criteria. Khemlani (2005) names this approach reverse engineering and describes when she herself developed prototypical system at the University of Cambridge in the UK.

> *"…given the required day lighting levels in a room, the system would generate all possible window configurations which satisfied those criteria, from which the desired configuration could then be selected."*

The idea is not to let computers take over the design completely, but to assist with generating aspects of the design that are well-defined and can be algorithmically calculated (Khemlani. (2005). One example is the materials.

According to Kalay (2006), the properties of the building materials have been an inseparable part of the architectural design process. Smart building materials can be engineered to fit the needs of the building even when the building changes over time. This does not only determine how the building is designed, but also what can be designed. Instead of designing the building for a finite stage, designers who use smart materials can design their buildings for a sequence of behaviors (Kalay, 2006).

2.3.3. Architectural value vs. quality

Beim et al. (2006) expresses architectural value as something that can have relative proportions in relation to something else. She gives as example the conservation of a building, when someone is trying to find comparable buildings with a similar value. According to Beim (2006), the architectural value is something that can change quickly because of external factors and attitudinal changes, and without further notice. Architectural quality on the other hand is often used in a more universal context and can change from day to day resulting in a loss of some properties of the building. The architectural quality studied in this thesis has both qualitative and quantitative parameters. Technical aspects have an impact on architectural quality, though the quality is more than the "house standing straight" or to comply with building regulations. Also aesthetic, functional, and economic aspects among others are in balance to secure architectural quality.

3. Empirical methodology

In this section the applied scientific research method will be presented and motivated. The structure of the interviews and the process of the empirical data selection will be explained in detail.

In this study, the aim has been to learn deepen my knowledge in how technical platforms and BIM affect roles and work processes in the practical reality. To achieve an extended depth to the empirical findings, the empirical study contains two parts: the first part has been case studies of how technical platforms and BIM are used in two specific projects while the second part was used to add a general point of view of technical platforms and BIM and the architects' approach to it.

Having the research question in mind, different alternatives were considered on how to gather the empirical data. In collaboration with my supervisors at Chalmers University of Technology and Skanska, case studies became the primary sources of the empirical information. Nevertheless, the supply of comprehensive and detailed case studies was limited.

3.1. Selection of method

The alternative selection of method discussed for this study was a questionnaire, though the result of using questionnaire as a method for empirical data collection was expected to not give sufficient and exhaustive answers. Another argument for not choosing a questionnaire as a method was that the experience in using Skanska Xchanges platform systems is still limited. To be able to respond to the purpose of the questions, face-to-face interviews were decided as suitable. To gain further knowledge and to get an added empirical foundation, qualitative interviews were carried out with researchers/experts in technical platforms and BIM and participants in two Skanska Xchange projects.

3.1.1. Face-to-face interviews

During the interviews I was allowed to make changes in the order of the questions and to add sub-questions to get new inputs and a deeper explanation and understanding of the interviewees experience in the matter. However, according to Holme and Solvang (2006) this flexibility can also make it difficult to compare information from the different interviewees due to the problems experienced by the interviewer and separate conditions during the interviews. This limitation has to be considered and was minimized by having the same interviewer asking the questions for all interviews and using the same process when asking the questions.

The distribution of the interview questions into subareas aimed to provide an easier understanding. The questions intended to provide different parameters within technical platform and BIM that are expected to affect the role of the architect in construction projects.

3.2. Case studies

The first part of the empirical study has been case studies of how technical platforms and BIM are used in two specific projects. Both projects have been using the SXC Multi platform. At the start of this thesis, these two projects were the only ones running as Skanska Xchange projects in Sweden which limited the selection.

Representatives of the working teams of the two projects have been chosen to give a broad view of the matter and examine it from several perspectives. The interviewees represent both consultants and persons on the contractual side. The designing architect, the modeling architect, the HVAC engineer, the BIM-coordinator, the Superuser and the design manager are the persons being interviewed. The roles of the participants are further described in *4. Results*. The interview questions were formulated for the interviewee to think freely at the same time as providing the master thesis with thoughtful information (See attachment 1.).

Due to the time constraint of this master thesis and the scattered locations of the SXC projects in Sweden, continuous face-to-face contact with every participants in the two projects would be too time consuming. Therefore the decision to visit the offices of the interviewed once was taken. For additional interviews and clarifications real time technology, phone conversation and email were used. Furthermore, internal written material such as protocols from planning meetings has been processed to be a part of the empirical framework in this master thesis.

3.3. Survey

Five researchers and experts were interviewed. They were selected based on their knowledge and expertise in this field. All of the five interviewees have a long experience in architectural practice; two of them have more than 30 years of experience in industrial building. Two architects, two engineers and one landscape architect were the persons being interviewed. The survey questions concerned how the role of the architect looks like today and how it has/will change with the implementation of BIM and use of technical platforms. The interviews also contained questions about what it is in the use of platform systems and implementation of BIM that would change the role of the architect (See attachment 2).

3.4. Qualitative vs. quantitative

This empirical study has a qualitative design and is built up by a relatively small number of semi-structured and open-ended interviews (Silverman, 2005). This approach is expected to understand and deliver the interviewees' experience, attitudes, way of reacting to the increased usage of platform systems and BIM. Both Trost (2005) and Silverman (2005) emphasize the view of the reality as complex and our choice of study method as not always obvious. The qualitative method is used when there is a wish to describe things that already exists. According to Silverman (2005) one should never assume that the qualitative method is preferred before the quantitative, without first asking oneself two important questions:

- “Exactly what methods do we have in mind (e.g. interviews, focus groups, observation, texts, audio, video recordings)?
- In what ways are these methods relevant to our research problem and to our model of how the world is put together?”

4. Results

In this fifth chapter an overview of the Skanska Xchange (SXC) system is presented. Further are interviews with the selected participants in the two case studies and the interviews from the survey summarized. The statements consist of subjective perspectives of the respondents, even if their views sometimes are presented as facts.

4.1. The Skanska Xchange system

In this section literature from the internal web pages of Skanska Xchange are presented. The aim of this section is to provide a comprehensive insight in how technical platform and BIM are thought to be used in Skanska Xchange Multi house construction projects.

4.1.1. Introduction to Skanska Xchange

Skanska Xchange is a program, aiming to create a competitive advantage by combining the strengths of the Nordic countries business units within Skanska. The core of the project is to share best practice across the Nordic countries, to develop the best way of working. The workflow is supported by an industrialized process (IP) and BIM, which together with technical platforms and components are intended to reduce rework and save time. (The Skanska Xchange homepage090812)

4.1.2. The Skanska Xchange program

SXC has over the last two years been developing a system with flexible platforms for both multi- and single family housing. This project is called Skanska Xchange and has during this time employed around 70 people (Hindersson, 2009). The project is primarily about cutting costs on internally developed buildings. The mission has been to define processes and technical platforms that together make it possible to achieve cost savings for Skanska CS (Construction Services) and Skanska RDN (Residential Development Nordic). The aim is also to enable continuous improvements and consistently high quality and help the project organization concentrate on the "unique aspects of the location, living area design and the demands from the target group" (Skanska Xchange, 2009a). As mentioned above there are platforms for both single- and multi houses. This thesis will focus on the SXC Multi platform by reviewing two Skanska projects where this system is used.

In addition to the single- and multi platform there are additional tools that Skanska Xchange is using to execute a construction project. A brief description of the tools is outlined below:

SXC Industrialized Process is a joint process of internally developed housing projects. The collaboration is between the Nordic countries and the purpose is to share best practice between the countries.

SXC Design process is an expanded collaboration between participants in the construction project and the activities that are performed during the design phase.

SXC Codes include a structure of codes to enable a rational way of handling information. The system also helps to navigate the design system. The system of codes was developed to establish a common function-based coding enabling an open approach towards suppliers. The purpose was to create a coding system that clearly classifies different structures and classes of a building as well as its surroundings and that can be used in all Nordic countries.

SXC planning describes how Skanska Xchange structures planning and interaction during the construction phase of a housing project.

SXC Design systems purpose is to provide a theoretical and functional system in which all housing projects are given their form and good architecture is created.

(The Skanska Xchange homepage090820)

4.1.3. The SXC Industrial Design and Construction System

This system contains best practice within residential development and construction from the Nordic countries. It supports five processes, see figure 4.1: *Land Acquisition & Zoning, Premarketing & Design, Reservations, Detailed Design & Preconstruction, Sales & Design* and *Customer Services*. The focus of this thesis is on the second, Premarketing & Design phase and the third, Reservations, Detailed Design & Preconstruction phase. The SXC Industrial Design and Construction System is operated in parallel with SXC technical platforms, components and standard operational procedures (SOPs) and builds on a foundation of customer values as well as continuous process and product improvement.

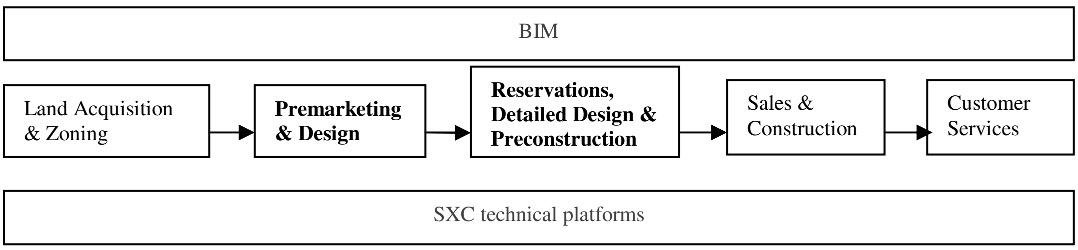


Figure 4.1. The five processes in a Skanska Xchange project. Source: the SXC Multi platform manual.

To keep track of who is responsible for what, the involved divisions within Skanska (RDN Residential Development Nordic, CS Construction Services and SXCR Skanska Xchange Residential) have each been assigned responsibilities in the five phases. Each division's responsibilities are shown in figure 4.2. Before starting a new phase certain requirements have to be fulfilled. For the project to be able to begin the *Reservations, Detailed Design & Preconstruction* phase following requirements have to be completed:

- Consumer[5] selection possibilities (RD assortment) decided
- Project web and consumer portal established
- Design and RD-BIM, meaning that geometries and aspects visible to the consumer, including reservations from technical engineers, are locked
- Financial budget with pricing based on new market analysis and cost estimate based on building parts
- Initial data to some suppliers, e.g.to precast concrete and elevator producer, and to procurement purchasing.
- Building permit application sent

Responsibilities **Premarketing & Design**:	Responsibilities **Reservations, Detailed Design & Preconstruction:**
Residential Development, RD • Development of pricing strategy • Decision on selections that will be made possible for the consumer, from RD assortment, and respective point in time for choosing these • Decision on design entry point, i.e. previous design, layouts or components • Concept development, with input from manager by Concept Approval • Design according to project requirements and platform guidelines, by an architect in cooperation with system architect and technical designers Construction Services, CS • Constructability of design • Supply (sourcing & logistics) situation at proposed design • Risk assessment • Cost estimations • Initial discussions with firms of contractors • Initial data to some suppliers enabling rough production planning and procurement RD & CS Together Concept development: • Target price determination • Design start-up meeting • Designer contracts • Design schedule Design: • Design meetings • Building permit documentation SXCR • Support designers to design with platform guidelines	Residential Development, RD • Preparation of sale start application, including set sales price, construction preparation, etc. • Decision on level for reservations for construction start • Marketing and sales preparation and execution (when reservations at decided level, ~ 50%) • Preparation and establishment of tenant's owner association • Product audit, ensuring "the right product" is being developed • Consumer selections, if applicable Construction Services, CS • Coordination of all designers (including the architect; HVACE engineers and consultants for fire protection, acoustics and environment) • Production of detailed design, by architect and structural and HVACE engineers (SCUP) • Construction preparation and planning, as far as to main act and building acts • Estimation of costs and preparation of procurement and logistics RD & CS Together Detailed Design: • Design Meetings • Supplementary selection of products • Preconstruction: • Design integration meeting • Decision to start construction SXCR • Support of designers regarding platform guidelines • Verification of platform compliance in application for sale start

Figure 4.2. The tables show the responsibility scheme from the initial Design phase to the start of the Construction phase. The figure is adapted from http://navigator.sxc.skanska.com/MultiProject

For a project to achieve an approval for starting the *Sales and Construction* phase, the following requirements have to be accomplished in the *Reservations, Detailed Design & Preconstruction* phase:

[5] Consumer is the potential user of the end product.

- Marketing materials, mirroring Skanska branding (green, etc)
- Set sales price for units and selections offered, in application for sales start
- Sales start application approved
- Consumer reservations
- Potentially, some consumer design choices
- Clash-free BIMs and drawings
- Construction planning
  - Organizational
  - Time
  - Purchasing orders and logistics
  - Risk assessment
- Safety and environmental planning
- Financial budget with all costs specified
- Building acts
- Construction start approval

The checklists are used in Skanska Xchange projects to secure quality in both design and planning. In order for Skanska Xchange to improve the platform manual, the project should give feedback to Skanska Xchange. Feedback regarding the platform guidelines should be done in the Premarketing and Design phase as well as the Reservations, Detailed Design and Preconstruction phase. In the Premarketing phase also the platform performance should be commented on and in the Reservations, Detailed Design and Preconstruction phase the area efficiency should be explained.

4.1.4. The Multi platform

The Multi platform is a technical platform developed by Skanska Xchange. The platform consists of predefined groups of well defined platforms and is based on well-tested standardized components and processes (Skanska Xchange, 2009). At the moment the last bits are put in place. According to best practice within the Nordic countries, standardized elements, components and material are put together to optimize the building process. The best practice is built on information about what the customer wants and needs, but also on national and regional requirements. The aims of these platforms are to work more efficient and increase quality, green aspects and safety. The goal is also to build houses that are very attractive for the customer. (Skanska Xchange, 2009a)

According to the SXC platform manual, the system is built as an open system to make it possible to develop the building elements separately and later fit them into the whole system. This creates a more flexible system and does not limit the production to one specific supplier. The overall idea is to define the function of the interface between two or more parts in a building system, e.g. a detailed design of the connection between two components, such as walls and intermediate floor.

4.1.5. BIM in Skanska

A 3D drawing can be viewed from almost any angle and is therefore easier to interpret than traditional 2D drawings. Additionally, BIMs include information such as detailed descriptions of parts of the building, e.g. characteristics of materials, size and location. Moreover, information on construction schedules as well as on bills of quantity and cost analysis can be combined (The Skanska Xchange homepage 090820). According to Tiina Koppinen, BIM Project Manager at Skanska, BIM is a modern way to manage the information and design buildings in construction processes. The BIM processes in Skanska focuses on

- BIM
- Virtual Design and Construction (VDC)
- Product Modeling
- 3D-design
- 4D (3D + Scheduling)
- 5D (4D + Costing)

However, the use of BIM requires openness in learning new ways of working for all participants in the project. One important task before the BIM implementation is to secure that the applications are easy to use and that adequate support can be provided (The Skanska Xchange homepage 090820).

Why is BIM implemented in Skanska?

- To **save time and money** by building a strong information management foundation and improving the possibility to spread and maintain the information needed in Skanska's processes. Examples of such information are documentation and instruction of services and maintenance of the building.

- To **support industrialization** by defining and adopting a macro design tool for early phase design and use product libraries in delivering and storing products and information to and from customers and manufacturers.

- To **make a better design** by developing and using the methods of producing good quality design. The 3D model makes the communication easier by transferring the information to other processes like marketing, quantity surveys and technical installation.

(Source: the Skanska Xchange homepage 090820)

Software requirements:

The software program Revit consists of many programs used by different participants in a construction project. Skanska does require that the architects use Revit Architecture. Revit will also be used by the HVAC engineer when it is out on the market and until then the HVAC engineers use MagiCAD. The structural engineers in Skanska Xchange projects use TEKLA and the participants who do collision controls use Solibri or NavisWorks.

4.1.6. How Skanska Xchange use platforms and BIM in architectural design

The initial design of the architect is based on the selected platform, for example the Multi platform. Additionally a model with requirements, a spatial model and initial data are provided by the technical designers. These four parameters results in a preliminary architectural BIM. The preliminary architectural BIM is then used for:

- Comparison of structural elements and structures
- Calculating key figures
- Managing quantity data
- Cost calculation and tracking
- Preliminary measuring of structures
- Comparison of design with objectives/requirements
- Feasibility studies

(Skanska Xchange, 2009b)

The preliminary architectural BIM defines zones, space and preliminary structures. The spatial objects must be updated with any changes occurring during the architectural design. The content of the model and the structural types have to be in accordance with the SXC codes and the structural engineers requirements. According to Skanska Xchange (2009b), the architect does not model foundation elements; instead one strip of the plinth is modeled to enable the creation of façade drawings. The integration and implementation of BIM is the responsibility of the BIM expert. However, the architect must attain the architectural quality by assuring that:

- The model has been created using an agreed version of IFC[6]
- The model defines the storey's
- The building elements have been defined for each storey and these (walls, slabs, etc.) can be reliably identified
- The spaces on each storey have been defined, and their types have been correctly defined. The space height has been defined
- The model does not include any extra, overlapping or double structural elements
- The model does not include any major overlapping components
- The spaces are limited by other space components, surrounding walls and slabs. No overlapping may be present, and there may be no empty spaces between components
- The model includes gross floor areas. The spaces, walls and columns cover the gross floor area of each storey
- The spaces are in compliance with the spatial program
- The zones have been defined as agreed
- The structural types used are the correct ones

[6] The ***Industry Foundation Classes*** **(IFC)** is a data format to describe, exchange and share information typically used within the building and facility management industry sector (AEC/FM). The data is object-oriented data and based on class definitions representing the objects (such as building elements, spaces, properties, shapes, etc.)Source: http://www.iai-tech.org

- Special attention must be paid to visual reviewing of the HVACE spatial requirements (ascending shafts, horizontal routes).

(Skanska Xchange, 2009b)

In accordance with the Multi platform some design rules are mandatory, while others are design recommendations. The design rules for each component, the kitchen layout and location must be placed as the Multi platform prescribes. Any deviations from the mandatory design rules have to be explained in writing and the decision to allow deviation is taken by the SXCR Platform Manager, Executive Vice President for CS and the Executive Vice President for RDN. The design recommendations are however optional, but recommended to achieve high cost efficiency and high quality. An example of a design recommendation is the 90 degree angle of all exterior corners. Any deviations from the design recommendations can be decided by the project manager and reported to Skanska Xchange. In addition, Skanska Xchange prescribes three different *Design entry points* which the project design should work in accordance with.

1. Re-using layouts
2. Create a new building based on predefined macro components and design rules within the platform.
3. Create a new building based on the predefined components and design rules within the technical platform.

Depending on the project conditions different Design Entry Points (DEP) are suitable. On a site in the city center the platform needs to be fully flexible and it may be required to fulfill local regulations to fully adapt to the environment. For these complex situations the SXC Multi platform prescribes DEP3. However in cases with less strict requirements, DEP2 may be more useful in order for the project to achieve an efficient solution and act in accordance with to the Multi platform. According to Skanska Xchange (2009c), the introduction to the Design entry points is an important step towards a continous improvement in design. By documentation and the assessment of the project design from the different stakeholders' starting points, the design development will be facilitated.

4.1.7. Feedback Log System

The questions that appear concerning the implementation of the SXC Multi platform are gathered in the SXCR Feedback Log System (FLS). The system has been developed to ease implementation and to secure further development of SXC processes, manuals and components etcetera. The FLS is used throughout all the Nordic countries which allow the supporting organization to provide the right information at the right time and it facilitates the flow of feedback between a Skanska Xchange project and the supporting organization. The FLS also provides an overview of the current need of support and what type of issues that are occurring on a regular basis. In addition, the system presents the status of an issue and keeps track of personal responsibilities. However, questions and feedback issues from the SXC projects should in the first place go to the National support contact person. Then if the National support function is not able to solve the question, it is forwarded to SXCR Project Support, see figure 4.3.

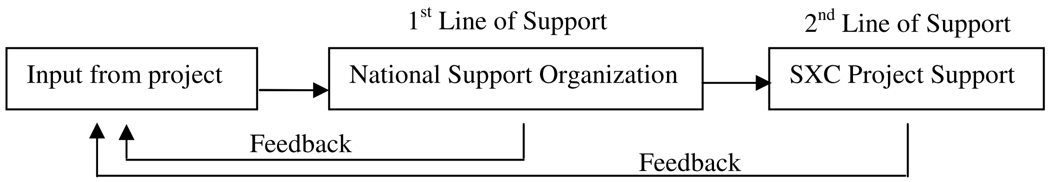


Figure 4.3. Shows the Feedback Process from the SXC project support organization and the national support organization to a Skanska Xchange project. Adapted from the Feedback Log System found at: Skanska Xchange (2009d).

4.2. The Case studies-an introduction

The names of the participants in the two projects are kept confidential so also the names of the projects. Instead the projects are named Project A and Project B, while the participants are named e.g. the designing architect and the HVAC engineer. The results are sorted in: *Implementation and use, Collaboration and communication in the design phase and Architectural design.* The participants interviewed in the two case studies are:

- **The Designing Architect** is the participant responsible for the concept and design of the building. The designing architect is also responsible for attaining the architectural quality by assuring that certain requirements in the manual is fulfilled.
- **The Design Manager** leads the project team and is responsible for managing the communication within the project. The design manager is also responsible for coordinating the contractor staff and the execution in the design phase.
- **The BIM-coordinator** is responsible for the maintenance and questions concerning the BIM model. The BIM-coordinator is also responsible for the collision controls and controlling the accessibility of the building.
- **The Modeling Architect** is responsible for modeling the design in 3D. If the designing architect does not have the skills, a modeling architect from Skanska may model the design fin collaboration with the designing architect.
- **The HVAC engineer** is responsible designer of the sanity ware, heating, and water.
- **The Superuser** (Skanska's own name for the Skanska Xchange project support) works as a second line of support and helps the appointed Skanska Xchange projects with questions concerning the new system. Figure 4.4 shows the communication dependencies in Skanska Xchange projects. The Superuser is also part of an implementation group for Skanska Xchange and is responsible for the communication between the development organization of Skanska Xchange and the projects.

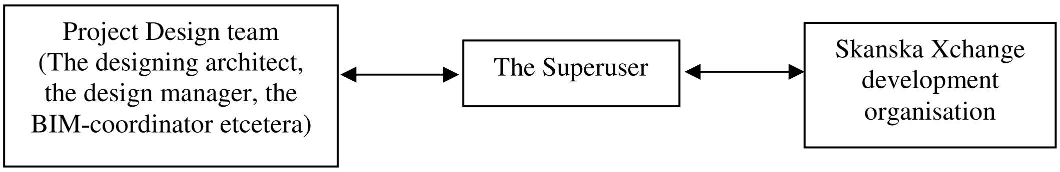


Figure 4.4 Communication dependencies between the SXC project, the Superuser and Skanska Xchange.

Before describing the results from the case studies and the survey, a brief explanation of some frequently used terms by the interviewees is provided.

The basic training course

The basic training course is a three day course aiming at giving Skanska employees an introduction to Skanska Xchange, the SXC manual and BIM. The first day consists of an explanation of what Skanska Xchange is, the SXC Industrial process and Key performance indicators. The next day goes more into detail about the platform, SOPs and the process of follow up. The last day discusses BIM. The course is given on request by the development organization, but the intention from Skanska Xchange is that the course should be provided at every level of the organization, however although those who are directly affected by the new system and those who may educate the next level have priority. The course includes a lot of team building. Just recently Skanska Xchange started a one day course called Basic training light.

BIM and BIM steps

Building Information tools are being used to support the design and construction process in Skanska Xchange projects. It has been decided that all after 2009 internally developed projects that include design should be modeled with BIM. To help avoiding design errors, the building is built virtually as a 3D computer model before the construction begins. The model is also used as input for quantities, cost estimation, procurement, scheduling etc. Many of the solutions and components will be found in BIM libraries to facilitate the use during and after the design. The SXC system has been more or less developed and implemented in the Nordic countries. This development is explained by the BIM steps, figure, 4.5:

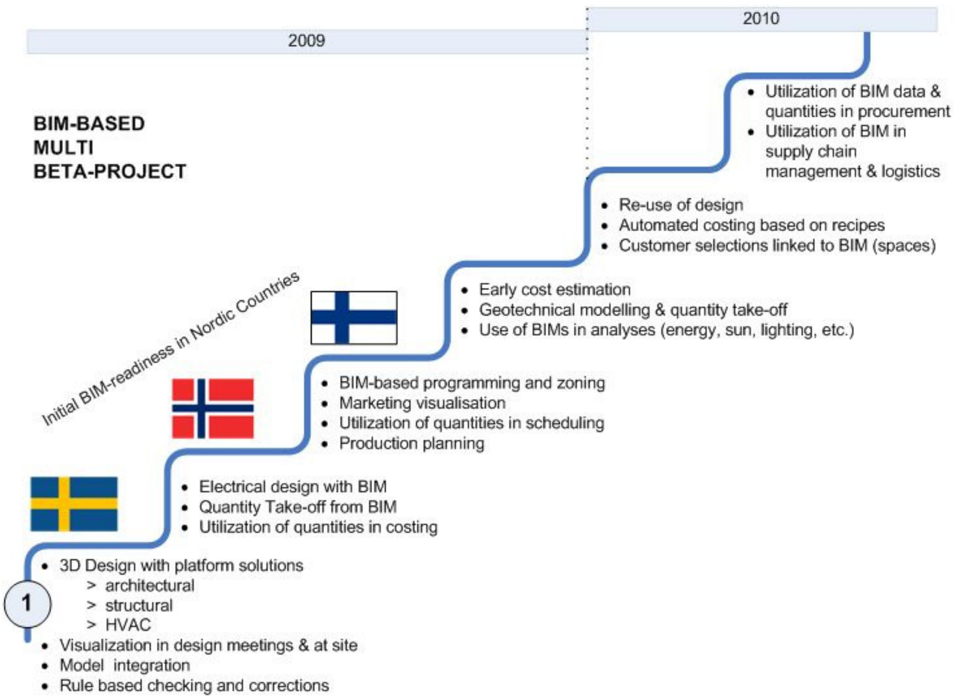


Figure 4.5.The BIM steps show the level of BIM implementation that the Nordic countries use in Skanska Xchange projects today. Source: Skanska Xchange

Project A.

This project is marketed as a new attractive district. It is situated 10 minutes with the car, bike or tram from the city centre. The closeness to the nature and extracurricular activities attract a diverse audience. The building design consists of two five stories slab blocks with seventy-seven apartments in total (see figure 4.6.).The project is an internally developed project and the client is Skanska RDN.

Figure. 4.6. Project A: A two five stories slab blocks with garage and basement below. Source: Skanska Xchange.

The project started as a parallel commission between four architect firms. One of Sweden's biggest architect firms, active nationally and internationally for 20 years won the competition. Due to the timing in design and time it was decided that the project should be a Skanska Xchange project supported by Skanska Residential Development Nordic, RDN and Skanska Xchange, SXCR. Also the Detail plan made the project suitable for a first Skanska Xchange project. Due to insufficient software skills, Skanska decided that the design should be finished in-house by modeling architects within Skanska in collaboration with the external architect firm. The design manager worked as a communication channel between the external architect firm and the project.

In Project A all the participants except the designing architect worked within Skanska. The HVAC engineer and the Superuser were located in Malmö, the modeling architect in Växjö, the structural engineer in Stockholm and the BIM-coordinator and the design manager as well as the designing architect in Göteborg. The participants' educational background varied, even though most had their major in engineering. The designing architect was the only one who was licensed architect. The modeling architect had education and working experience within design, but no architectural degree.

At this stage the construction documents are finished and the sales start begins in February 2010.

Project B.

The project consists of two seven stories buildings containing 24 apartments. The two buildings are being built next to the sea (see figure 4.7.). Project B is an internally developed project and the client is Skanska Hus Norr. Due to the design and timing it was decided that the project should be a Skanska Xchange project supported by Skanska Construction Services, CS and Skanska Xchange, SXCR. Also the Detail plan made the project suitable for a first Skanska Xchange project.

Figure. 4.7. Project B: A two seven stories buildings with service on the ground floor. Source: Skanska Xchange.

The architect firm designing the buildings is a local, smaller sized firm with a lot of experience and interest in working with systemized designing. The local architect firm was chosen because of their former experience in working with systemized design and the tools that were intended to be used in this project. Since the local architect firm had such an experience in the software that is used in the SXCR system, they were employed as the designing as well as the modeling architect in this project. In this case the designing architect was not replaced with a modeling architect from Skanska as was the case in Project A.

Except from the designing architect and the modeling architect all the participants worked within Skanska and had an engineering background. The HVAC engineer and the Superuser were located in Malmö, the structural engineer, the BIM-coordinator and the design manager in Stockholm. The participants' educational experience varied, even though most had their major in engineering. The designing architect was the only one who was licensed architect, even though the modeling architect worked closely and in the same small architect firm as the designing architect. The modeling architect had ten years of experience working as architect yet no educational experience in building design.

The *Sales and Construction* phase has started (November 2009) after 12 out of 24 sold apartments and an approval from CS and SXCR.

4.3. The Case studies-the results

The results from the case studies are divided into two parts: the process and the product. 5.1.1 Implementation and use and 5.1.2 Collaboration and professional roles in the design phase consider the process and 5.1.3 Architectural design considers the product.

4.3.1. Implementation and use

In the beginning of every Skanska Xchange project the participants receive the SXCR manual explaining what tools and components to use in the different phases of the construction project. In addition, the SXCR Multi platform and the BIM processes are introduced in a three day basic training course given by persons within the development organization. All participants in a Skanska Xchange project are recommended to take part in the course; however the Focal Point[7] decides who should take part. The Multi platform contains requirements and design criteria for the platform and the platform based projects. Energy, acoustics, fire safety, sustainability, etc have their own section in the manual where the requirements are described. Each project must be designed according to and fulfilling national regulations and prerequisites prescribed in the Multi platform. National and local standards must be fulfilled unless something else is stated. Skanska Xchange also state that only well documented material and products, in accordance with national regulations should be used and documented. Below the results regarding use and implementation of the technical platform and BIM in two Skanska Xchange projects will be presented.

Former experience

Both project A and project B states that in order for a successful implementation of a new system, and to be able to fully use the system, former experience in such system is important. This is also something that the participants in project B agreed upon. In project A the modeling architect and the superuser had experience in BIM. In addition the designing architect, the modeling architect and the BIM-coordinator had experience in 3D modeling. However, only the superuser had former experience using the SXC Multi platform. In project B on the other hand, several of the interviewed participant's had former experience in BIM, 3D modeling and the SXC Multi platform. The superuser, the BIM-coordinator and the design manager had several years of experience using BIM and the design manager and the BIM-coordinator belonged to the SXC concept development group. The participants in project A claimed if the former experience is low and the organization has decided that the systems should be used, the organization has to provide choices and levels of implementation so that the participants are able to work with the system. The superuser in project A mentioned the BIM-steps (see Figure 5.1) as one alternative where it is possible to decide how much BIM should be implemented in each project.

Training and education

Many within Skanska have heard about the concept/program of Skanska Xchange, but several of the interviewed stated that few know what it really does and how it should

[7] A Focal point is an expert appointed by Skanska Xchange to support and educate projects using the SXC system.

improve the organization. The design manager and the modeling architect in project A attended the three day basic training course that Skanska Xchange prescribes, while the BIM-coordinator and the HVAC engineer got their education through colleagues. The designing architect in project A got an introduction from the design manager. In project B the superuser and the design manager attended the basic training. In addition, according to the design manager in project B, the whole project organization understood the goal of the project, which made it easier to follow the planning schedule.

Software program

In the world of computer technology, development happens fast and program updates are needed often. According to several of the interviewees the knowledge in how to use software programs is still limited in the construction industry. A geometric view is modeled, but the text and the detailing is added afterwards, stated the BIM-coordinator. According to the designing architect and the BIM-coordinator in project A, stalls and lack of compatibility in the software programs cause delays, create misunderstandings and give the designers a hard time communicating. Also the shift from 2D to 3D created some problems with finished floors (FF) on different heights. In project B the interviewees did not know to what extent the software programs should be used. The design manager, the modeling architect and the HVAC engineer stressed the need for improvements in Skanska's education about the software programs and the SXC manuals.

Design complexity

The complexity of a design is dependent on many things. In project A, the late entrance of Skanska Xchange required the designing architect to do many adjustments to the initial design. According to the designing architect these adjustments were in some cases difficult to make due to the complexity of the building design and project surrounding. Some solutions had to be custom made by the designing architect because the guidance could not be found in the SXC manual. Other things that according to the interviewees in project A caused rework were changes to the preconditions made by Skanska Xchange retrospectively, also the preparations before deciding that project A should be a Skanska Xchange project were long and complicated. In project B, however, the building design was a plain structure, both technically and installation. The design manager based on former experience claimed that working with BIM costs more than traditional way of working because the software programs require updates and education. The interviewees in project B also stated that the high expectations from within Skanska, caused by the fact that part of the system is from the program of Moderna Hus added to the complexity of the project.

4.3.2. Collaboration and professional roles in the design phase

Nothing is said in the SXCR Multi platform about the collaboration and professional roles in the design phase; however do the rules and recommendations that are included in the manual affect the collaboration and the professional roles within the project? The support organization shown in chapter 3, figure 3.6, consists of a first and a second line of support. The aim of the supporting organization is to provide the right information at the right time and also to facilitate the flow of feedback between a Skanska Xchange project and the supporting organization.

Responsibilities

With a not fully developed SXC system, according to the designing architect in project A, the hand over from the designing architect to the modeling architect create problems in who were responsible for what. Also who would be responsible for making sure the intentions of the designing architect are kept throughout the whole project became an issue. The problem with who owns the idea if one architect is designing and another is modeling the building was another thing mentioned in the interviews. The designing architect in project A underscored this problem and stated that not being part of the whole design process gave the architect no chance to comment on and review the suggested solutions from the other participants. Hence, the designing architect's original thoughts could easily be forgotten. In Project A the design manager was assigned to be the communication channel between the project and the designing architect, even though this was successful, the designing architect not taking part in meetings and answering the questions direct possibly created a higher risk of rework according to the designing architect. In project B, on the other hand, the designing architect and the modeling architect worked close together in the same firm and any disagreement between them was described as being solved smoothly. However the interviews in project B state it is also not clear when the architect responsible for the building permit shall hand over and who should take over the process. Furthermore, the system expects the participants to be done with their design earlier than in a traditional project; everything is expected to be solved and designed before the construction phase starts.

Communication and concept clarification

According to the interviews, two messages were sent out from Skanska Xchange: the first said that the SXC manual should be used 100% and very few exceptions can be made. The second message said that the system has potential and should be used as much as possible, the closer to 100% the better. In project A the design manager highlighted the effectiveness of milestones if properly explained. In addition one interviewee in project B state it is easier for the BIM-coordinator to convey requirements in the design phase in a project with technical platform system and BIM. According to interviewees in project B the BIM model also facilitate communication and explanations to complex issues, visualize the end result to the client and make it possible for the project organization to show that they can reach the project goal.

The superuser in project A argued it is a matter of anchoring the philosophy within the whole organization. No one wants a manual to read, saying what to do, if not giving an explanation to why they should do it. The whole top down organization has to be active and enthusiastic and show that they believe in the concept. The interviewees in project A stated that Skanska Xchange has to be proactive and inform the organization about the benefits and challenges with the new system. Both project A and project B stated that the communication has been facilitated by almost everyone working within Skanska, even though as commented on by the design manager in project A the participants within Skanska worked in four different parts of Sweden. On the other hand, according to several of the interviewees, the communication with Skanska Xchange was minimal. In both projects the designing architect worked in an external firm and in project B did also the modeling architect work in the same firm as the designing architect. For meetings real time technology was used, which according to the design manager in project A for most parts resulted in decisions, guidance and distribution of tasks being made on distance. The design manager in project B brought about another concern when stating that even if the engineers are working in the same organization, they do not always work as one organization. The communication gap within the organization did sometimes cause misunderstandings.

Although the interviewees were convinced that the concept/program of Skanska Xchange contains a lot of good thoughts and ideas some, of them missed clarification to the tools and processes. According to interviewees in project B it was often hard to get quick answers from Skanska Xchange and any deviations from the SXC manual had to be done in writing, explaining why a deviation was necessary. The internal net worked out well for the internal organization, however the interviewees sometimes felt it was harder to provide the information to the external participants.

New roles

According to several of interviews in both projects the way of working is not very different compared to a traditional project, even though many of the participants believe that the introduction of the BIM-coordinator will affect the future project process. According to the interviewees the role may contain managing the 3D model, supporting the design manager and to visualize critical work processes in order to rationalize and minimize risks. Another role and knowledge that many of the interviewees assume will be important for in future construction processes is the designing architect. The architect's knowledge in visualization will encourage further exploration of the architectural design and possibly minimize architectural errors. If used to its full potential several of the interviewees believe that with BIM, each participant can have a digital copy of the drawing during meetings and in that way discover errors in detailing and make decisions immediately.

Ownership and support

To explain the level of support and expectations from Skanska Xchange both projects state it is important to be able to use the SXC manual properly. According to the superuser in project B a high dependency may foster the user of the model to count too much on the model. Another opinion is that a system creates a higher risk that the project participants choose a finished solution, adjust it a little and say it is finished without reviewing if it actually works with the initial design of one specific project. Ownership was something that many of the interviewees said was important: to know what, how much and when to do certain things. The increased amount of information to handle in the design phase was another thing that the interviewees took into consideration and suggested checklists to keep track of the activities. What the cost savings do to the architectural quality was also highlighted by some of the interviewees. The modeling architect in project A got instructions to keep the costs down.

4.3.3. Architectural design

This section describes the interviewees' thoughts about architectural design and quality. According to the SXCR Multi platform manual, BIM is used to define zones, spaces and preliminary structures of the architectural design. In addition, the content of the model and the structural types have to be in accordance with the SXC codes and the requirements of the structural engineers. Unlike traditional construction projects, the architect does not model foundation elements. Further the BIM-coordinators is responsible for the integration of the different parts, even though the architect still has to attain the architectural quality by assuring that certain requirements are fulfilled.

A good design and architectural quality

The interviewees in both project A and project B believe that good design and architectural quality is an essential part of construction projects and the quality in design is a crucial factor for getting the end product sold. The architectural design solution in Project B was a relatively simple structure, which according to the designing architect made it easier to use SXCR Multi platform and BIM and at the same time maintain the architectural quality. Several of the interviewees point out that the function and design goes hand in hand in a good design. To some of the interviewees the architectural quality consists of the external appearance of the house and the architect might overemphasize design in relation to function. According to some of the interviewees the different professions in a construction project have different focuses. The BIM-coordinator in project A stated that the focus should be on the functional aspect more than trying to create something that is modern today, the project design can be hip, but has to be thought through from every aspect in order to function as a good design and not ”castles in the air”. To the designing architect it is very important that the material and tool library of the SXC systems is large enough to be able to create high architectural quality. It is the detailing that makes the design. This is also something that the designing architect in project B emphasizes defining good design and architectural quality as a functional building with a high-quality aesthetic: good spatial solutions and a view of the building as part of a bigger whole within its environment. However the designing architect in project B states that in the end it is the design program that governs the result of the design. Often the architect has to stand strong for what he believes in, even though one can see if the building is designed by an architect, in both materials and design thoughts. A building should have a good design and carry a strong quality both today and in ten years to be of architectural quality. The thoughts of the interior design is often not as long-term as those of the exterior design due to the users desire to choose their interior design themselves.

The end user

According to the designing architect in project A, the relation between the construction and the surrounding buildings is essential in order for the project to represent a good architectural design. The building has to be designed to fit the circumstances and surrounding environment. Also light, spatiality, choice of material and details are things that both the designing architects find important. According to the designing architect in project A that discussion is sometimes forgotten in construction teams where only participants with technical backgrounds are represented. Another thing that several of the interviewees emphasized was the focus to please the users’ needs. “Start with the functions inside and work yourself out”. Additionally the design manager in project A stated that everything we do in a project has to have someone that pays for it and that the architectural design is the foundation of everything in a construction project. Further the designing architect in project B focuses on the things that add architectural quality to the building, instead of wasting energy on the limitations of the SXC Multi platform. Skanska Xchange provided a framework and it was the duty of the project participants to use the tools and the framework and design a building that is to be sold and appreciated.

The architectural knowledge

Many of the interviewees see a risk in a system like SXC. The designing architect often works outside the big contractor firms and with the development of more systemized way of performing a construction project, the knowledge of the architect is in danger of being replaced with computers and engineers. One interviewee said it is important that Skanska does not decide everything and does not take over the role of the architect. Another interviewee said Skanska Xchange will have a challenge incorporating designing architects' desire for flexible systems and has to take into consideration the risk of being blocked in a mindset. However a third interviewee stated the architect encompasses a knowledge that engineers do not have and the system may if developed carefully invite the architect to be more involved in the process. This is the intention of Skanska Xchange. A good design and architectural quality is achieved if the product is designed, constructed and utilized in an effective way. There should be space for extraordinary design, even though the function has to be maintained stated the BIM-coordinator in project A. The architectural knowledge is equal to good function and the architectural quality is achieved by breaking the stereotyped parts and roles of the construction process stated one interviewee in project B.

The exterior and interior design

According to the interviewees in project A it is mainly the exterior design that is changed when the SXC Multi platform is used. This is also something that most of the interviewees in project B agree upon. According to the interviewees the interior design did not change very much. In addition the balconies and the placement of the fan room on the roof were mentioned. In both projects, the number of corners allowed for each building and the fitting of the bathroom modules also caused extra discussion. In the end several of the interviewees believe that the detail plan restricted more than SXC Multi platform.

The flexibility and creativity

The flexibility and the limited space for conceptual ideas is something that often is questioned when talking about technical platform. In project A the designing architect agrees with the limited flexibility and points at the attempt to minimize the spatiality of the apartments as something that is more difficult when using modules. Several of the interviewees in project B believe that the SXC Multi platform changes how things are executed, but the result may be the same if the platform were not used. The architects' task is to catch and bring forward the character that will give the user a higher quality of living.

Several of the interviewees in both projects state that creativity has been high since every participant has been forced to think outside their own comfort zones and fit their design to the developed SXC system. One interviewee claimed that the participants had to continuously consider the aim of the SXC system to build less expensive buildings providing more people the opportunity to acquire an apartment. According to several of the interviewees the adaptation to components, new technical solutions and geometrical rules require that the whole organisation is open for a change. All in all, stated one interviewee in project B, the creativity is placed in the developing phase, which requires less creativity at a later stage, however it has to be remembered that other things such as a market recession can also limit the creativity in the project.

4.4. The Survey

The results from the survey are sorted into themes under which questions are answered. The themes are *Industrialized building – the evolution and attitudes and Processes and professional roles,*

4.4.1. Industrialized building- the evolution and attitudes

Has the attitude towards technical platform changed in recent years?

This question has often been debated during recent years. Some of the interviewees argue that the engineers' attitude is more positive while the architects are more negative towards technical platform. One view believes the skepticism from the architect has to do with the architects' profession of removing boundaries and strong fear of being restrained. The construction industry has not changed in years and it is necessary that the architect consider the new systems to be competitive. Another interviewee says the attitude towards technical platforms is constantly changing and the development of the systems happens rapidly even though a few materials and techniques with long traditions are always present. There is an attempt in the construction industry today to rationalize how things are done by increased use of components and module frames in design. One challenge with this development is the intersection between an open and a closed system. The bigger contractors want to develop closed systems, but the market is too small. Nevertheless, the interviewees agree that closed systems result in conform buildings. A technical platform system has to provide a choice of levels and components that do not make the architecture uniform. One view is that it is a matter of standardizing the right things, while another respondent state it is not about standardization but modularization.

Is knowledge of the benefits and obstacles of technical platforms greater today than before?

Different types of platforms have been used in the construction industry for many decades. One of the interviewees mentioned the traditional half timber houses, popular in the south of Sweden. One also said "Every era has its vernacular architecture". It is a matter of how smart the technical platform system is and the industrialized building needs to be looked at as a conceptual building system. Another opinion states that it depends on what definition the system has, pointing out that the systems in the 1960s focused on standardization of the product and without considering the surrounding environment. Since each building is placed in different surroundings, the focus should be on the process and not the end product. The development from templates and Indian ink to digital technology may take the soul of the design. Meanwhile in the younger generation the aversion is not as big as with the older generation due to the high exposure and the younger generation being raised in the digital media.

What are the big differences for the architect in the new vs. the old way of working?
According to one of the interviewees earlier it was more common that the architect had a role of a project manager, nowadays that role is often given the contractor. The contractor develops a framework for the building design and leaves the architect to focus on the plan and not the spatiality. An architect's professional creativity has to be present even if the process is restrained by a well developed technical platform system. One interviewee explains that those architects who are more functionally oriented have a higher acceptance towards the technical platform. However, the architects prefer the use of the concept of aesthetic platform system, which looks at a building over time and brings forward the similarities that show good solutions. It is important to remember that even in projects where a technical platform is not used, different clients have different requirements and the architects' professional role is to solve a problem. The architects who are skeptical towards the systems can according to one interviewee be seen as professional who wants to expand and improve the systematic idea. To accept the diversity among architects is a way of spreading knowledge in design, unfortunately the architect has lost a lot of knowledge in building technology and can therefore be an obstacle one interviewee states.

One interviewee said that all architects have their own toolbox with solutions that they reuse and modify for each project. A difference from the traditional way of working in an open system is the gradient of how much you have to use the system and not every time go into detail. Also the access to an infinite amount of information is a positive thing that encourages creativity.

How can BIM change the design process?
The development of BIM is dynamic. One interviewee states that the name should be Building Information Management since the concept changes the process and requires commitment from the whole organization to be successful. The use of BIM in construction projects today is limited and the development is slow. BIM is used for collision controls, HVAC and sound simulations and energy controls. However more and more things are being tested digitally and it is in the big contractor organizations that the development happens. The development for the future BIM encompasses the linkage between choices of constructions, building descriptions and technical computer drawings. The product is very much bound to the contractor who, according to one of the interviewees, has a lot of things left to learn about BIM and its opportunities. If staying open to improvements, the project organization can communicate easier and develop a common language with the help of BIM. However, the BIM tools have to be coordinated in order to increase the effectiveness and decrease the errors (LEAN). One of the interviewees points out that the system requires more time in the early phases of a project, which can help the fragmented construction industry to be more effective. Another crucial thing mentioned by several of the interviewees is being able to see outside the box and share and appreciate knowledge not just within the organization. NCC-komplett had one

organization, one process owner to synchronize easier, but this created a closed world and the concept had to be put on ice.

4.4.2. Processes and professional roles

How does the use of technical platform and BIM affect the role of the architect?
The increased use of technical platform introduces new roles in the construction process. Project Information Officer (PIO) is one managing role, CAD-coordinator is another role, that the architect may have. Those architects who take advantage of the increased use of BIM may get a more integrated role and get higher involvement in the projects. Possibly the architect may get a role of managing the sub-consultants. One point that all the interviewees agreed on is that the knowledge and the role of the architect will contribute with enhanced perspectives during the development of a technical platform system. The result may be a less fragmented construction industry and the architect teaches himself to frequently value what his design is worth. This way the architect has a more central role and takes part in assuring the project quality. Today the architect works as an aesthetic and interior expert, while the project manager role is mainly the role of the engineer. By integrating the engineering and the architectural education practice, the role and knowledge of the architect will more frequently flourish in the bigger construction companies in the future.

Even though the use of BIM in Landscape architecture provides an immediate receipt on the heights and run-off, the future will have to tackle the interface between ground and technical platform system which will be more difficult. One view was that the landscape architect may take a role as coordinator in initial phases; however the architect must keep updated with the software programs and its possibilities to stay competitive. It is not necessary for every designer to work in a digital mode, though it is harder to compete if not doing so. Those who see the architect as an artist have a limited perspective and knowledge of the architect's professional role. One interviewee mentioned that earlier it was the computer modelers who worked with BIM, not the architects or engineers.

Does a technical platform system require new work processes?
One view in the interviews claims that the greatest difference between working with or without technical platform is that in the traditional way of working the architect knows what he delivers while in the new system information is uploaded in a database. This results in design information being reused with the architect having no control over the situation. The risk of ending up with different versions of the original building is likely. The know-how, copyright and immaterial rights in general (and related economical matters) and the specific immaterial rights related to the architect's knowledge (e.g. the design) are issues that need to be discussed when developing a technical platform system. Is the architect's knowledge appreciated? Who decides how much the design is worth when being reused later in the process? These questions are among the concerns several of the interviewees expressed. It is obvious that information may be stored, used several times and in different stages of the project, and possibly in subsequent projects. Matters related to ownership, payments and contracts are therefore crucial. Also the risk that the architect may be replicated as an industrial designer is evident. Nevertheless, the

architect's knowledge in geometric modeling can considerably strengthen the role of the architect in future construction projects. The implementation form may change introducing a shared ownership, minimizing the risk of the client claiming that the project is too expensive. According to one of the interviewees there may be a shift to focus on; when are the deliveries, what is delivered and do the deliveries have zero errors.

How is the communication affected by technical platform and BIM?
The demand for more effectiveness is increasing. According to one of the interviewees this issue has been debated for decades, but the industry has a slow pace. The construction industry today may be regarded as low-tech compared to other markets and as soon as a technical platform system is established the companies can invest in information technology. However, to perform a successful implementation of the information technology the development team has to be interdisciplinary. Not only engineers, client and architects, but also construction workers, personnel and contractor expertise have to be asked to give their professional opinion. A more long-term partnership makes it possible to have higher security margins. One of the interviewees refers to this as Horizontal integration. Also increased use of BIM processes in Private Public Partnerships will be more popular according to one interviewee.

According to several of the interviewees technical details today are equivalent and restrictions exist with or without a technical platform system. Architects must look at the positive aspect always having total control and be able to work flexible and create freedom within the framework of the technical platform system. BIM has the opportunities to create advanced solutions and take design and architecture to new territories by facilitating communication within a construction project. How to communicate is an essential issue in the implementation of technical platform and BIM into an organization. The introduction and persuasion of the benefits must be honest and convincing. Otherwise the collaboration could inhibit the innovation and competitiveness. The knowledge of how to create good design and focus on the linkage between the components is essential.

Does a technical platform system harm the creative spirit in the design process?
Creativity is where you have to search for new solutions and knowledge. Research and hypothesis development are examples of creativity. Standardization is to lower the variation and is considered not compatible with creativity. Several of the interviewees mentioned that: "The more I do one thing in one way the less willing I am to change". One of the interviewees states that the architect has to be aware of the cost advantages in the virtual design and BIM to find their place in the future. Additionally one claimed that Mozart was not creative because he made variation of the same theme, while Bach was creative because of the created themes. The superficial expressions need media and the building design still needs to be experimental and innovative.

A project process using a technical platform system and BIM face a greater workload in the initial design phase and require more money in the early phases. This issue creates both risks and possibilities. The future's more systemized way of working encourages architects among others to make a business out of the initial costs.

5. Discussion

Below are the aspects and questions that this study has aimed to find answers to. One should remember that the attempts to increase efficiency are many and this study has only been researching two of the tools that can be used, technical platform system and BIM. The chapter will begin by presenting how does the use of BIM and technical platform impact on the architect's role and work processes. Answers to how BIM and technical platforms affect the collaboration and communication between architects and other participants within the project will follow. Finally which perceived influence and impact BIM and technical platforms has on architectural values, style and design quality will be discussed.

Role and work processes

Kalay (2006), Baldwin & Clark (2000) and Rudberg (2007) are among the authors who discuss what effect the increased use of technical platform have on the architects' roles and work processes. Both Rudberg (2006) and Baldwin & Clark (2000) describe the challenge in the modern situation in how to incorporate the architects' knowledge in construction projects. Already in the mid nineteen seventies, Mitchell (1974) saw that the role of the architect would shift from a craft-based type of work to more structuring of data and conceptualizing general principles that are fundamental to specific situations. Before that the hand-made drawings, the spatial puzzle solving and the experienced-based knowledge were skills that the architect was employed for, while the development and increased use of systems has shifted the role to be more about manipulating complex structures and analyzing the current state, to produce design proposals to give advice for the future.

As pointed out by s some of the interviewees, a technical platform, that changes the roles and way of working in a project so distinct, firstly, has to consider the dynamic process of the project and, secondly, the end result and the actual components needed for the end result. Harbraken (2002) writes about levels, where the level of systemization and design control depends on what is prescribed. His theory distinguishes between "the support" being the rigid part of the building such as the structure that does not have to be changed from one project to another. The flexible part called "the infill" he says could be modified during and after the project. To a larger extent this open way of systematization allows the user to a larger extent design his own home and then alter it continuously, which according to Day (1996) would result in a building really adapted to the environment. This open system would introduce the user as a very important role in the construction process.

The interviews and the theoretical framework indicate that the rework and errors in the construction industry has a lot to do with the inadequate preparation and organization of the construction process. Instead of stopping and correcting things in momentum, cultural and attitudinal prejudice makes the construction industry lose time and money. Also the time spent on convincing the own organization about the benefits and the positive difference a system, like the SXC system, can make has to be of highest prioritization of the top level management and those responsible for the implementation. A clear result from the case studies show that explaining what is to be performed, who should perform the task and why this task should be performed is crucial to be able to perform a high quality job. This may seem obvious and one may say that the SXC manual contains all the information necessary. However to receive a thick manual and go through all that information, even if the excellent ideas are there, it is too much to ask of the SXC project participants. Many of the interviewees, both in Project A and in Project B, agreed on the lack of clarification of the massive amount of information in the SXC manual. The interviewees claimed that the SXC manual contained too much information and said it was hard to understand what information was applicable to what situation. A second concern that the project participants had with the implementation was the lack of support and great confusion to what to do and who to ask, if a problem occurs and the solution cannot be found in the manual. In addition an insufficiently structured construction process creates insecurity among the participants regarding knowledge and professional roles. A team in the design phase often consists of a multidisciplinary group of people with different knowledge from different firms. The team is also often temporary and put together based on previous relationships. This temporary nature of a construction project may hinder a systematic knowledge feedback from on project to the next.

The interviews brought up many interesting perspectives to BIM and 3Dmodeling, and several of them stressed the importance of early training and involving all participants in the system from the beginning. A good design does not just depend on a few actors on management level. To create a building with architectural quality and future value all participants have to be engaged and fully believe in the concept. According to on interviewed in the survey, "*Construction is no one man show, it is teamwork and relies on distinctness*!" To be able to implement such a global system one has to take into consideration that some construction projects are not able or need a longer wakening up period stated one interviewee in the survey. Furthermore Harbraken (1987) underlines that architects are trained to se three-dimensional space, unlike the user who often are unable to imagine how the design will be after the construction phase. This is something that is supported by the interviewees who says that also the engineering profession has a hard time visualizing three dimensional space. Thus the architectural knowledge and mindset are needed throughout the construction project and especially in the design phase.

As mentioned by Little (1988) the architects were some of the earlier users of CAD technology, nevertheless the construction industry today lags behind many industries such as the automobile industry and the shipping industry. Reasons for this are many, some of the interviewees say that rejection and the slow adaptation depends on the lack of communication in why the use of technology is better than years of experience. Others mention that when few people know the systems fully and there are not enough resources to explain what to do with the technology, the resistance to a new way of working will be higher. One of the interviewees stated that the culture of the company at all levels has to be treated and a clarification of how much a system should be implemented in each project has to be apparent to minimize the resistance from within the organization. Both the literature study and the eighteen interviews all mention the importance of clear instructions when implementing a new way of working.

Another thing that many of the interviewees have agreed on is the significance of knowing the goal of the project and where the focus is. This is in agreement with Simpson (2004) stating that it is imperative to understand and fulfill the diverse wants and needs of each individual user at the same time as achieving a low cost. Kalay (2006) has a suggestion what to do in this situation saying that by including interrelated events both in the building components themselves and in the benefits of bringing them together, the process of construction and the end result will be able to respond to the changing needs of the user without re-design. The role of the architect in this changing process would be as a resource questioning the interrelation between the different parts and maybe also communicate the experiential ingredient of the product to the user. Interaction, participation and clarity will have a meaningful role in the work processes.

Collaboration and communication

The use of a technical platform system creates a demand for different forms of collaboration. For the systems to work efficiently and generate the benefits such as decreased project time and costs, the project team must have trust and consensus. If the concept of partnering should be used, the collaboration must be extended to include not only the contractor and the building constructor but also the consultants. This master thesis does not treat collaborative arrangements in depth; however a long-term partnership such as strategic partnering may be an alternative for a future collaboration. A partnership during a construction project with feedback and knowledge transfer can contribute to the ideas of BIM and technical platform. The technical platform aims to create a system to reuse good solutions and not having to start from scratch every time. In a long-term collaboration a greater focus on making the process more effective could be in place.

A risk when one organization possesses every role in a construction process is that the innovation and valuable discussions are being lost. Unconsciously the organization that develops the system may jeopardize the quality of the end result. Even if the organization is built up by individuals, external knowledge is necessary. This is something that the interviewees in the case studies agree upon. The collaboration with external architect firms is very important to maintain the quality of the end product.

This study has underlined the importance of communication between the project participants and suggests that the aims and requirements are easier communicated if modeled in 3D. According to most of the interviewees, the readability of a complex situation is facilitated by a visual presentation. This is one of the strengths of BIM. Nevertheless, Bergmark (2004) states that to be able to work with BIM it is required that all the participants in the project uses programs that are object-oriented, can handle both 2D and 3D and communicate with other applications so that the information exchange is facilitated.

The empirical study clearly shows a difference in how successful the two projects have been with implementing the SXC system into the project. Most likely, the difference depends on two major things: firstly, the participants previous experience in working with the system and secondly, the complexity of the building/project. At this stage the SXC system is ready for a building with not too many corners and a simple spatial solution.

Seemingly, it is possible to develop a concept that increases productivity and efficiency within an organization but it may be even harder to ensure that the whole organization understands the concept fully and uses it to its full potential. Many of the interviewees underscored that collaboration across organizational borders is necessary to assure that the concept is successfully implemented. The more perspectives with different experience and education that can give their view of the system, the more prepared is the concept when the multidisciplinary project team is introduced to the system.

Many articles describe the benefits of BIM, highlighting the open process in which 3D visualization allows all players easily to stroll around the model and communication thus is facilitated. In Skanska Xchange BIM include information such as detailed descriptions of parts of the building, construction schedules as well as on bills of quantity and cost analysis. BIM is a modern way to manage the information and design buildings in construction processes. Consequently it is more than 3D and some aspects of BIM are harder to implement. How the organization meet the skepticism towards change, and the cultural differences are among the things mentioned in this study. Clear leadership is important in this kind of major shift as BIM presents. This includes increasing the awareness of BIM and its potential in the organization. (Each level of employee in the organization must understand what BIM is and does in Skanska and how it should be used). This requires careful planning and very simplified checklists that says what BIM can do for the particular project. The SXC manual state that the use of BIM requires openness in learning new ways of working for all participants in the project. Further the manual prescribe that before BIM is implemented Skanska Xchange must secure that the applications are easy to use and that adequate support can be provided.

Architectural value, style and design quality

As stated in the theoretical framework many parameters affect the architectural style and the value and quality of the design. Noted from the interviews is that designers with an architectural background generally show more interest in the details and emphasize the importance of long-lasting materials. The architects also state that the adaption to the environment and what the architectural business call “Genus loci”, the soul of the place, is very essential to the success of the construction project. Many of the interviewees and also the theoretical framework express that the increased systematic design process require a different mindset to maintain architectural quality. Nevertheless the interviewees in the survey as well as in the case studies do believe that the systematic thinking has a great potential. According to the interviews it is a matter of modularizing the “right things” and focusing on maximizing the process planning and the use of the diverse knowledge of the various participants in the construction project. Some of the interviewed in the survey believed that mainly focusing on the end product may create a less adaptable system. The SXC system does focus on deliver a high quality product to reduced cost. The real world places are compared to the virtual world dynamic and changeable. Natural forces such as wind, sun and rain does not appear at the same time and from the same direction every day. Therefore the accuracy of the simulation in BIM

must be questioned and challenged so that the virtual world is not treated as the truth. Nevertheless does the theory state that depending on who is experiencing the place the place can range from sublime to terrifying and by simulating a real world environment the designer increases the chance of creating a valuable place for the specific customer.
Creativity is another word that frequently appears when systematic design is discussed. The interviewees in the survey do not see that technical platforms limit the creativity while several of the articles in the theory state that the creativity is limited. As mentioned in the case studies, a construction project is limited by several requirements from for example the client and the detail plan. The innovation and creativity within a technical platform system is not mainly limited by the platform, but the initial instructions and the representation of every participant in a construction project affect the architectural quality.

Some of the engineers in the empirical study stated that architects often forget the functional aspect of the design, while the architects claim that they often have to push the importance of the users' perception of the place. Interestingly both Champion (2007) and Bouchlaghem (2005) comment on the architectural experience of a place, claiming that virtual systems like BIM are designed to quantify rather than qualify the experience of a place. These systems create a static view that does not change over time (with weather, season etc) as Champion (2007) and Bouchlaghem, (2005) state is the case in the reality.

Thus, the constantly changing surrounding of where the building is placed is an issue that has to be incorporated into the technical platform system. Not only have the interviewed architects mentioned this as a very important factor, but also the engineers. Another thing that most of the eighteen interviewees brought up as a reason for a highly flexible and easy adaptable system was the project environment and temporary project organization. Low flexibility and no choices create a system where the architecture is lost and the end result becomes flat and looks very uninteresting. Additionally the risk of losing valuable information, knowledge and time is high if the architect is not taking active part in the design phase.

Throughout the literature study of this thesis it has become evident that a certain degree of modularization has always been used within construction projects. Early computer programs as the IMAGE and the General Space Planner required a new mindset within the industry, and so does a technical platform system and BIM. Also the skepticism and criticism towards such system have been present since the mid seventies. However as pointed out in the case studies the development of information technology encompasses many great ideas that can facilitate a construction project, but is the organization, from bottom to top, not fully aware of the benefits, the challenges and the opportunities that follows, the organization has no chance to implement fully. Skepticism is as one of the interviewees in the survey stated a way of showing that one wants to be a part of the process and improve the system.

6. Conclusions and recommendations

Chapter six will present the conclusions drawn from this master thesis study. In addition the recommendations aim to improve the SXC Design system.

The Swedish government approved an action program regarding architecture and design in 1998. The program states that the government's engagement in architecture and design should make sure that quality and aesthetics does not become out-maneuvered by short time economic aspects. Skanska just as several of the larger contractors in Sweden, has expanded their traditional role as building contractor to assume a more administrative and process steering role, while the architects have maintained their role and knowledge as designers. What the future roles in the construction industry will look like no one knows, but the increased use of technical platforms systems and BIM has a potential of changing positions. As mentioned in the theoretical framework, it has been argued that the construction industry has had slow development towards a more efficient way of performing. Further, technical platforms and BIM each contain many smaller processes, of which this thesis has only discussed a few.

The emphasis in the empirical data has been on the interviews with participants using the SXC Multi platform in two Skanska Xchange projects. The five interviews done with researchers and experts were conducted to add general perspectives of technical platforms and BIM in design. The purpose of this master thesis is to investigate the use of BIM and technical platforms from an architectural perspective, and to investigate the topic the following research questions have been addressed:

- How does the use of BIM and a technical platform impact on the architect's role and work processes?
- How does BIM and technical platforms affect the collaboration and communication between architects and other participants within the project?
- Which is the perceived influence and impact of BIM and a technical platform on architectural values, style and design quality? Which management is needed to be successful?
- How can the Skanska SXC system be improved to better support design processes (suggestions/recommendations)?

Overall, the study shows that the SXC system consists of many well formulated ideas but that more time and effort are required to a make the positive effects of the system come across to the organization and project team. Below are five conclusions generated based upon the results of this master thesis:

- The risk that relying too much on the technology may lead to decreased quality due to less questioning was mentioned both in theory and by the interviewees. Since a building is created and designed to experience and live in, participants in every phase of the construction project have to attain an active role to assure that the end result has a high quality of living. Computers and technology facilitate in many ways, but they do not, as humans do, possess the ability to guide feelings and coincidence. This is something that Day (2006) emphasizes with the statement:

"Computers only address the mechanics of communication; they pass the messages back and forth more quickly, but they do not deal with the extent to which the content of a message is useful to the recipient, nor with the context in which the message is being sent or received."(Day 2006)

- All the interviewees agreed about the significance of clear instructions when implementing a new system. This view gains strong support in the theoretical framework, where marketing to assure that the whole organization has fully understood the system also is highlighted. Apart from the clear instructions, continuous support and initial education were factors mentioned frequently by the interviewees in the case studies.

- The technical platform system limits the choice of solutions possible, provides other requirements than in traditional projects, changes the roles in the design phase and creates a risk that the role of the architect is replaced by a more computer skilled designer or engineer. Even though the interviewees in the case studies strongly pointed out that every professional role in a construction project is necessary to be successful, it is clear that it is not so much about the professional role as it is about the competence, knowledge and skills. If an organization can manage to keep a balance between standardization and continuous improvement by effective knowledge management the architectural design and quality is improved.

- The impact of BIM and technical platforms on architectural values, style and design quality is by the interviewees in the case studies perceived as limiting in several ways: in the choice of detailing, in the flexibility in finding the soul of the place (the "Genus loci") and in the frequency in questioning the virtual design. Overall the architect is more concerned with the detailing and the choice of material than for example the engineer is. The architect is focusing on the whole picture and believes that it is essential to fit the right material to the right environment. It is not just a matter of choosing a material that is right today, but to think about how the material changes over time. Also the users' perception of a place has a high priority to the architect. The results from this thesis show that the participants with an engineering background care more about the logistics, the functional aspects and the amount of work that the system can facilitate. The conclusion drawn from this is that a construction project needs every perspective and to assure the best architectural quality possible a fruitful collaboration must take place.

- How multidisciplinary development is organized, the level of initial education and previous experience and how much a participant is encouraged to share professional knowledge are all factors that have a large effect on the success of the end result. The experience in technical platforms and the education in the SXC system provided made a great difference to the communication and collaboration in the design phase of the two Skanska Xchange projects. In the case where the participants had experience and education, they were a lot more positive and managed to see more positive effects to the technical platform system than in the case where only one or two had former experience. This shows that careful preparations are very important also long before the start of the design phase.

Right now the construction industry faces a massive technology boost and the word efficiency is nowadays a buzzword. However it is remarkable since efficiency has been talked about for decades. And even if the term BIM is rather new, the processes and aims have been flourishing in the construction industry for a long time. The facilitation of communication happens only when the purpose and planning are clear to the whole organization. I have only looked at the surface of one organizational attempt to implement technical platform and BIM, but in the end this process is dynamic and constantly changing and therefore needs a system that allows this change to happen.

Recommendations

The development of technical platforms and BIM is constantly ongoing. During the research and the writing of this thesis, the SXC system has been advanced and further built up. From the research and especially after completing the interviews, the following four suggestions may improve the SXC system in the short-term perspective. In the long-term perspective it is recommended to look into the concept of strategic partnering as a method for long lasting relationship built on trust and shared risk taking. Another suggestion for long-term thinking is effective use of knowledge although, as shown below, this can also be done in a shorter perspective.

- A work plan should be developed for each role explaining what Skanska Xchange represents in this project, how the technical platform system and BIM should be used and why and what the expected outcome is. This plan would facilitate the understanding of the SXC manual and save time in the project. Further, the work plan would visualize the requirements from Skanska Xchange and provide the project participants with a document showing what they can expect from Skanska Xchange.

Work plan

The designing architect

What is Skanska Xchange in this project?

- ....
- ....
- ....

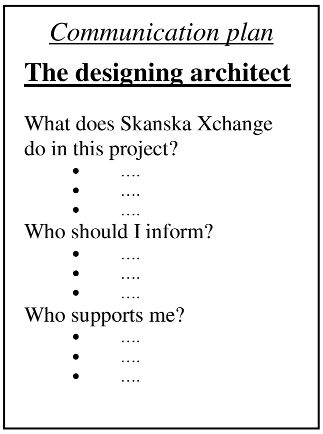
The technical platform system & BIM

- ....
- ....
- ....

The expected outcome:

- ....
- ....

- A straight forward and simple structured communication plan would minimize misunderstandings and provide each participant with clear responsibilities. The communication plan would also assist the SXC development organization who can then easier focus on taking a supportive role.

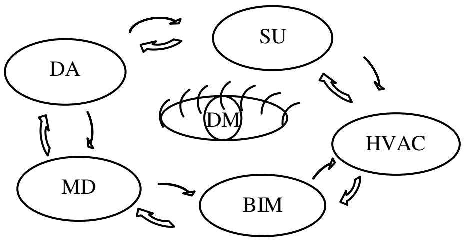

Communication plan

The designing architect

What does Skanska Xchange do in this project?
- ....
- ....
- ....

Who should I inform?
- ....
- ....
- ....

Who supports me?
- ....
- ....
- ....



The design manager functions as a supportive role and has the overall picture of the project.

- The third recommendation concerns the need for advanced knowledge management. Knowledge should be shared and reused not just after finishing each phase of the project, but also during the work process. At the start of every project, brief information could be handled out to each project participant, describing the knowledge and strengths of all of them. To follow-up, the same procedure may be taken during and in the end of each phase to visualize the use of knowledge and competence.

- Last but not least, doing a system step-by-step change is suggested. An adoption of a system like the SXC system entails a great proportion of patient engagement from every level of an organization and clear step-by-step implementation strategy is needed in order to be successful.

Further interviewee suggestions

In addition, the interviewees stated opportunities and challenges for the SXCR system. Below is a joined summary of the improvements suggested by the interviewees:

Architectural design and quality

To accomplish high architectural quality, improvements in detailing, a developed component library and a focus on interfaces and relationships between building parts and materials were seen as important. Space for exceptions, flexibility in choice of detailing and a discussion about what consequences the exclusion of knowledge and design thoughts have are also challenges highlighted by the interviewees in the case studies. The adaptation of the industrialized built building to its environment and the importance of not losing the reality in the virtual software world was also emphasized, as well as compatibility. The theoretical solutions must be accommodated to the reality.

The role and work process

To accomplish a well functioning and productive team a detailed work plan should be developed for each role. To fully make use of the diverse knowledge of the participants and be able to give feedback, a systemized way of handling the knowledge is necessary. Due to inadequate skills the designing architect had to be replaced in one of the case studies. To minimize misunderstanding and assure that the quality is not decreased, there should be a plan for what to do when the shift in roles is necessary.

Collaboration and communication

Throughout this study several of the interviewees have expressed that clear instructions and continuous support are two essential ingredients that has been lacking in the two projects. To gain trust and participation early, an education program explaining the purpose of the Skanska Xchange system and a presentation of the organization and work processes of Skanska Xchange must be provided. The financial benefits for the participants changing their way of working and collaborate should also be clarified.

7. Further research

This last chapter present thoughts and questions that have turned up during this study and would be interesting to research further.

This study has inspired many interesting topics that would be worthwhile investigating further. Below I have listed five topics with potential medium- and long-term effects on how the construction industry will develop into the future.

- *How does the influence of a country's culture and traditions affect the role of the architect?* In the UK it is not unusual that an architect occupies the role of a project manager or a contractor and in Dubai the architect could have the role of the client. In Sweden this can rarely be seen. However, Sweden as well as other countries has to take into consideration the increased globalization.

- *How does the work process and the quality of the end product differ in an multidisciplinary organization that contains both designers and technicians, compared to an organization that only involves one of them?* This thesis has suggested that close communication decreases misunderstandings and facilitates the minimization of errors; nevertheless there is no evidence that the quality of the end product is improved.

- *What can be expected from the development organization to maintain a high architectural quality?* Many suggestions have been stated in this thesis, such as a multidisciplinary development organization, involvement by the users and a flexible platform. However, the focus of the system is crucial. Time, money and not to mention energy are lost because of no clear guidance.

- Is a technical platform the best solution when an organization wants to increase its productivity?

- How can an organization balance between standardization and continuous improvements?

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Figures.

Appendix 1. Interview Questions – the Case studies

Intervjufrågor – Fallstudier

Bakgrund

1. *Information om intervjupersonen:*
    a. Vilken är din bakgrund (utbildning, erfarenhet, mm)?
    b. Vilken är din roll i projektet?
    c. Vilken tidigare erfarenhet har du av BIM eller 3D-modellering? Vilka fördelar och nackdelar har det?
    d. Vilken tidigare erfarenhet av detta har kontoret? Vilken strategi har ni?

Effekter, processer och roller i detta projekt

2. Vad innebär en god gestaltning och arkitektonisk kvalitet för dig?

3. Vad har varit <u>bra</u> i projektet, nämn 3 saker?

4. Vad har varit <u>mindre bra</u> i projektet, nämn 3 saker?

5. Vilka kompetenser/verktyg har ni behövt utveckla alternativt skulle ni behöva utveckla för att arbeta i den här typen av projekt?

6. Hur introducerades ni till Skanska SXC plattformssystem av Skanska? Utbildningsinsatser?

7. Vilket budskap kring de tekniska plattformarna sändes ut från Skanska?

8. Vilket budskap kring BIM verktyg sändes ut från Skanska?

9. Hur har anpassningen till Skanska SXC plattformssystem påverkat byggnadens gestaltning?

10. Skiljer sig flexibiliteten i detta projekt från den i ett projekt utan plattformsystem?

    a. Om Ja, Hur skiljer den sig?

11. Skiljer sig den kreativa processen från den i ett projekt utan plattformsystem?

    a. Om Ja, Hur skiljer den sig?

12. Hur har arbetssättet med Skanska Xchanges tekniska plattfrom system och BIM skilt sig från projekt där dessa system inte använts?
    a. Arbetsuppgifternas innehåll
    b. Samarbetet med andra projektörer och Skanska (rollerna i projektet)
    c. BIM-koordinatorns roll
    d. Kommunikation och möten
    e. Tidplanering och processtyrning
    f. Annat.

Förbättringsförslag

13. Anser du att Skanska SXC plattformssystem skulle kunna utvecklas för att förbättra förutsättningarna att uppnå god gestaltning och arkitektonisk kvalitet?

    a. Om Ja, Hur skulle Skanska SXC plattformssystem kunna utvecklas?

14. Anser du att arbetssättet i projektet skulle kunna utvecklas för att förbättra förutsättningarna att uppnå god arkitektonisk kvalitet?

    Om Ja, Hur skulle arbetssättet kunna förbättras?

15. Finns det något mer som du vill tillägga?

Appendix 2. Interview Questions – the Survey

Intervjufrågor - Survey

Bakgrund

2. *Information om intervjupersonen:*
    a) *Utbildning, yrkesroll, erfarenhet.?*
    b) *På vilket sätt har du kommit i kontakt med industrialiserat byggande?*

Allmänt om industrialiserat byggande och arkitektrollen

3. Vilken är din attityd till tekniska plattformssystem?
    a. Hur har systemen utvecklats över tid?
    b. Hur har arkitekternas attityder utvecklats över tid?
    c. Är det nödvändigt för alla arkitekter/arkitektföretag att vara öppna för nya sätt att arbeta?

4. Vilken är din attityd till BIM verktyg?
    a. Hur har systemen utvecklats över tid?
    b. Hur har arkitekternas attityder utvecklats över tid?
    c. Är det nödvändigt för alla arkitekter/arkitektföretag att vara öppna för nya sätt att arbeta?

5. Vilka är de största skillnaderna för arkitekterna i det gamla och det nya sättet att arbeta?

Processer och roller

6. Hur påverkar det ökande användandet av tekniska plattformssystem arkitektens roll?

7. Hur påverkar det ökande användandet av BIM verktyg arkitektens roll?

8. Hur påverkas samarbetet mellan parterna? Ställs det krav på nya genomförandeformer?

9. Vilken kunskapsbas anser du vara nödvändig för att implementeringen och användandet av tekniska plattformssystem ska ge en grund för en god gestaltning och arkitektonisk kvalitet?

10. Anser du att kraven som ställs på vilka program och verktyg som måste användas i projektet, påverkar arkitektens design process?

    a. Om Ja, Hur påverkas arkitektens design process?

11. Anser du att gestaltningsförutsättningar och samarbete mellan aktörerna i ett projekt påverkas av att de tekniska plattformssystemen oftast är utvecklade av byggföretag/ entreprenörer?

    a. Om Ja, Hur påverkas gestaltningsförutsättningarna och samarbetet?

12. Tekniska plattformssystem och BIM anses av många öka effektiviteten, sänka kostnader och korta ner tiden för projektet. Håller du med om detta? Vilka fördelar resp. nackdelar ser du med dessa två system?

13. Är standardisering och kreativitet varandras motsatser?

14. Vad bör tänkas på för framtida utveckling inom detta område?

15. Finns det något mer som du vill tillägga?