CHALMERS
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Development of BIM Roles in Infrastructure Projects

Master's thesis in Architecture and Civil Engineering

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ABSTRACT

This study focuses on the current BIM roles and their development within a small infrastructure consultant company referred to as OfficeBIM in the study. It is conducted with the help of a questionnaire, complementary interviews and personal observations at the company office in Gothenburg, Sweden. The study demonstrates that there are problems with definitions of the existing BIM roles and their responsibilities. Even so, new BIM roles are emerging as well. One of these new roles under construction at OfficeBIM is a "*BIM supervisor*". In addition, the BIM role titles can differ among companies and countries. In this study, the role of a BIM manager is regarded as "*Business Area Responsible in 3D/BIM*" or the role of a BIM modeler is referred to as "*3D/BIM Designer*" at the company examined. Whereas, in other cases the role titles can be the same between companies and the literature, such as the role title of BIM coordinator at OfficeBIM which was consistent with the literature.

The company has also recently managed to create a manual, in which all BIM roles' responsibilities have been defined respectively. However, many of the BIM actors have the belief that the manual is mainly for guidance for newly recruited employees to know what is expected from them to deliver. In contrast, they believe a BIM actor shall know as much knowledge as possible, as BIM itself is rather broad. Thus, the BIM actors depend on each other's skills and constantly work as a chain in BIM projects where everyone in reality knows a bit of everything. When it comes to BIM assistance in infrastructure projects, BIM actors of this study believe that time and cost saving along with useful information, competitive advantages and effective work processes are among the most beneficial factors of BIM utilized for infrastructure.

Key words: BIM, BIM Actor, BIM Roles, Infrastructure, Construction

Utveckling av BIM-roller i infrastrukturprojekt

Examensarbete inom mastersprogrammet: Internationell projektledning

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Nyckelord: BIM, BIM-roller, BIM-aktörer, infrastruktur, konstruktion

Contents

Preface

The following study is a master's thesis encompassing 30 credits, which has been conducted for the master's program International Project Management, MSc. at Chalmers University of Technology. The master's thesis was conducted during the Spring semester 2018 at the department of Architecture and Civil Engineering, for the division Construction Management.

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1 Introduction

This chapter starts with a background to the issue under enquiry, followed by the aim of the study, the work boundary and the research questions of the examined study issue.

1.1 Background

Infrastructure projects are challenging to structure and deliver. For instance, it is difficult to manage all the different stakeholders who enter the project in various stages of the project. It is hard since most of the stakeholders have different roles and responsibilities. Moreover, they also have conflicting interests. Due to the fact that infrastructure projects are huge and costly, Building Information Modeling (BIM) is a profoundly useful tool being used in assisting infrastructure projects. The companies need to invest time and money to plan and educate themselves, so that they can benefit from BIM properly. This is because some companies believe that they already have implemented BIM, but in fact, they only use 3D drawing processes, which is not enough (McKinsey, 2013).

BIM refers to the comprehensive procedure of digital simulation of construction project phases using computer-generated models in more than two dimensions. BIM can be regarded as modeling technology that can be used in designing, communicating and analyzing building models (Galiano-Garrigos, 2017). BIM is a process which uses 3D-modeling software to inform and communicate project decisions (Autodesk, 2018). In BIM, models of buildings are characterized by components that are represented by digital objects containing data on graphics, parametric rules and attributes. The data carried by the elements shows object-related behavior which is significant in performing analyses, such as performance testing, data conversion, quality checkups and more (Galiano-Garrigos, 2017).

The BIM concept was founded by Professor Charles Eastman at the Georgia Tech School of Architecture in late 1970s (Latiffi, 2014). However, BIM was first mentioned in 1990s. In early 2000s, the term Building Information Modeling gained a huge reputation and became ubiquitous. By then, different corporations began to produce special software tools for BIM. One of them was Autodesk which has developed the software Autodesk Revit to implement BIM. Furthermore, Graphisoft has developed the ArchiCAD which is considered to be the first software for representing BIM that is capable of creating both 2D and 3D structures and can be used from personal computers. Such BIM software revolutionized the building process by representing it digitally, which vastly assisted engineers. The software tools depicted the building project as an object-oriented model in a database. By forming a digital building information model for the actual building, the project engineers were now able to perceive their project optimally and deliver it more efficiently than before (Eastman et al. 2008). A key characteristic of BIM is that it

took the traditional building design based on 2D-drawing to 3D, along with 4D representing time and 5D representing cost. With respect to that, BIM implies more than geometry and involves various aspects of buildings and infrastructure (Abramova, 2015). The applications of BIM in the project phases are referred to as BIM uses that are comprised of various activities conducted with BIM, such as clash detection, cost estimation, 3D coordination, quantity takeoff and more. Taking such things into concern, BIM can be utilized for any phase of a project lifecycle ranging from planning to design, construction, operation and maintenance (National Institute for Building Sciences, 2017).

According to the McKinsey report from 2013, infrastructure assets are important for economic growth and social development. The World Bank estimates that a 10 % rise in infrastructure assets instantly increases GDP by up to one percentage point. Due to this fact, countries highly prioritize infrastructure projects. However, infrastructure projects usually have issues related to cost overruns, delays and procurement failure. These problems occur since they have a lack of professional, forward-looking risk management (McKinsey, 2013). These issues happen in all stages of the value chain and throughout the whole life cycle of the infrastructure project. One issue in the early stages of the project could have a negative effect on the later stages. With an appropriate risk management, these issues could be avoided and attract private financing. These concerns need to be managed properly, otherwise the countries will see a loss in GDP growth, but also reputational and societal effects. These types of problems will most likely become worse since the infrastructure projects are getting larger and more complex. In addition, there will be more ongoing infrastructure projects. This will lead to a demand for new solutions, in which BIM and BIM actors will have a paramount role (National Institute for Building Sciences, 2017).

A BIM actor is the person undertaking the responsibility of implementing BIM in a corporation. This person can have various titles depending on the roles the actor undertakes such as BIM coordinator, BIM manager, BIM modeler and others (Joseph, 2011). However, as hinted previously BIM and the BIM roles are constantly advancing in the industry. This has complicated what responsibilities a BIM actor is expected to undertake. The roles of the BIM actor can be different and vary at different firms. Thereby, there is an uncertainty in the definitions and responsibilities of the BIM roles (Building and Construction Authority-BCA, 2013). Due to that reason examining the BIM roles and their development is important, in order to acquire an explicit picture of what each role is and what they are expected to deliver. As previously highlighted, infrastructure projects are distinctive in nature from other smaller building projects. Thus, examining BIM roles' development in infrastructure can be interesting in such a distinctive context.

This study is a continuation of an ongoing research of Chalmers University of Technology, in which various companies of the construction industry have been investigated about development of BIM roles. For the broader Chalmers research, a

questionnaire survey was sent to different companies including architects, real estate developers and contractors. However, this study applies the same questionnaire to a new empirical context, namely to an infrastructure consultant company and expands the results using interviews and observations as additional data.

1.2 Aim and Research Questions

As previously highlighted, BIM became ubiquitous in the 2000s and it is consistently undergoing a rapid development. Thus, the roles and responsibilities of BIM actors also comply with this development and are defined differently by different companies. Hence, the aim of this study is to investigate the development of BIM roles including their future development and how their responsibilities and tasks are currently defined. This is done by studying a small infrastructure consultant company in Sweden which works with design and Heating Ventilation and Air Conditioning (HVAC). Based on this specific context, the study seeks to add more information to the research field of BIM role development.

The study is written for Chalmers University of Technology and the consultant company for which it is conducted. In addition, the company of the study is referred to "*OfficeBIM*" by the study authors.

RQ1: How are the current BIM roles, their responsibilities, tasks and requirements defined?
RQ2: Are there new BIM roles developing?
RQ3: How do BIM actors think BIM is useful for infrastructure projects?

1.3 Work Scope

This study revolves around OfficeBIM solely, which is located in Sweden and involved with infrastructure. Therefore, the study does not consider other companies which Chalmers University of Technology has investigated in its previous research. It focuses specifically on current and developing BIM actor roles of OfficeBIM and the company's approach to BIM implementation. Relevant theory from the construction industry is presented in the study which discusses BIM roles.

2 Methodology

This chapter explains how the research has been conducted starting with the research approach, which describes the different thesis steps. Afterwards, the sections of research approach, data and ethical considerations are presented. The structure of the methodology comprises relevant theories about how a methodology should be conducted, followed by how the authors of this study have conducted the methodology based on these theories.

2.1 Research Approach

The research started with gaining theoretical knowledge about the topic through literature studies. This was done in order to investigate BIM roles and their responsibilities in infrastructure projects from other researchers' point of view. Thereafter, a questionnaire was sent to the employees, to get their perspective. This endeavor aimed at getting a picture of the studied company (OfficeBIM) via its employees. That was also to check the reality of the research issue from an empirical perspective and juxtapose it with the theoretical findings in a comparative context. Interviews were also done, as a follow-up of the questionnaire results, to acquire deeper knowledge within the field of research. In the meanwhile, observations were done at the company office during weekly meetings on Mondays to further acquire more knowledge about the work environment of the company. Finally, an analytical discussion was conducted to compare all the different method approaches of the questionnaire, interviews and observations with the theoretical findings. This paved the way for getting an overall conclusion of the study based on both the theoretical and empirical findings.

The main approach that has been used is deduction, which is an approach based on premises to reach a logical, certain conclusion Björklund & Paulsson (2014). Theory has been utilized as a starting point, to forecast the empirical data, which means that deductive reasoning has been used. The deductive approach is illustrated in Figure 1.

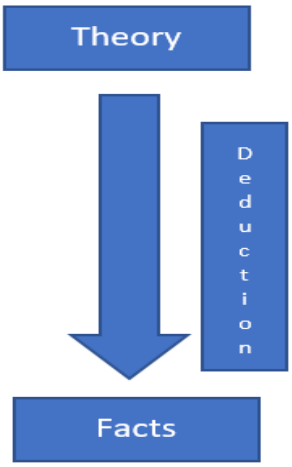

Figure 1 Illustration of deductive approach adopted from Björklund & Paulsson (2014).

Depending on the aim of the study, an appropriate method should be selected. If it is measurable, a quantitative method needs to be selected. On the other hand, if it is not measurable, it is a qualitative study, with the aim to gain greater knowledge for a specific scenario (Björklund & Paulsson, 2014). In this research, mixed methods have been used, including both qualitative and quantitative methods. For example, both a questionnaire and interviews were done to increase the study validity and credibility. According to Bryman and Bell (2015) qualitative and quantitative approaches can be combined. Combining the two have a main advantage which is increasing credibility of the research and avoiding bias. When quantitative data is supported with qualitative data, initial findings can be explained better. That is because quantitative data delivers statistical type of results while qualitative data helps to explain these results. Therefore, this approach of mixed methods was used which favored the study optimally.

When planning mixed method procedures, four different aspects need to be considered. Timing is one of the aspects. Sometimes, qualitative or quantitative data can be collected at different times and in other cases at the same time. It is often more productive to collect all the data at the same time. However, in this study, the quantitative data was collected first, since the qualitative data was only complementary. Weighting is another important aspect, which is related to the previously mentioned sentence since it concerns whether the qualitative or quantitative approach is emphasized first. In this study the quantitative approach has been prioritized because of this reason. An additional aspect is regarding mixing qualitative and quantitative data by merging, keeping separate but still connecting to each other, or combining in some way (Creswell, 2011). The qualitative and quantitative data of this study is kept separate but is still connected because one set of data is based on the other one. Both the qualitative and quantitative parts complement each other.

Validity and reliability are important aspects in research according to Björklund and Paulsson (2014). Validity is the trustworthiness of the research. While, reliability is the consistency of the research measures (Björklund & Paulsson, 2014). To increase the validity and reliability of this study, the questionnaire participants were anonymized. Since the participants work for the company, it will remain unclear if they answer truthfully as they might be concerned about their positions and the company image. However, to ensure more accurate answers, the participants were told that they and their answers will be anonymous both inside the company and in the study. Moreover, the interviews which took place subsequent to the questionnaire further increased the reliability and validity of this study by doublechecking the major areas covered in the questionnaire. Therefore, the interview questions were formed based on the questionnaire results.

2.2 Data

This section comprises information about the data collected for forming this study. Initially, information is denoted about how the data was collected along with the types of data. Thereafter, an introduction is presented about the interviewees of the study.

2.2.1 Data Collection

The data was collected through literature studies, a questionnaire, interviews, observations and the role manual of the studied company. Literature studies are beneficial for various reasons. For instance, it is possible to collect data during a short time without financing or to get a compilation of different authors' findings. It is helpful because it facilitates the mapping of existing knowledge within the subject to develop a theoretical framework. A drawback is that it is not always mentioned how authors' data was collected, and what their purpose was. It is therefore important to always control the collected data which will be used (Björklund & Paulsson, 2014).

Collecting data through a questionnaire is not that time consuming in comparison to other approaches such as interviews. It is worth the time, because it is possible to receive considerable data. A drawback is that body language cannot be interpreted. There is an increased risk of misunderstandings, since it is not as easy as in interviews to ask for a clarification. There is also a risk that the questionnaires are not filled in by the respondents for a long time. Often there is a need to remind the respondents to fill in the questionnaire, in order to reach an acceptable response frequency. Another drawback is that answers tend to be shorter compared to interviews (Björklund & Paulsson, 2014). As hinted at previously, this study is a part of the ongoing Chalmers research which is partially based on a pre-constructed Chalmers questionnaire that has been used for the previous research. Thus, the same questionnaire had to be used to create consistency and coherence with the previous Chalmers research. However, it was adapted after the company and was re-constructed into the company intranet. Therefore, the same questionnaire was sent to all the 39 company employees to participate in it voluntarily. The reason for sending to all was to increase the chance of getting as many participants as possible, to enriching the study and making it more reliable and trustworthy.

The questionnaire text was in Swedish since it was easier for the employees to understand. In addition, the participants were asked to indicate the importance of each subject on a Six-Point Likert Scale. The questionnaire had a deadline because of the time limits of this research. The deadline was later extended due to the lack of adequate responses. Only nine employees answered the questionnaire fully by then. One answered partially, whose participation was later dismissed. A few employees were confused about a couple of the questions in the questionnaire. This was a barrier for participation which later resulted in participation dismissal. However, other barriers for non-respondents could have been lack of interest or workload. Furthermore, only one female had participated out of many women present at the

company office. Therefore, an incentive (gift voucher) was offered to attract more participants and the questionnaire deadline was extended. It had a slightly positive effect, since two more employees answered, one of whom was a female. Nevertheless, still two females out of 11 participants was less than optimal. So, finally 11 employees participated in total. This number covers over a quarter of the employees which can be considered representative. The participants had various roles in the company. The questionnaire was handed out electronically in March 2018.

After the data from the questionnaire was collected, the interview process began in which four interviews took place. Interviews give a deeper knowledge and possibility to read the respondents' body language. A drawback is that it is often time-consuming and sometimes costly because of travels (Björklund & Paulsson, 2014). In this research four semi-structured interviews were conducted through face-to-face meetings. Semi-structured interviews were chosen so the interviewee could answer more freely, but at the same time the interviewers could ask follow-up questions. The interviews were mainly in Swedish apart from one, since it was easier for the employees to express themselves with a duration of approximately one hour for each interview, depending on their level of experience. The interviewees were selected based on their previous participation in the questionnaire and their roles in the company in a hierarchical manner, where each BIM role could be represented by a BIM actor. Thus, a BIM manager, coordinator and modeler were selected. For getting a more explicit comprehension of the company, the company CEO was also among the selectees for interviews which together made a total of four interviewees. The interview questions were based on the questionnaire results. For instance, some results from the questionnaire which were unclear or diverse were asked about during the interviews. The interviews were performed during April 2018.

Moreover, observations are another type of data collection method. This method is time consuming and can be performed in different ways. Therefore, it is difficult to understand the real value of observations beforehand (Björklund & Paulsson, 2014). However, the research authors visited the company almost weekly, ate lunch together with the employees, worked on the study at the company and attended their weekly meetings. Therefore, some observations of the work environment were made and utilized in this study, for consolidating the study's reliability and validity.

Finally, the company's role manual was used for comparison and juxtaposition of the BIM role titles stated in the literature and those present at the company. That is because a few BIM role titles at the company were not the same as those in the literature and the role tasks were required to be able to match and recognize the roles with the ones of the literature. Moreover, investigating the company BIM roles required their responsibility and task instructions.

2.2.2 Interviewees

The role titles at OfficeBIM were incompliant with the international ones mentioned in the literature. Thus, based on the role responsibilities at the company, the roles were matched with the ones of the literature for knowing who is doing what and avoiding misunderstandings. The interviews were carried out at the company's Gothenburg office over the course of two days.

2.2.2.1 Employee 1: BIM Manager

The first interviewee has a bachelor degree in Civil Engineering with focus on Design and Structuring. He further has a master's education in Design and Construction Project Management. Initially he had the role of a modeler but later became a BIM-Coordinator at OfficeBIM. One year later he became Business Area Responsible in 3D/BIM which he continues with today. He has worked at the company for five years and has a vast amount of knowledge in BIM, which junior employees turn to for assistance. His role corresponds the one of a BIM manager.
Interviewed on 26th April 2018 - Company Office, Gothenburg, Sweden.

2.2.2.2 Employee 2: BIM Modeler

Employee 2 is from a vocational university. The interviewee is still a student of a program called CAD/BIM Building Designer. She is in her final year of education and will finish in two weeks from the interview date. She is currently carrying out a paid internship at OfficeBIM as a part of the final period of her education. She has been working at the company for six months in total as a 3D/BIM design engineer which is translated to BIM modeler. She will officially be a full-time employee of the company from May 2018 onward. Employee 2 is a junior internee, thus was considered important for this study to get a junior's perspective as well.
Interviewed on 26th April 2018 - Company Office, Gothenburg, Sweden.

2.2.2.3 Employee 3: BIM Coordinator

Employee 3 has three educations related to the construction industry, which are product design, CAD/BIM design and building design. His education as a CAD/BIM designer is comprised of a two-year educational program from a vocational university in Sweden. Employee 3 has also worked with the role of a BIM coordinator for ten months in total, nine of which are at OfficeBIM. He was selected as an interviewee, due to being the only one officially having the title of a BIM coordinator at OfficeBIM.
Interviewed on 27th April 2018 – Company Office, Gothenburg Sweden.

2.2.2.4 Employee 4: CEO

The fourth and final interviewed person is the CEO at OfficeBIM's Gothenburg office. He is also a project manager for one of the ongoing company projects.

Employee 4 is a graduate from Chalmers University of Technology, with a degree in building engineering with focus on installation. He was selected for an interview due to not being a BIM actor himself, in comparison with the other interviewees. That was to have different interviewee samples and get diverse perspectives.
Interviewed on 27th April 2018 – Company Office, Gothenburg Sweden.

2.2.3 Data Analysis

There are several data analysis methods. One of the methods is to use analysis models, to structure and evaluate collected data. Another way of analyzing data is to utilize descriptive statistical analysis, to gain new information. Furthermore, simulations can also be done to test the collected data (Björklund & Paulsson, 2014). In this research, descriptive statistical analysis such as calculating mean values and deviations have also been done to obtain new information, from the collected data in the questionnaire. This is mainly because, the sample was rather small. Furthermore, the questionnaire results were analyzed based on own perception and interpretation. The same method was also followed for the interviews. The interviewees' responses were analyzed and interpreted. Thereafter, observations were done only in a cognitive way, without writing notes. Following such an analysis framework in this study was the most optimal way to go, due to time restrictions. Thus, no certain analysis models, categories or similar methods have been used for the data analysis of this study.

2.3 Ethical Considerations

Ethics is an important aspect of report writing, which seeks to resolve questions about morality by considering concepts such as right and wrong, good or bad, just and unjust etc. (Creswell, 2011). An ethical way of thinking was pursued for shaping this study. For instance, the anonymity aspect of ethics was secured by anonymizing the examined company of the study, along with its employees. The participants of this study were informed about the benefits of participating in the study for helping their company to develop further. They also were clearly assured about their anonymity, to erase any doubts in their mind.

3 Theoretical Framework

In this chapter relevant theoretical data is demonstrated regarding BIM in infrastructure, various BIM roles and hindrances concerning the development of new BIM roles. The theoretical framework is based on various authors' previous research which has been utilized in the study.

3.1 BIM in Infrastructure

Nowadays, BIM is implemented in most of the infrastructure projects to be competitive enough on the market. Companies which use BIM in their projects have a competitive advantage. They need less modifications and it is less probable that defects occur. Moreover, their collaboration is improved. They also benefit from all the design data, which supports the running, maintenance and object management (Autodesk, 2015).

Due to new technologies such as automation, some roles disappear and some roles emerge. As an example, robots are working faster and with less amount of errors compared to traditional workers. This will lead to other types of roles developments. Emerging BIM roles are one case in infrastructure projects. The way of working has changed due to new responsibilities for the employees. This requires updated role descriptions. One of the issues related to that is how BIM roles can be implemented to infrastructure projects as effectively as possible. BIM has been implemented in many companies, new roles and job titles have therefore emerged (Akintola, Venkatachalam & Root, 2017).

The companies which are starting to work with BIM also need to identify standards and regulations. Moreover, it is also necessary to identify relevant types of software and hardware. After implementation, they also need to do a proper documentation and improve their processes (Autodesk, 2015). Furthermore, when they, for instance, want to make a change which affects the whole construction, the software will understand this directly, and modify automatically for those places which are needed. In other words, they do not need to do it manually, which is time consuming (Autodesk, 2015). BIM also helps to solve design conflicts before the construction is built, which will lead to reduced costs and time spent on the project (Harris, 2017).

In the recent past, BIM technology has gained popularity in the construction industry. Despite the numerous advantages the technology has its shortcomings. Utilizing BIM solutions in infrastructure projects is critical to success. The technology offers various benefits throughout construction projects from initial design to completion. Among many other purposes, BIM is an excellent tool for project management due to its effectiveness in the elimination of waste, coordination and communication between project owners, contractors and subcontractors. BIM improves visualization. The benefits of good visualization are a great overview, risk reduction, compatibility and clash detection. Visualization of 3D models offers great understanding of concepts

and details of designs which form a better common mental picture than the traditional drawings (Eastman et al., 2011). In line with Eastman et al. (2011), 3D models of visualization enable the designing of perceivable comprehensive structures with reduced risk of errors during the construction process.

The ability of BIM in clash detection and control is essential in reviewing potential drawing errors that might result in a collision of structural members. Research conducted by the Centre for Integrated Facilities Engineering (2007) at Stanford University on 32 construction projects indicate that up to 10 % savings of contract value can be reached by use of BIM in clash detection (Salman, 2008). While various subcontractors work to complete different parts of a building their installations can run into one another. For instance, electrical wires running through a structural element. BIM tools provide the best solution through 3D visualization that helps in monitoring whether everything fits. Improved collaboration and project prediction are benefits that can be derived from the use of BIM. The software technology facilitates increased coordination, reliability and communication regarding project design among stakeholders (Price, 2017). Better information exchange facilitated by correct utilization of BIM improves rapid decision making by engineers and the project team in applying changes to the predicted model. BIM can also be used in the evaluation of what-if scenarios.

According to Clevenger (2015), there was a study which determined that 67 % of the users of BIM associated with infrastructure were seeing positive return on investment (ROI). BIM can also be used to optimize roadways through visualization, simulation and analysis in the design process. Asset management in infrastructure projects also get easier with the usage of BIM, since they in an easy way will know what the organization owns. Moreover, they can access information about last performed service on a given component. Sensors could provide data about current conditions, which will help, for instance, health and safety issues (Clevenger, 2015).

Despite the many proven benefits of BIM in construction project management, there are many shortcomings to its implementation. One major problem is that BIM training investment costs and software purchase is relatively high compared to traditional construction designing techniques. Due to these challenges, there is a widespread shortage of skilled personnel with expertise in BIM technology and structural engineering. The legal issues surrounding the implementation of BIM also act as obstacles to its full potential (Udom, 2012). Issues like ownership of the model, regulation of responsibilities and rewards from improved collaboration are a tremendous legal risk that requires management to facilitate the adoption of BIM. Resistance to the approval of newer technology is another disadvantage because it entrenches workers from people-oriented tasks. According to Lee (2015), there are 28 different key factors which impact BIM acceptance. In other words, there are many reasons for resistance.

Another problem which could occur is lack of understanding of roles and responsibilities. Implementation of BIM is an investment for companies. They need to

invest some time and money in the beginning to educate themselves and buy the software and hardware (Migilinskas, 2013). However, later it will lead to many benefits, such as time saving, reduced costs and better knowledge management.

There are numerous pros and cons in the use of BIM for production in infrastructure projects. Unlike in building and construction, the use of BIM in the infrastructural project is critical to the viability of the whole process. It plays an important role in procurement audits, feasibility tests, management and reduction of wasteful construction related activities. The utility of BIM in infrastructure projects promotes efficient production processes (Udom, 2012).

3.2 BIM Actor

As previously highlighted, there is not a standardized title for the profession of BIM actor or various BIM actors. Different corporations address the profession by differently related titles depending on the type of roles such as BIM lead, BIM manager, BIM coordinator, BIM engineer, BIM designer and so on. Occasionally, multiple titles can refer to the same BIM actor with multiple BIM roles. (Uhm, Lee and Jeon, 2017). The profession concerns an actor in the construction industry that carries out various BIM-related activities. In reality, architects, civil engineers or any other corporate actor can also be a BIM actor with skills in BIM software more or less. Nevertheless, the profession of a BIM actor is aimed at professionals who specialize in BIM to carry out BIM work in a corporation (Succar, Sher and Williams, 2013).

Competency is defined as the capability to perform relevant tasks and deliver expected results (Succar, Sher and Williams, 2013). BIM competencies in relation to an individual's traits, skills and knowledge are considered Individual BIM Competencies (IBC). They are divided into eight categories according to Succar, Sher and Williams (2013) which are the following:

1. **Managerial**
   Managerial competencies involve leadership, strategic planning and BIM management. The category includes having the ability to oversee and manage BIM implementation, followed by setting strategic plans for goal accomplishment by utilizing BIM software tools.

2. **Administration Competencies**
   Administration competencies involve administration, guidance, economical aspects such as finance and accounting, budgeting and resource management. The category includes administrating daily BIM activities to meet planned goals and outcomes, having the ability to find necessary BIM items for conducting projects, inspiring teams to utilize BIM software tools in their work and identifying the teams' responsibilities. Furthermore, to have the

ability to utilize BIM economically in projects by measuring their financial performance is also an administrative competency needed for a BIM actor.

3. **Functional Competencies**
   Functional competencies involve collaboration, facilitation and information management of BIM. This includes being a collaborator, facilitating BIM implementation for the project team when conducting BIM projects and managing BIM-related information via corporate systems.

4. **Operational Competencies**
   Operational competencies involve the ability to utilize BIM for operating and maintaining facilities. This includes design, analysis, estimation, simulation, qualification, defect detection etc.

5. **Technical Competencies**
   The technical competencies involve the technical usage of BIM software, such as having the ability to create actual digital models as representations for facilities to be built. This also includes the final documentation of BIM models to be prepared for the construction phase of the building.

6. **Implementation**
   The implementation competencies involve having the ability to take necessary steps to implement BIM in the organization. Such steps include selecting the appropriate BIM software tools, managing BIM models, developing BIM components and offering technical BIM assistance for those in need of it to implement BIM.

7. **Supportive**
   Supportive competencies involve maintaining information technology and communication systems in the organization. Such steps include testing the current organization system to see whether they are appropriate, managing the network, handling software-oriented issues and being a mediator between the organization and its BIM software vendor.

8. **Research and Development**
   Research and development competencies involve skills for forming an R&D plan for the organization in relation to BIM and sharing knowledge about BIM in the organization by forming non-technical educational material for the employees to support them in perceiving BIM.

The exhibited competencies are expected from a BIM actor to have, according to the BIM literature. However, the reality might not look as complicated as claimed by Uhm, Lee and Jeon (2017). All these competency requirements might not be expected from every individual simultaneously. They assert that the competencies related to the

profession of the BIM actor are viewed differently as different employers require different skills for a BIM actor to have. It is common that employers consider having skills in the technical usage of BIM software as the main competency required. They account for competencies related to the application of BIM software for its main modelling purpose as the essential competencies, followed by having knowledge in BIM literature, BIM standards and network-oriented BIM management which come as secondary competencies (Uhm, Lee and Jeon, 2017). The BIM researchers Uhm, Lee and Jeon (2017) highlight particular BIM job advertisements in their research from construction companies which have the following BIM competency requirements:

- "*As our BIM manager, this job requires practical knowledge of BIM modelling software and the ability to focus on the benefits BIM can add. Thereby enthusing and supporting others in its adaptation and use.*" (Uhm, Lee and Jeon, 2017, p.70).

- "*Having practical knowledge of BIM modelling software, ability to focus on the benefits of BIM, enthusing and supporting others in its adaptation and use.*" (Uhm, Lee and Jeon, 2017, p.70).

The two actual exemplary job advertisements from the reality assert that having technical skills, such as BIM software usage, are primarily valued by employers over other compliant competencies (Uhm, Lee and Jeon, 2017).

3.3 Current BIM Roles and Responsibilities

In this section, the responsibilities and tasks of a BIM actor are described generally in both projects and organizations. Subsequently, tasks and responsibilities of each current BIM role are specifically identified.

3.3.1 BIM Actor Responsibilities in Projects versus Organizations

The responsibilities of a BIM actor in general are divided between two categories: project-based and organization-based. As BIM is undergoing rapid development, new BIM roles emerge for a BIM actor to undertake. A few prominent current BIM roles are defined to be BIM manager and BIM coordinator (Davies, Wilkinson, McMeel, 2017), followed by BIM technician (Joseph, 2011). Thereby, a BIM actor can be any of these roles with similar and interconnected responsibilities. The following explains the generic responsibilities BIM actors are expected to undertake on both project and organizational bases, according to Building and Construction Authority-BCA (2013):

Project-related BIM actor responsibilities

- Formulating a strategic approach for the implementation of BIM in a project
- Information management throughout the project in relation to BIM
- Model coordination
- Clash detection

- Quality follow-up
- Quantity follow-up
- Facilitation by assisting the team in design and BIM implementation

Organizational BIM actor responsibilities

- BIM strategic planning in the organization
- Development of BIM in the organization through training, innovation and BIM-oriented knowledge management
- Application of BIM protocol in the organization
- Application of BIM on organizational projects
- Management of information in the organization

Any BIM actor is expected to know the demonstrated, basic responsibilities. However, with further development of BIM in the construction industry, the responsibilities are divided among new BIM roles, each with specific tasks (Joseph, 2011).

Most of the sources such as guidelines and handbooks focus on the BIM roles in projects, not really in organizations as discussions and arguments still continue about each role's organizational responsibilities. However, most of the sources identify the role of a BIM manager to be both in the project and in the organization. A few organizational responsibilities of the BIM manager are considered to be responsible for BIM training, followed by hardware and software compliancy issues. Hong Kong BIM Project Specification and similarly New York City Department of Design and Construction BIM Guidelines denote training and technical assistance for the modelling team as the organizational responsibilities of a BIM manager. As for organizational responsibilities of a BIM coordinator, they are mainly considered the same as the ones of the BIM manager. Whereas, a BIM modeler responsibility mainly lies within the project boundary such as the delivery of BIM models but the role also provides guidance about software usage and relationships with software vendors for the organization, which are considered organizational responsibilities (Davies, Wilkinson, McMeel, 2017).

The data about BIM roles' responsibilities illustrates interconnections, overlaps of responsibilities and thereby properly demonstrates complexity in the identification of each BIM role's responsibilities. With respect to that, two or more BIM roles might be merged into one and their responsibilities will be undertaken by the same actor depending on the size of the organization (Joseph, 2011). E.g. Davies, Wilkinson, McMeel (2017) claim that in reality, the organization's BIM manager frequently is the same as its BIM coordinator. Thereby, it is not unusual that a BIM actor can have multiple roles in an organization.

3.3.2 BIM Manager

The BIM manager is a main BIM actor whose role is essential throughout the project in relation to managing and implementing BIM as a BIM facilitator of the project. Immense technical BIM knowledge is not necessary for a BIM manager, who merely has the role of BIM management. Usually, the BIM manager is a manager of other BIM sub-roles such as BIM coordinators or BIM technicians (Joseph, 2011). According to Davies, Wilkinson and McMeel (2017) and Joseph (2011), a few notable responsibilities of a BIM manager are**:** being responsible for delivering and elaborating a BIM Execution Plan (BEP) and forming BIM protocols for projects. Additionally, the BIM manager has to identify the project BIM uses (activities conducted in BIM software) and manage BIM models, followed by generally managing BIM coordination. Furthermore, conducting design review and managing overall BIM activities in projects through supervision, BIM information management and leading BIM conferences with project stakeholders fall within the tasks of a BIM manager. Moreover, the BIM manager must make sure that the stakeholders have the required skills of BIM, know their responsibilities and the expected BIM objectives in the project are accomplished.

The BIM manager is generally recognized by the project phase in which (s)he manages BIM, such as a design BIM manager who is accountable for the design phase or a construction BIM manager who holds responsibility for the construction phase. In his turn, the BIM manager is a subordinate of the general project manager to whom (s)he reports the BIM outcomes and performances (Davies, Wilkinson and McMeel, 2017).

3.3.3 BIM Coordinator

The BIM coordinator is a main BIM actor who is essential in the design and construction phases of a project. The role is a secondary subordinate role under the direction of the BIM manager (Davies, Wilkinson, McMeel, 2017). Joseph (2011) recognizes this role as a *BIM job captain* or a *Model manager*. Whereas, Davies, Wilkinson and McMeel (2017) call it a *BIM coordinator* but also a *model manager*. The main reason for Joseph's (2011) disagreement about the coordinator term is that it merely points at the coordination perspectives of the role and omits the technical aspects of it. Thus, Josephs (2011) argues that this term is not appropriate for this role but the term *model manager* is more apt. Nevertheless, the responsibilities of the BIM coordinator remain the same, for which a high level of expertise in BIM is required. A few prominent responsibilities of the BIM coordinator role are**:** being responsible for forming design models and construction documents in BIM, identifying BIM uses (activities conducted in BIM software) and supervising the modelling and documentation processes. Moreover, the BIM coordinator must ensure that the team adheres to the specific project templates and coordinate BIM models and modelers. Coordinating with contractors, subcontractors and relevant designers, detecting clashes, ensuring the quality of the BIM models and providing directions and guidelines for the team are also considered tasks of a BIM coordinator (Davies,

Wilkinson, McMeel, 2017). Moreover, development of BIM and collaboration methods, for instance task planning and communication protocols, is also carried out by a BIM coordinator (Joseph, 2011). The BIM coordinator also conducts design reviews by auditing design models and drawings and reports data to the BIM manager and relevant stakeholders (Building and Construction Authority-BCA, 2013).

3.3.4 BIM Technician

A BIM technician is a prominent BIM actor, whose role is preliminarily designing and modeling projects. Thus, the BIM technician role is also referred to as a *BIM modeler*. Whereas, others recognize it as a *BIM author*, *BIM operator* or *BIM user* (Davies, Wilkinson, McMeel, 2017). The role refers to a highly-skilled modeler in BIM software, which requires immense expertise in design and modeling. The role is a subordinate to the BIM coordinator and the BIM manager (Joseph, 2011). Joseph (2011) argues that this role can also be undertaken by juniors as long as they are technically skilled to fit it or are interested and eager to train for it. According to Davies, Wilkinson and McMeel (2017) and Joseph (2011) a few prominent responsibilities of the BIM technician role are the following**:** BIM modeling and design, ensuring the accuracy of BIM construction documents, co-operating with higher and relevant BIM actors in case of design modifications and challenges. Moreover, the BIM technician has to comply with the specifications of the BIM Execution Plan (BEP) of the project, prepare drawings and models for authoritative stakeholders and audit them mutually in BIM coordination conferences. Having immense skills in writing and communication and being the main responsible actor for BIM software proficiency and utilization are also falling within the tasks of a BIM technician.

3.4 Hindrances for Development of New BIM Roles

When it comes to the development of new BIM roles, there are several hindrances preventing them. One of the essential hindrances is that the current BIM roles' responsibilities are quite unclear, with a lot of interconnections and overlaps. Thus, a united global standardization of the roles and their clear duty identifications are necessary. That is not yet accomplished as BIM is still undergoing development in the construction industry. Whereas, in fact the BIM roles' responsibilities can even differ by companies of the same country (Davies, Wilkinson, McMeel, 2017). Companies are yet to adapt to BIM in terms of knowledge and implementation, prior to developing new BIM roles. Yet, there is a lack of adequate BIM knowledge and BIM professionals in corporations (Löf, Kojadinovic, 2012). Another hindrance factor is cost, as in many companies one BIM actor undertakes multiple BIM roles. That is more suitable for the companies economically, rather than having various BIM actors with specified roles and paying them simultaneously when one can undertake multiple roles and responsibilities. Hence, developing new BIM roles is also an organizational question, whether the senior management and its executives prefer that or not. Therefore, a time is needed for the emergence of new BIM roles until the current roles and BIM-compliant issues are standardized and settled (Uhm, Lee and Jeon, 2017).

4 Results

This chapter kicks off with the results of a questionnaire achieved from the 11 participants. Thereafter, the results of four interviews made with employees of OfficeBIM are presented. Finally, the results of a weekly observation by the authors are illustrated which marks the end of the empirical findings of this chapter.

4.1 Questionnaire Results

The following is the results taken from the 11 respondents from the company OfficeBIM, who participated in the questionnaire. The six-point Likert scale has been used as a measurement for some themes of the questionnaire, where 1 is ranked lowest and 6 highest.

4.1.1 Background of Questionnaire Respondents

This section briefly describes the 11 respondents' background in terms of age and gender distribution, educational level, their current roles in the company, when they worked latest in a BIM project, the number of participated BIM projects by the respondents and how much time an average employee at OfficeBIM dedicates for BIM tasks.

The vast majority of the respondents are male (82 %) as *Table 1* illustrates. The respondents' age range is up to 60 years old and more than half of the respondents (55 %) are younger than 29 years old, who had an education overwhelmingly from regular university.

Table 1: This table illustrates the background of the employees. (Suleymanshar, Saleh, 2018).

Employees (nr: 11)	**Proportion**
Gender:	
- Male	9 (82 %)
- Female	2 (18 %)
Age:	
- Up to 29	6 (55 %)
- 30 – 44	3 (27 %)
- 45 – 59	2 (18 %)
- 60 and above	0 (0 %)
Educational level:	
- Primary School	0 (0 %)
- High School	0 (0 %)
- Vocational University	2 (18 %)
- University	8 (73 %)
- Other	1 (9 %)

Furthermore, the majority of the respondents had the role of BIM and 3D Designer (BIM modeler) as *Table 2* shows.

Table 2: Current role in the company. (Suleymanshar, Saleh, 2018).

Employees	Company Roles
Employee A	BIM and 3D Designer
Employee B	Supervisor BIM and 3D
Employee C	BIM and 3D Designer
Employee D	IT-Responsible
Employee E	BIM-Coordinator
Employee F	Technique Responsible/Project Manager
Employee G	BIM and 3D Designer
Employee H	BIM and 3D Designer (intern)
Employee I	BIM and 3D Designer
Employee J	Business Area Responsible 3D/BIM
Employee K	Administrator Tele-System

According to the data presented in *Table 3*, the majority of respondents have worked in multiple BIM projects.

Table 3: Respondents' participation proportion in BIM projects. (Suleymanshar, Saleh, 2018).

Number of BIM projects participated	Proportion
Never worked in a BIM project	1 (9 %)
1 project	2 (18 %)
2 - 3 projects	2 (18 %)
4 projects or more	6 (55 %)

Furthermore, the majority of respondents are currently active in BIM projects as *Table 4* shows.

Table 4: The 11 employee's latest work within BIM projects. (Suleymanshar, Saleh, 2018).

Work latest in a BIM project	Proportion
Working in a BIM project currently	8 (73 %)
During the last year	3 (27 %)
1 - 2 years ago	0 (0 %)
More than 3 years ago	0 (0 %)

Further, *Table 5* explicates the respondents' amount of work time spending on BIM tasks. According to *Table 5*, the respondents spend in average 64 % of their work time on BIM-related tasks. However, the standard deviation for this amount of time is high, ranking 33 %.

Table 5: Amount of work time in % dedicated to BIM tasks. (Suleymanshar, Saleh, 2018).

Employees	Mean Value	Standard Deviation
11	64%	33,19

4.1.2 Development of BIM Roles

This segment displays information regarding BIM roles at the OfficeBIM company.

Table 6 describes whether the participative employees believe that the company has explicitly defined its BIM roles in relation to expected responsibilities and task undertaking. The table displays an average of 4,45 out of 6 points on the six-point Likert scale, which shows that the company has almost clearly defined the BIM roles. Point 5 stood for high extent, whereas 4 was slightly high.

Table 6: Whether OfficeBIM has clearly defined BIM roles and responsibilities in projects. (Suleymanshar, Saleh, 2018).

Employees	Mean Value	Standard Deviation
11	4,45	1,86

Moreover, *Table 7* explicates the respondents' view about the future development of BIM roles, in which almost everyone believes that BIM roles will certainly develop in the future, with the majority believing it will be more important.

Table 7: Considered development of BIM roles in the future. (Suleymanshar, Saleh, 2018).

Future Development	Proportion
Will disappear	0 (0 %)
Be less important	1 (9 %)
Keep the same importance	0 (0 %)
Be more important	6 (55 %)
Be much more important	4 (36 %)

Table 8 describes the barriers in front of the development of BIM roles, in which respondents denote the *lack of financial resources* as the main barrier and *unclear career development* as the minor barrier.

Table 8: The extent to which the following barriers oppose BIM roles' development. (Suleymanshar, Saleh, 2018).

Barriers	**Mean Value**	**Standard Deviation**
Lack of financial resources	4,55	1,29
Lack of collaboration between projects	4,27	1,35
Unclear distribution of responsibilities	4,27	1,35
Lack of experience by BIM actors	4,18	1,40
Lack of knowledge by other	4,18	1,47
Lack of time	4,00	1,61
Opposing organizational culture employees about BIM	4,00	1,73
Lack of educational opportunities	3,91	1,14
Lack of organizational structure	3,91	1,38
Insufficient management support	3,90	1,22
Lack of experience feedback	3,90	1,22
Lack of supportive strategic decisions	3,55	1,21
Unclear career development	3,09	1,45

Finally, in *Table 9* the respondents themselves wrote down their anticipations about the future development of BIM roles in OfficeBIM. Once again, the majority expresses a positive future view about the BIM roles in the company.

Table 9: Predictions of the future development of BIM roles in OfficeBIM. (Suleymanshar, Saleh, 2018).

Employee A	Will be important.
Employee B	The current development goes forward. Hopefully it will subside in line with

	that the roles get defined.
Employee C	Greater and broader knowledge per person within BIM. It leads to better and faster communication ways and better co-operation. Everybody understands each other's problem conditions which paves a way for common understanding. Tougher focus on goals.
Employee D	It will develop the more time goes, when there is a will but we are fully busy on the (working) days. More BIM-responsible ones will most likely be appointed in the future.
Employee E	Only when there are possibilities to innovation.
Employee F	BIM-responsible ones are needed in all projects minor as major and should be included within a board/leading group.
Employee G	Good prerequisites, but it needs likely to be illustrated more clearly for those who are BIM-Coordinators, what type of tasks they have.
Employee H	Unclear
Employee I	It looks really good.
Employee J	BIM within OfficeBIM continues to grow with for example the introduction of the VR-Technique and VR-Room. It will require greater engagement from the BIM side in coming and current projects. It can even require that project managers would need to have competences within BIM to secure the success in management, planning and implementation of projects.

4.1.3 Requirements from a BIM Actor

This section demonstrates personal information regarding BIM actors at the OfficeBIM company, such as preferred personal characteristics, skills and education.

Table 10 exhibits data about the personal characteristics of a BIM actor according to respondents, in which *having good cooperative skills* and being *structured* are ranked highest and having *leadership qualities* and being *diplomatic* are ranked lowest.

Table 10: Extent to which a BIM actor needs to have the following characteristics. (Suleymanshar, Saleh, 2018).

Characteristics	**Mean Value**	**Standard Deviation**
Have good cooperative skills	5,27	0,65
Structured	5,27	1,01
Flexible	4,82	0,98
Have good communication skills	4,82	0,98
Strategic	4,82	0,98

Have good problem solving skills	4,82	0,98
Demonstrate commitment	4,82	1,17
Change-oriented	4,73	1.10
Have good ability to handle criticism	4,64	0,92
Able to make demands	4,64	1,36
Curious	4,55	1,37
Driving	4,36	1,12
Have good patience	4,36	1,12
Pedagogical	4,09	0,83
Outgoing	3,64	1,12
Have a critical approach	3,64	1,36
Diplomatic	3,36	0,67
Have leadership qualities	3,36	1,21

Also, according to the respondents, the most paramount skills for a BIM actor is to have *experience from design* and *3D-modelling*. Also, the least important educational factor is to be have an *education in IT and computer engineering*. These results are demonstrated in *Table 11*.

Table 11: Considered type of experience and/or education a BIM actor shall have. (Suleymanshar, Saleh, 2018).

Experience/education	**Mean Value**	**Standard Deviation**
Experience from design	4,91	1,30
Experience from 3D-modelling	4,91	1,64
Understanding of professional groups' needs	4,36	1,50
Understanding of the construction process	4,36	1,57
3D-modelling education	4,36	1,63
Experience from project	3,73	1,62

management		
Worked with computer technology/IT	3,55	1,51
Building engineer education	3,18	1,66
Experience from production	3,00	1,67
Computer Engineering/IT education	2,82	1,17

Furthermore, *Table 12* displays that the respondents believe that a BIM actor is highly influential for the success of a BIM project. The respondents denote an average of 5,18 out of the six-point scale, which means that they consider a BIM actor to be of high importance for project success. Point 5 indicated high importance, whereas point 6 indicated very high importance. Thus, the average 5,18 was slightly above high importance.

Table 12: Considered importance a BIM actor has for projects' success. (Suleymanshar, Saleh, 2018).

Employees	**Mean Value**	**Standard Deviation**
11	5,18	0,75

4.1.4 Tasks and Involvement of a BIM Actor

This section, explicates what tasks a BIM actor should have and in which project phase(s) the actor should be involved.

Table 13 demonstrates that the respondents expectedly believe that the most important project phase is the *design* in which a BIM actor's involvement is necessitated. Whereas, the least important phase is the *demolition* which does not require the BIM actor's implication.

Table 13: Considered extent of involvement of BIM actors in suggested phases of the building process. (Suleymanshar, Saleh, 2018).

Phases	**Mean Value**	**Standard Deviation**
Design	5,27	1,35

System management	4,27	1,68
Handover	4,27	2,00
Tender/Calculation	3,82	1,25
Sales to external customers	3,73	1,42
Renovation	3,45	1,57
Management	3,36	1,69
Production	3,27	1,68
Application phase	3,20	1,55
Demolition	2,55	1,37

Regarding tasks of a BIM actor, the respondents in *Table 14* deem *make quality control of the model* as the most essential task, followed by *make cost estimates* as the least essential.

Table 14: Correlation between the following tasks and tasks one considers a BIM actor shall have in projects. (Suleymanshar, Saleh, 2018).

Tasks	**Mean Value**	**Standard Deviation**
Make quality control of the model	5,45	0,52
Establish and maintain coordination models	5,27	0,65
Create virtual models of completed buildings	5,27	0,79
Manage model-based information	5,00	1,00
Make collision control	4,90	1,64
Quality assure delivery to customers	4,82	0,98
Support cooperation through visualization of the model	4,82	1,08
Maintain BIM requirements	4,82	1,17
Coordinate delivery to customers	4,73	1,10

Prepare the model for the management phase	4,73	1,42
Quantity decrement	4,55	1,13
Manage goals	4,36	1,12
Create a foundation for project follow-up	4,36	1,36
Compile BIM experiences from the project	4,36	1,43
Establish BIM action plans	4,27	1,85
Facilitate communication in projects	4,18	1,25
Set up BIM requirements	4,18	1,72
Simulate scheduling	4,00	1,41
Create information channels between various involved actors	3,91	1,64
Determine metrics	3,82	1,33
Manage metrics	3,82	1,17
Set goals	3,72	1,42
Simulate workplace disposition	3,64	1,75
Coordinate building designers (consultants)	3,36	1,86
Coordinate contractors	3,20	1,62
Create a basis for risk analysis	3,11	1,54
Simulate building logistics at workplace	3,09	1,70
Participate in consultancy procurement	2,91	1,38
Make cost estimates	2,45	1,57

4.1.5 BIM Importance for Companies & Projects

This section demonstrates how BIM assists the company and the projects.

According to *Table 15*, the respondents believe that BIM is assisting the company by providing it with *competitive advantages* and implying more *efficient work processes*. Whereas, they do not consider BIM influencing the *bureaucracy* of the company.

Table 15: Perception regarding BIM for OfficeBIM. (Suleymanshar, Saleh, 2018).

Effects	**Mean Value**	**Standard Deviation**
Gives the company competitive advantages	5,55	0,52
Entails more efficient work processes	5,55	0,82
Increases the company's profitability	5,00	1,18
Contributes to a positive corporate image	5,00	1,26
Is a supportive feature of the company's construction projects and management	5,00	1,49
Affecting recruitment positively	4,91	0,94
Helps to retain employees	4,91	1,04
Permeates the entire business	4,91	1,04
Increases cooperation between different units within the company	4,82	0,87
The use within the company has clear goals	4,73	1,27
Opens up new markets	4,64	1,03
Provides satisfied staff	4,27	1,27
Involves more work in the projects	4,18	1,25
Provides increased bureaucracy	3,00	1,49

Table 16 describes that BIM mainly improves *quality* and *reduces issues on site*, according to the respondents. Whereas, they believe BIM does not influence *procurement* and *scheduling*.

Table 16: Considered extent that BIM improves the following in projects. (Suleymanshar, Saleh, 2018).

Improvement areas	**Mean Value**	**Standard Deviation**
Decreases number of issues that need to be solved on site	5,45	0,82
Quality	5,45	0,82
Productivity	5,36	0,67
Shorter construction time	5,00	1,05
Design	5,00	1,18
Cost savings	5,00	1,41
Risk management	4,91	1,51
Information management	4,64	1,50
The opportunity to test more alternatives	4,60	1,07
Environment and/or energy analysis	4,60	1,43
Communication	4,55	1,13
Construction logistics	4,45	1,21
Cost analysis	4,45	1,29
Workplace disposition	4,40	1,65
Workload	4,27	1,35
Follow-up	4,27	1,68
Project management	4,18	1,40
Experience feedback	4,18	1,66
Staff	3,91	1,22
Scheduling	3,55	1,44
Procurement	3,55	1,81

4.2 Interview Results

The following four interviews were made as a follow-up of the questionnaire results, for which specifically four participants were selected after a hierarchical structure of BIM roles and roles in the company. Thereby, a BIM Manager, BIM Coordinator and a BIM Modeler were selected along with the CEO of the company's Gothenburg office.

4.2.1 Employee 1: BIM Manager

The reason why there are so diverse opinions regarding how well BIM role responsibilities are defined, is because it depends on which role the employee has at the company. There are BIM designers (modelers) who are working with design, and project managers who do not necessarily work with BIM. So, the project managers and designers have different views. Then, there is a BIM coordinator, looking on everything. Therefore, it depends on the role of the employee. OfficeBIM is in a state to create a BIM and CAD manual, which will strictly define the roles and their responsibilities. The manual is developed since the employees who are working with BIM are involved in several different projects, with different roles and responsibilities. Moreover, OfficeBIM works with large companies, and therefore needs to follow the recommendations of BIM given by the counterpart companies and also their customers. Thus, OfficeBIM develops this manual of BIM role responsibilities and tasks, which is adapted after the companion companies' and customers' BIM requirements. The manual shows the requirements, but then exactly how they are followed is unclear. For that reason, the manual is flexible. Moreover, different BIM actors can undertake different roles in different projects. Therefore, the roles are flexible and follow projects as well. E.g. the BIM manager can undertake the responsibilities of a BIM coordinator inside a certain project. Thus, the employees have certain official roles at the company but can contextually undertake other roles as well.

BIM is useful for the whole project life cycle (the entire lifespan, including operation and maintenance). BIM should be involved throughout the building life cycle. BIM can cover everything. The reason why employees in the company think that BIM is more useful for the design and delivery phases of the project is because the employees are not working directly with the production, the main contractors do. OfficeBIM is a consultant company, but in some bigger types of projects it is only a sub-consultant. In smaller projects, OfficeBIM works directly with the main contractor/consultant.

A BIM model at OfficeBIM can be shared with the clients or partner companies if they wish to see it. The BIM models are also sent to others to check it and see if they fulfil the requirements. Instructions are given to OfficeBIM on how they shall prepare their models.

Lack of economic resources is not a barrier for development of BIM roles. When OfficeBIM started, there were only two people working with BIM. But as the company grew and projects diversified, new BIM roles were developed so that not only two people did everything. The barrier to developing new BIM roles is the "*change*". So, there is a tendency for some people to not change as things go well. So, with changes towards growth, new BIM roles get developed. It also takes time to specifically define the BIM role responsibilities, as only now, after all these years, the company creates a manual to separate the responsibilities. Therefore, time and growth-related change in the company can be barriers to the development of new BIM roles.

The BIM roles in the company can be undertaken by various employees depending on the projects. E.g. there are people who can manage the actions of a BIM coordinator, so they undertake the role during different projects. One employee works as a BIM specialist, but (s)he also works as a BIM coordinator for installations in a certain project. BIM can be viewed both as a product and a process. So, there are different answers depending on the understanding of what BIM is. BIM means something for each of the employees. History paves the way for the future, the company had two BIM roles in the beginning, but now several different roles exist at OfficeBIM. Hence, there is a pattern, the more the company grows, the more BIM roles are needed to be developed.

With the help of Virtual Reality (VR) equipment, there is a possibility to see things directly without drawings. When you use this equipment, you see everything with options, it is a virtual world. VR is taking the BIM coordination to the next level. This technique facilitates problem detection and process follow-up in BIM. So, it is a part of innovation for BIM and also helps to reduce costs by detecting defects, instead of looking at drawings on paper. Also, it is easy to look at the models for people such as clients who do not know how to read, for instance, electrical drawings.

The three most important characteristics a BIM actor should have are: experience in working with computers (being good at using software), willing to co-operate to find mutual beneficial solutions and having competence in quality-assurance, to be able to assure that the product is following the quality requirements demanded by the client.

OfficeBIM is working with technique installations, which do not necessarily need to be used in buildings only. A BIM actor can have a background within mechanical or electrical engineering, rather than a building engineer who knows a little bit of everything. An electrical engineer has specific knowledge about electrics and a mechanical engineer knows about Heating Ventilations and Air Conditioning systems (HVAC). So being a building engineer is not that important, as mechanical and electrical engineers are also required by the company. Experience in 3D-modelling is important on the other hand, which is embedded in all these engineering fields. That is why the questionnaire respondents have denoted that being educated as a building

engineer specifically is not important. However, the person should have an engineering education or a relevant education in general. Having the degree is beneficial, because it opens the road to go further in one's career. Sometimes, for project performance clients require actors with education (relevant degree), especially in large projects where real employee qualification is required. In this context we need employees who have the relevant education.

4.2.2 Employee 2: BIM Modeler

Everybody in the company does not work with BIM. There might be ten people who work with BIM. This can be a reason why employees have diverse responses regarding whether the BIM roles are clearly defined or not, in relation to responsibilities and tasks. Employee 2 has gotten a role manual from the company, in which it is stated what responsibilities and tasks she has as a 3D-design engineer. Thus, the responsibilities are explicit for her.

BIM should be widely used, even for management and maintenance of the project. If there is a problem, one shall be able to check the model and find it. However, the company is more HVAC-oriented which needs cautious and detailed work to be able to see that everything is in the right place. Thus, BIM is profoundly important, especially in the design phase.

OfficeBIM is frequently cooperating with other actors who belong to other companies such as the architect from a certain company, whose models are needed by the company for putting in their HVAC components and basing their work on them. Occasionally, OfficeBIM works alone as well. Currently, the company is working with large projects where considerable mutual co-operation is ongoing.

The company is undergoing development itself. The larger it gets with time, the more BIM actors and roles are needed. Thus, the quantity of BIM roles also complies with the scale and size of projects. As long as the company grows, novel BIM actors are required. The growth of the company is in compliance with the development of BIM roles. However, if growth stopped then a barrier to developing new BIM roles will certainly emerge. By looking at the company history, a growth pattern is perceived in relation to its size and BIM actor quantity. Thus, based on that, it can anticipated that more BIM workers will be needed in the future.

The company has further introduced a so called VR-Technique located in a specialized room of its office. The technique is used for creating a copy of a BIM model. It resembles a 3D virtual world, where you can go in and move inside the model. Then you are able to detect errors, know where and how items shall be located and adjust them. Thereby, a great perception is achieved about the created model, thanks to this technique which facilitates the work. One is taking on specialized 3D-glasses and enters the model likewise a virtual world. If there were problems detected,

then it is available to click on a button and take pictures of them. In this way, a clear picture is acquired about everything. So, it is a very smooth and fast working approach.

When it comes to personal characteristics it is important for the BIM role of a designer to be self-propelled, quite fast and structured. However, the personal characteristics vary depending on the type of the BIM role. For instance, a BIM coordinator must be able to maintain a group of BIM actors together, that everybody creates models in a similar way and everybody does everything similarly thus being able to create coherence within the design team. Thus, the coordinator also needs to be highly structured and have a single work approach. Furthermore, the BIM coordinator must be considerably stressed-resistant. In addition, generally one needs to be co-operative, to make sure that everything is consistent and that the team utilizes each other's skills. Every individual is competent at something but lacks skills in other things. Then, one is dependent on other co-workers' assistance. Therefore, co-operation can be viewed as paramount for their work.

Personally speaking, the building engineer education is important for BIM. However, in the company the employees have diverse educational backgrounds. Thus, they might believe that being educated in 3D-modelling is more important compared to being a building engineer, which is a skill BIM actors have in common despite their diverse educational backgrounds. To be able to work with BIM, one must have knowledge of 3D-modeling, not necessarily be a building engineer. However, education is important for employment in the company. Currently there are four employees who come directly from university, while a few others have been employed based on many years of work experience. Nevertheless, based on speculation if one solely had knowledge in BIM and 3D-modeling (s)he would be employed. Perhaps the company had advised the person to go and study a relevant program such as a two-year one from a vocational university, but experience overweighs education more commonly.

4.2.3 Employee 3: BIM Coordinator

A BIM actor shall have broad knowledge, not only about his or her role but generally about BIM. However, BIM itself is also vastly broad so that a BIM actor frequently does not know all the details about it. Therefore, there can be overlaps about various BIM actors' responsibilities and task definitions. With regard to this context, knowing what responsibilities you have as a BIM actor is project-oriented as well - which role the BIM actor undertakes in a particular project. A BIM actor can be assigned the role of a BIM coordinator in a project, but also undertake other BIM roles otherwise. Therefore, broad knowledge and competency are required. One must be ready and comprehend BIM in its entirety. BIM touches many areas such as bearing capacity, air flow, electricity etc. One cannot know all these functions. Thus, tasks are allocated to BIM actors after their fundamental educations and knowledge. Everybody is doing

his or her part and is dependent on the colleagues. However, as a BIM coordinator one has the role of a controller, to overlook that everybody has done their job right. With regard to that, BIM is broad, it is not an easy task. Occasionally there can be problems for Employee 3, perhaps that is also due to being rather new both in the company and in BIM Coordination or due to the educational background causing limitation. Generally, it is about knowing considerably about BIM and learning as much as one can. E.g. Employee 3 has lesser skills about documentation in BIM for which he seeks assistance from other co-workers. So, the BIM roles and responsibilities in reality are contextual and interdependent. However, in the company there is a manual giving a basic definition of the tasks and responsibilities of every BIM role. That is merely for the new employees to get started and have a general overview about what to deliver.

The information from BIM that is delivered should be covering the entire life cycle of the project and exceed the design and delivery phases to operation and maintenance phases, even reaching the final demolition phase. That is in order to be able to understand what materials the project is comprised of, regarding environmental impact during the demolition and recycling of the materials. By having the excessive information of the project components, we can be able to know how to demolish the building project optimally, in a more environment-friendly way and recycle the materials. In this way, a lot can be saved and BIM can imply sustainability. Therefore, BIM shall not be viewed as a mere design tool but more than that and shall be utilized in the best way and in as many ways as possible. It is quite interesting to use BIM for sustainability and not solely for building faster and easier. To think critically and inquire how BIM can be used for more, to the fullest. Thus, BIM is for saving money, time and resources and shall be used for all the project phases equally.

The BIM models are normally formed, adapted and delivered following the requirements that are given in specific projects by the client or other parties such as contractors. E.g. while working with a contractor, the BIM models must be in compliance with the instructions of the contractor and the final client requirements and be certified accordingly. Thereby, there is considerable co-operation in-between.

As for barriers, the major barrier in front of the development of a BIM actor is time limitation, speaking from a personal point of view. The BIM actor is given a certain timespan within the project to deliver his or her tasks. The time that is left is normally used for follow-ups and control by the BIM actor. Therefore, the BIM actor normally has no time to try to develop and learn novelty or to explore to find new solutions or learn new BIM tools. One is frequently faced with time constraints.

Regarding the future development of new BIM roles, it depends on future automatization and how much the roles are getting automated. The roles are getting more complex, so that employees need a considerable level of competency and education. As it is noticed currently, different items are developed and are more automated day by day. The BIM actors will comply with this development as well. Thanks to automatization, various activities will be easier. E.g. by doing a thing once,

numerous copies will follow automatically. The world is navigated towards automatization, facilitation and time saving. This will cover all aspects of life and the construction industry will not be outside this trend as well. It is an adaptation question and a matter of time. Thus, roles and tasks will decline and get substituted by automatization. This enables a BIM actor to more easily undertake the roles of various BIM actors and deliver their tasks with haste and ease. Thereby, based on such speculations BIM roles will decrease in the future. However, the education might be more complicated and demanding for those who are becoming BIM actors. They will have to acquire more skills in IT and automatization. Today, the automatization is growing rapidly in all industries, not only in construction. We can take a look at the car industry, when soon there are self-driving cars. So that people in the future do not have to drive cars themselves. A similar pattern is accounted for in construction as well. Building and construction will be easier, perhaps people will build their own houses themselves and will not need everything that is needed today. With regard to this speculated facilitation, perhaps both the number of BIM roles and the difficulty of the work will decrease in the future. E.g. Autodesk has already developed software that calculates different mathematical problems automatically, in comparison to quite recent years when engineers had to do such themselves. The BIM actors similarly will follow this trend, an actor will undertake various roles. Then, a designer for example will not only be responsible for design but also for management.

The company has introduced the VR-Technique which aids in faster communication and virtual meetings with other project parties from their own offices without the need for direct meetings. It also helps in finding errors faster as you are inside the digital model virtually. Now, one has a sense that (s)he is there by the actual project in real life, even though (s)he is looking at it in a virtual world with the help of glasses taken on inside the VR-Room in the company office. Also, one is able to contact relevant project actors from different counterpart companies via the VR-Technique. The models are no longer sent physically to the other project actors to wait for their responses which can take a considerable amount of time. Now the company is able to bring out live communications and meetings virtually with relevant parties from the same location and quickly get their feedback just like face-to-face meetings. Hence, much time is saved. Once you are inside the model virtually, you have an avatar and other actors have it as well. You meet each other as avatars inside the digital project model in a virtual world. The technique is rather new for the company which has just introduced it. Therefore, thorough tests are currently being conducted by the company to try it out.

From a personal point of view Employee 3 believes that it is vastly important for a BIM Coordinator to be tolerant. That is because the team members under his or her responsibility are carrying out various tasks. "*Everybody is doing something*" according to Employee 3. They draw and process information in different ways. Thus, for the role of a BIM coordinator, considerable socialization and tolerance are necessary. E.g. if one has drawn wrong in one aspect which leads to the entire work being chaotic as the models need to be coherent, then you as the coordinator must

maintain positivity and sympathize with the team member who may already be feeling embarrassed by the mistake, in front of the others. That is instead of pouring more fuel onto the fire. To handle human factors is very important for the role of the coordinator, as a lot of socialization is implicated. Also, that is why the colleagues overwhelmingly believe that co-operation is a crucial personal characteristic for a BIM actor to have, as everybody is dependent on each other. If one does something wrong, it will affect the entire work. As previously mentioned, BIM is highly broad and it is not possible for everyone to know everything so that everybody is utilizing each other's skills. Secondary to being tolerant, it is also highly useful for a BIM actor to be knowledgeable in BIM. However, with time more knowledge is acquired.

The relevant education of Employee 3 is CAD/BIM designer for his career. Thus, anyone educated in 3D-modeling can work with BIM. (S)he does not necessarily need to be a building engineer. That might be a reason to why most of the company employees did not see having an education as a building engineer as important for being a BIM actor. However, Employee 3 does not really agree with whether having experience in 3D-modelling precedes the importance of having relevant education. He believes that both are equally important. One should have a theoretical and relevant education for his or her career to build upon. As for employment being based more on education or experience in the company, Employee 3 believes if one had experience without necessarily having an engineering education from university (s)he has the chance of being employed. He believes it is about one's ability and usefulness for the company. E.g. he himself was hired through a vocational university education which is considered lower than a normal university education.

4.2.4 Employee 4: CEO

The simple reason of why the employees at OfficeBIM believe that BIM role responsibilities are unclear is because of a high number of new employees at the company. The others, who know what roles and responsibilities they have, have more experience. Furthermore, everyone is not from the same background which is another reason for confusion about the BIM role responsibilities. OfficeBIM has a role description for each and every role.

BIM is equally important for all the different building phases. OfficeBIM does not work that much with the production phase. However, BIM is certainly important for the entire project life cycle. However, the responsibilities differ depending on which project OfficeBIM is involved in. OfficeBIM almost always work with others, so the partners have a full view of everything.

OfficeBIM needs someone who wants to learn in the company. A willingness to develop is one of the main barriers, since there is no lack of financial resources. There should be people who take responsibility for the development. OfficeBIM can buy

expensive software to develop BIM, but there should be someone who takes responsibility for the development.

There will be new BIM roles in the future. OfficeBIM has already introduced a new role called "*BIM supervisor*". OfficeBIM also tries to choose titles that match the English role titles. In addition, as the company grows, more BIM roles will be needed. VR technology should be a design tool, improving OfficeBIM's work. For instance, it can detect errors in real time, which reduces costs. Soon, it will be possible to sit anywhere in the world and be able to see a design.

The most important characteristics for someone who is working with BIM are to be engaged (highly important), curious and careful and co-operative. OfficeBIM has employees which are working with different tasks, and these tasks create a whole. Therefore, it is necessary to co-operate and coordinate all of the time. Therefore, cooperation is essential.

There are not many employees at OfficeBIM who have studied building engineering. Higher education is important in order to work at OfficeBIM. OfficeBIM will not hire people without education even if they have extensive experience. The education level is very important. Employees with a university degree are problem solvers and can be a BIM coordinator after only a couple of years after they start working. Finally, in order to be successful in 3D-BIM, everyone must think about 3D-BIM. The leaders within the company have the responsibility to make everyone think the same way. Everyone has to think 3D throughout all of the processes.

4.3 Observation

Over the course of ten Mondays, when the company usually had their joint meetings starting at 8:30 am until 9:00 am, one or both of the research authors were present for observation. Also, on these same days the thesis paper was written at the company office. In this way, the research authors had the chance to socialize with the employees, e.g. through lunch meetings and table tennis matches, and observe the company more closely. In addition, there was a number of newly recruited junior employees in the company which made the company appear to be more dominated by younger employees.

The areas of observation touched anything relevant to the BIM company such as the organizational culture, organizational structure, diversity among employees, way of working, work environment etc. The organization has an open culture and is flat combined with a hierarchical structure. Based on work experience, junior employees turn to senior ones occasionally for assistance. Also, for having a meeting with the CEO of the company, appointments must be booked in advance. There is also a diversity among the employees in relation to cultural, educational, gender and experiential backgrounds. Moreover, the employees are sitting closely to each other

not based in isolated rooms. They sit in an open space, working closely to each other and collaborating. In addition, the company also provides social opportunities for its employees, such as dedicating a certain area of the office for playing table tennis during lunch time leftover. Thus, it is an open work environment, surrounded by large windows, high technology and novelty which paves the way for a socially and psychologically thriving work environment.

Moreover, during the observation it was noticeable as well that the number of female employees was slightly fewer than the number of the male ones. It is further noteworthy to highlight that most of the company employees are BIM actors and work with BIM at the company office. Thereby, this was an endeavor to observe their work life more closely. There was a number of newly recruited junior employees in the company. Also, the company informed the study authors that this is the first time that students conducted a thesis study at their company (Gothenburg office).

4.4 OfficeBIM Role Manual

The manual of OfficeBIM is still under construction by the company. Hence, the following role definitions are a part of the still-developing company manual, which covers only descriptions for the two finished roles BIM manager and BIM modeler. The manual is in Swedish and was translated into English for this study.

BIM Manager

- Take responsibility for joint review internally and among disciplines.
- Represent installations externally at BIM-coordination work with customers and partners.
- Take responsibility for BIM-coordination in Navisworks and Solibri.
- Take responsibility for review planning, packaging and delivery of models and drawings.
- Establish model and CAD manuals.

BIM Modeler

- Obtain necessary information for the design work.
- Establish a basis/models in accordance with the customer requirements and prerequisites.
- Establishment of 3D-models and 3D-modelling work with the help of Revit/CAD/Civil 3D or project-related software.
- Build up a database with information of components which is related to the facility.
- Communicate and contribute at co-reviews internally and among disciplines.
- BIM-coordination in Navisworks and Solibri.
- Establish drawings and schedules in AutoCAD.
- Create and establish variety lists and tag lists.

- Drawings and model documentation
- Prepare a basis to supervisors, senior supervisors and the project management.
- Prepare a basis, pictures and texts at investigations, technical documents and ongoing project administration.
- Continually report to senior and experienced supervisors about work progression.

5 Discussion

This chapter comprises a comparative analysis binding together the theory and empirical findings of interviews, observations and questionnaire results. In this chapter a detailed comparison with the authors own reflections is conducted.

5.1 Background of Questionnaire Respondents

The majority of the participants were junior employees under 29 years of age, which is in line with the weekly observation taken at the company office in Gothenburg. They also overwhelmingly had the role of BIM modeler, which is obvious as according to the interviewees new employees begin as modelers and later obtain higher roles. Thereby, the company is young and male dominated, taking the number of its employees into account. This demonstrates that OfficeBIM strives for enabling opportunities for younger graduates to be a part of it and develop. In addition, the majority of the participants had degrees issued by regular universities not vocational ones, which are considered to be higher in value. *Table 1* provides statistical data about the mentioned information, followed by *Table 2* providing information about the participants' current roles in the company.

Table 3 demonstrates the questionnaire participants' involvement in a number of BIM projects. Here, only one participant has never worked in a BIM project which means (s)he is not a BIM actor and has given responses based on own opinions in the questionnaire. Moreover, the majority of these BIM actors have worked in four or more BIM projects. An even higher majority of 73 % of the BIM actors are working in a BIM project currently, as shown in *Table 4*. These further demonstrate a strong and reliable information source for the study results and heightens the study veracity and validity.

5.2 Development of BIM Roles

According to Davies, Wilkinson and McMeel (2017) the primary current BIM roles are BIM manager, BIM coordinator and BIM modeler. However, Uhm, Lee and Jeon (2017) state that the role titles are company-oriented and might differ at different companies. According to the OfficeBIM's own role manual and the interviews, the studied company has the same current BIM roles but a few role titles differ from the ones the literature is mentioning, as displayed in *Table 17*. A few are the titles of the roles "*Business Area Responsible in 3D/BIM*", which is correspondent with the role title BIM manager and "*BIM and 3D Designer*", which equals the BIM modeler. The following table provides a translation between the role titles at OfficeBIM and the more recognized role titles of the theoretical research:

Table 17 Translation between BIM role titles of OfficeBIM and the literature. (Suleymanshar, Saleh, 2018).

BIM role titles of OfficeBIM	BIM role titles of theoretical research
Business Area Responsible in 3D/BIM	BIM Manager
BIM Coordinator	BIM Coordinator (Model Manager)
BIM and 3D Designer	BIM Modeler (BIM Technician)
Supervisor BIM/3D	New role

Table 2 shows clearly that most of the company employees work as a BIM modeler, followed by a BIM coordinator and a BIM manager. The role as a BIM modeler is often a junior role according to the study observation and the interviews. This means that there is a clear hierarchical pattern at OfficeBIM. The observation also showed that the BIM modelers frequently direct questions to the BIM coordinator or the BIM manager, which also practically shows a clear hierarchical pattern at the company. Thereby, the hierarchical role pattern is not only on the company role manual, but also practically exists in reality. Moreover, there are new roles emerging in the company such as the role of "*BIM supervisor*", which is hinted at by Employee 4 (CEO) in the interview. This is an indication of the company's growth and progress, which both Employee 1 (BIM Manager) and Employee 2 (BIM Modeler) connect the company's growth with development of new BIM roles. In addition, Employee 4 (CEO) also admits that they strive for re-naming and adapting the BIM role titles after the internationally recognized titles. This is an innovational effort to connect the company with the outside world and develop it accordingly.

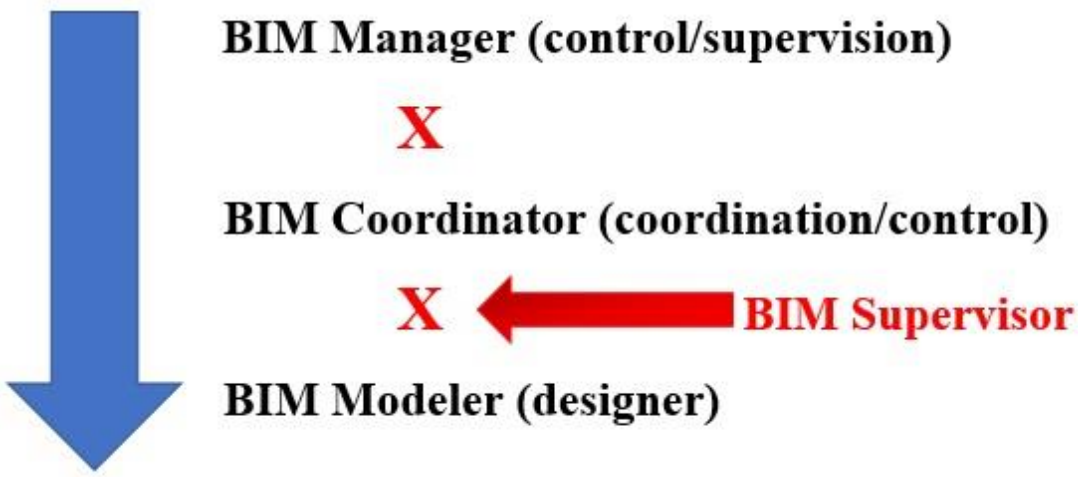

Figure 2 Emerging (developing) new BIM roles at OfficeBIM (Suleymanshar, Saleh, 2018).

A key interesting point at OfficeBIM is that, unlike what the literature suggests, efficiency and higher skills are by those at the top of the BIM role hierarchy. E.g. Employee 1 (BIM Manager) describes his work journey at the company when he has begun as a BIM modeler, then has become a BIM coordinator and finally a manager. This is unlike what Joseph (2011) suggests that immense technical BIM knowledge is not necessary for the BIM manager. On the contrary at OfficeBIM, the BIM manager

has immense expertise in BIM that other subordinate roles such as the modelers turn to him for assistance. Thus, when it comes to proficiency, OfficeBIM follows a top-down structure. Whereas, the literature used for this study denotes a bottom-up proficiency structure.

Furthermore, according to Singapore BIM Guide (Building and Construction Authority-BCA, 2013) and Joseph (2011) overlaps of responsibilities could occur due to the size of the organization and sometimes a few roles can be merged. This is also true for the OfficeBIM company, which has begun as a smaller company, where initially only two BIM actors have undertaken all the BIM roles and work. This was stated by Employee 1 (BIM Manager) and also verified by Employee 3 (BIM Coordinator). However, it can be questioned if the task overlaps are negative, from the company or project point of view. The overlaps can have mutual benefits for the company and projects, as they imply better productivity, time saving and co-operation among the project team members, as they back up each other. However, the situation has negative side effects as well, such as confusion, argumentation, disorder and more.

Moreover, the responsibilities of the BIM roles are also contextual, complying with the specific company and the country where it is located. Different companies define different responsibilities of the BIM roles, which is highlighted by Uhm, Lee and Jeon (2017) and verified by OfficeBIM's role manual in reality. Davies, Wilkinson, McMeel (2017) claim that in reality the organization's BIM manager frequently is the same as its BIM coordinator. This is highly in compliance with and verified by OfficeBIM. When observing the company's role manual precisely, these BIM researchers' claim is noticeable. There are considerable overlaps of the responsibilities, especially in-between the BIM manager and the BIM coordinator's tasks. However, as it is visible after numerous years of work, just currently the OfficeBIM company has begun to create a BIM role manual to define the roles and their responsibilities for its current and future employees. This asserts that previously there has been a disarray regarding responsibilities and task allocations for OfficeBIM employees.

In addition, as the interviews demonstrate, the BIM roles are also project-compliant. Different BIM actors change roles in different projects, despite having certain official roles at the company. This indicates that there are official BIM roles and project-based BIM roles. This further complicates the role responsibilities by the BIM actors. In accordance with *Table 6,* the company employees mainly believe that the BIM roles are clearly defined. However, not everybody agrees on that. For instance, Employee 3 (BIM Coordinator) believes that every BIM actor knows certain skills and BIM is highly broad. Therefore, they are in need of each other's assistance, as more often one does not know all BIM applications. Thus, the role manual defining tasks of each BIM role is a more theoretical framework so that employees, especially

the newly recruited ones, will have a clue of what is required from them at the company.

Furthermore, according to the interviews, questionnaire and observations, everybody in the company does not work with BIM. This can be a reason why a few employees have diverse responses regarding whether the BIM roles are clearly defined or not, in relation to responsibilities and tasks. Those who are senior with years of work experience know more about their roles and responsibilities. Moreover, as noticed through observations, there is a number of new employees who have been recruited by the company, of which some participated in the questionnaire. They might not be as familiar with their roles and responsibilities as the senior employees. This can be a reason why approximately a quarter of the questionnaire respondents express concern about their responsibilities through *Table 6*.

According to most of the questionnaire respondents in *Table* 7 and most of the interviewed employees, BIM is developing and therefore new BIM roles emerge. This claim is also supported by previous research by Davies, Wilkinson, McMeel (2017). However, Employee 3 (BIM Coordinator) thought differently since he thinks that because of the automatization where tasks will be done automatically, there will be fewer BIM roles. Different BIM roles will merge into one. For instance, currently mathematical problems are automatically solved by software. However, the trend will continue, and even more tasks will be done automatically. Thus, the quantity of BIM roles will decrease as roles will emerge into one. Thereby, new BIM roles will not emerge but even the current ones will decrease.

Regarding new BIM roles at OfficeBIM, the company itself is undergoing development. The larger it gets with time, the more BIM actors and roles are necessitated. Thus, the quantity of BIM roles follows the scale and size of the company and its projects. As long as the company grows, novel BIM roles will emerge. The growth of the company is in compliance with the development of BIM roles. Thus, OfficeBIM's context of developing new BIM roles for now follows the future suggestion of Davies, Wilkinson and McMeel's (2017), which indicates an increase in the number of the roles. This is already taking shape at the company as they contemporarily develop a new role called "*BIM supervisor*" which is hinted at by the company CEO (Employee 4). By looking at the company history, a growth pattern is perceived in relation to its size and BIM actor quantity. Thus, based on that it is anticipated that more BIM workers will be needed in the future. However, if the company growth stopped then a barrier to developing new BIM roles will emerge naturally, as until now the company has grown and the BIM roles with it. This is the actual barrier case for OfficeBIM, unlike what theoretical research hints at.

According to Davies, Wilkinson and McMeel (2017) along with Uhm, Lee and Jeon (2017) the main barriers of new BIM role development are cost and unclear role responsibilities, followed by the lack of BIM professionalism in companies. Out of which only cost is viewed by OfficeBIM employees as the main barrier. The questionnaire respondents in *Table 8* overwhelmingly denote that the main barrier to

the development of new BIM roles is "*lack of financial resources*" (cost). Even so, this claim is dismissed by the interviewees, especially Employee 4 (CEO) who argues that the company has no financial shortages for role development or personal development of its employees. This can be realized, by the company's development of the new BIM role "*BIM supervisor*" and its advanced new technology, such as the insertion of the new VR-technology into the company. Thus, the questionnaire respondents' claim on an economic barrier for new BIM role emergence can be derived from misunderstanding of the question related to barriers inside the questionnaire.

Uhm, Lee and Jeon (2017) describe that it is expensive to hire employees for new roles. It is cheaper to let employees manage different tasks rather than letting them focus on one task. Thus, such is a barrier to developing new BIM roles intentionally by companies that are stingy. This assumption might be true for many companies. However, in the case of OfficeBIM a number of new junior employees are recruited just recently in the company, as the observations hint. Thus, cost and economic barriers are not accounted for by OfficeBIM in relation to developing new roles, rather its own stop in growing will stop the development of new BIM roles which the interviewees hinted at. Perhaps, the company has a good profitability that it does not consider the cost of employing new BIM actors. On the contrary, OfficeBIM is in need of more personnel as they constantly are growing as a company.

5.3 Requirements from a BIM Actor

A BIM actor is deemed anyone working with BIM in the construction industry who can be an architect, a civil engineer or any other corporate actor with skills in BIM as defined by Succar, Sher and Williams (2013). However, at OfficeBIM those who are working as BIM actors have relevant engineering educational backgrounds either from regular universities or vocational ones. As perceived through the interviews, especially through Employee 4 (CEO) one definitely needs to have a relevant educational background in order to be employed and work as a BIM actor at OfficeBIM. Additionally, the level of education and degree is also highly essential for role allocation at the company which accordingly different BIM actors get different roles. Such happens subsequent to an initial period of work, when all the BIM actors begin as BIM modelers to gradually gain experience and get promoted to higher roles. E.g. Employee 4 (CEO) describes that BIM actors with regular university degrees will be promoted after a couple of years and get higher roles such as the role of BIM coordinator. This is in comparison to the other BIM actors with degrees from vocational universities which are considered lower, as they encompass fewer years of education. Thereby, education is deemed a basis for BIM actors' promotion in the company. Nevertheless, 3D-modelling is a key work skill of a BIM actor for which some basic expertise is needed as with time the skills will develop through work experience, as highlighted in *Table 11*. Thus, the company prioritizes education first, prior to work experience as it is the entrance key for being employed at OfficeBIM.

Nevertheless, in the questionnaire (*Table 11*) the employees believe that the least important education is IT and computer engineering for a BIM actor to have. This response seems misleading. However, a reason behind such an opinion is that BIM actors do not necessarily need to be educated in IT and computer engineering or building engineering as highlighted in the interviews. They can have various engineering educations of diverse backgrounds, which was the case at the company. Thus, the employees' responses emerge from reflecting on the company itself.

By observing the interviews, it is noticeable that it is unrealistic for a BIM actor to have all of the BIM competencies known as IBC (Individual BIM Competencies). Succar, Sher and Williams (2013) categorize them into eight areas which are vastly excessive to fulfill. The reality points at having some generic competencies, mainly in the usage of BIM software. Thereafter, new competencies will develop within the individual through work experience as time passes. This is stated by Uhm, Lee and Jeon (2017) and confirmed by the interviewees at OfficeBIM. Thus, here the theoretical data corresponds with the empirical one precisely, at least this is the case for OfficeBIM. Simultaneously, the reality might be the same as well for other companies for which Uhm, Lee and Jeon (2017) exhibit particular BIM job advertisements from real life. The result points at a consistency with OfficeBIM.

When it comes to personal characteristics of a BIM actor, the opinions are diverse and role-oriented. Depending on the type of role, different characteristics are expected for a BIM actor, which is explicated by the interviewees. Employee 1 (BIM Manager) believes being friendly and humble are the most favorable characteristics. Whereas, Employee 2 (BIM Modeler) believes being fast and structured are essential for a BIM actor, which are crucial for a modeler's role. This is also confirmed by the questionnaire results (*Table 10)*, in which being structured is ranked second highest among all of the other characteristics. Employee 3 (BIM Coordinator) further believes in humanist aspects such as being passionate and tolerant which are relevant for his role of coordinating various BIM actors' work all together and discouraging tensions, if a modeler made a technical mistake affecting all of the team's work. Finally, Employee 4 (CEO) believes being engaged, curious and co-operative are important characteristics for a BIM actor. Once again, his perception comes from his role as the company CEO which is what he expects from his BIM actor employees. However, the questionnaire respondents (including the interviewees) all together believe that being co-operative (*Table 10*) is the most paramount personal characteristic for a BIM actor, which is ranked highest. This perception emerges from the fact that BIM actors depend on co-operation and each other's skills as BIM is broad when they conduct projects. Each actor performs a task or multiple tasks of the project within the project team. Thus, the fuel for carrying out a project is co-operation. In addition, being flexible, strategic and having good communication and problem-solving skills, along with commitment are among the most preferred personal characteristics for a BIM actor with a mean value 4,82 each, according to the questionnaire *(Table 10).*

BIM is vast and implicates various functions which both the theoretical research and the interviewees hint at. E.g. the interviewees state that they are still developing and acquiring knowledge in BIM, as it is broad. Thus, they jointly state that they work like a chain and are dependent on each other's knowledge to work. Thus, reaching a professional level in knowing everything about BIM is quite out of reach. That is because BIM is broad with many software programs to use and learn. In addition, different BIM-related corporations such as Autodesk constantly modify or develop new software programs for BIM. Thus, coping with this trend and indoctrinating various BIM functions and programs can be difficult or quite unbearable. Moreover, the questionnaire respondents jointly hint at a lack of time for BIM actors to develop themselves in BIM (personal training) as they have project work to carry out during their working hours. This is also reiterated in detail by Employee 3 (BIM Coordinator). Whereas Employee 4 (CEO) believes there is a lack of will among the employees to dedicate their own time to develop more skills in BIM, such as learning new functions or software programs in contrast to the employees' point of view. This contradiction is highly anticipated, between the employees' blame on time and the company CEO's blame on their will. Such is a context of dualism (two-sidedness) which both the claims can be true simultaneously. Certainly, the company CEO has more expectations on the subordinates, who spend their work hours at the company on their actual tasks to deliver. Thus, there is a time restriction for personal development of BIM actors in BIM unless they dedicate their free time, outside the workplace for self-development.

Another issue before the development of BIM actors is cost. Ulom (2012) addresses the issue that BIM training costs and software purchase is relatively high compared to traditional construction designing techniques. Due to these challenges, there is a widespread shortage of skilled personnel with expertise in BIM technology. Even though the employees in the questionnaire state that there is a lack of economic resources for BIM actors' development, Employee 4 (CEO) firmly dismisses this claim. He (CEO) argues that there is no lack of financial resources in the company for employees' development. The company is willing to provide resources needed for its employees to train and develop more skills in BIM, if they desired to do so. Here, once again a contradiction is noticed between the two sides (employee versus CEO). A hypothetical reason behind that contradiction might be that the BIM actor employees have not inquired the company CEO for self-development in BIM, to provide them with necessary resources. They mainly assume that financial resources might be a barrier to their self-development in BIM. This logically explains the contradictory opinions between the BIM actors and the CEO, concerning economic resources.

On the other hand, both the CEO (Employee 4) and the BIM actors at OfficeBIM agree on development in newer BIM technology if there was a chance of enabling that. Thus, there is no resistance by the employees to the approval of newer technology unlike what Lee (2015) hints at. The company is highly open for

technological development and this can be observed through their introduction of the new VR-Technique which the interviewees speak of in detail. The insertion of this novel technique proves the CEO's benevolence and will to company development and further affirms that the company does not lack economic resources for development. Based on that fact, the company is highly ambitious to develop itself and its employees. However, the lack of time might be a real barrier to company and employee development.

5.4 Tasks and Involvement of a BIM Actor

Regarding tasks of a BIM actor in projects, the employees reiterate that design and quality control are among the primary tasks that a BIM actor shall carry out which are displayed in *Tables 13* and *14*. These two tasks are among the generic and essential tasks of BIM actors in projects, according to Singapore BIM Guide (2013). The employees also denote "*making cost estimates*" as the least important task in the questionnaire (*Table 14*), which is unexpected but comprehensible as the company mainly works with design and quality control of the designed models. In addition, since OfficeBIM is a project-based organization, the BIM actors constantly work in projects and have project-related tasks. Thus, no real data is displayed regarding organization-related tasks of BIM actors.

5.5 BIM Importance for Companies & Projects

It is important to hint at the empirical context of the study which consists of a smaller infrastructure consultant company (OfficeBIM) that utilizes BIM specifically for a limited work boundary of design and HVAC systems. Thus, the respondents' view and information about BIM usage emerges from this limited work boundary of the company. Thus, the empirical data coming from the company employees is limited and narrow compared to the data from the literature which considers BIM usage for the entire lifespan of a project. Nevertheless, consistent and parallel data co-exists between the literature and the empirical finings, from which essential outcomes can be derived.

The benefits of BIM are many, as it itself is highly broad. Infrastructure projects are vastly costly and large, which take a considerable amount of time to deliver among other factors. BIM has most notably facilitated this process by reducing time, cost, errors, and heightening the quality of the BIM projects among many other BIM services (BIM uses). This is highlighted by National Institute for Building Sciences (2017), Autodesk (2015), Clevenger (2015), Salman (2008), Price (2017), Udom (2012) and others who believe that BIM has positive effects on both corporate and project levels. This is also affirmed by the interviewees who had the perception that BIM is useful for the entire project life cycle, despite the company utilizing it mainly for design. The questionnaire respondents (*Tables 15 and 16*) of OfficeBIM also believed that BIM assists the company mainly by making it more competitive and

providing more effective work processes (mean value 5,55 for each of the effects, *Table 15*). Such are BIM advantages on a corporate level. On a project level (*Table 16*), the employees affirm that BIM mainly reduces problems on site during the construction phase and it heightens the quality and productivity of projects generally. Thereby, BIM implies various benefits for the company and its projects, confirmed by the theoretical and empirical data of the study.

However, BIM is vastly broad and implicates various functions which might not be utilized to the fullest. As BIM is primarily known as a design tool, it is broadly utilized for the project phases before the delivery, specifically the design. It might be less utilized for management and maintenance phases of the project, when BIM's usage is considered by Eastman et al. (2011) to be of high importance. This perception is visible by the employees' responses in the questionnaire (*Table 13*) which mainly point at BIM actors' involvement in the design phase primarily. They also believe the least important phase is the demolition which does not necessitate the BIM actor's implication. Thus, the trend is the longer the BIM project goes in its life cycle the lesser BIM is used, according to the employees. From this perspective, it is explicated that BIM might not be utilized equally in all project phases, especially during the management and maintenance phases after the project delivery. BIM users might have more knowledge about BIM used for designing, rather than other functions. The obvious reason for the employees' view about BIM usage in this way is that the company itself is a design and HVAC company, which is also reiterated by the interviewees. Therefore, OfficeBIM as a consultant company utilizes BIM within its own limited work boundary which touches design and HVAC. Other and larger corporations might utilize BIM more prevalently. Nevertheless, the employees jointly reiterate that BIM should be used equally for the entire lifespan of a project in order to utilize the software benefits to the fullest.

6 Conclusion

This chapter finalizes the study by providing conclusive responses to the research questions that initiated the study. The responses are derived from the examination of the overall study, by juxtaposing both the theoretical and empirical research.

The definition of BIM roles, their titles and responsibilities vary contextually between different companies and countries. Different companies identify different tasks and titles for each of the BIM roles. However, generally the roles are overlapping and are still in a state of development complying with the BIM development itself. E.g. the role of a BIM manager and a BIM coordinator, which greatly overlap with one another in terms of tasks. Thus, there is a disarray in the current BIM roles' definitions, not only at the company under enquiry in this study but also internationally, which the literature points at. Nevertheless, efforts are done to distinguish the roles from each other by identifying and organizing them more explicitly in corporate manuals defining each BIM role separately. Even so, in practice the responsibilities and tasks among the BIM roles still overlap as BIM actors work in BIM projects co-operatively as a chain. Nevertheless, there are new BIM roles getting developed following the development of BIM consistently despite the overlapping of the role responsibilities and tasks. The development of new BIM roles depends on companies' growth and progressed knowledge in BIM.

BIM has revolutionized infrastructure projects in multiple and innovative ways, most notably in time and cost saving ways, according to BIM actors. That is because whatever is done in the BIM software can be accessible by relevant project actors. Thus, better decisions can be taken as the project team has more information about the BIM project. BIM actors assert that BIM must be implemented throughout a project life cycle, not mainly being utilized for design. Thus, the full utilization of BIM is yet to be questioned.

7 Recommendations

In this chapter, a number of propositions are recommended for future studies and the future development of small infrastructure consultant companies based on the issues of the OfficeBIM company highlighted in this study.

7.1 Future Study

This study could be extended with further empirical research, based on independent sources outside OfficeBIM. Furthermore, as this study was an extension of a Chalmers University study it could be very much compared with the previous research and empirical data of this broader study at Chalmers. Also, the study authors further desired to compare the outcomes of this study, which is based in Sweden and on a Swedish company, with BIM roles outside Sweden to derive a further conclusion. Such propositions could enrich the study further and increase its validity.

7.2 Recommendations for OfficeBIM and Similar Firms

The following recommendations consider the company under enquiry in this study. However, they can be applicable to similar companies of the same context, with similar issues.

7.2.1 Incentives for Encouraging Better Commitment

Currently, the BIM actors at OfficeBIM complain about time restrictions that they do not develop their personal skills in BIM. The BIM actors dedicate their working hours at the company merely to conducting project tasks. In contradiction, the company CEO complains that the BIM actors lack willingness to self-develop as resources and time are not a problem. The participation in this research sees the CEO's claim as a fact, that out of 39 employees only 11 participated for the company development, even with the help of a gift voucher. Thus, a lack of commitment and loyalty towards the company can be noticed in this context, based on these results. The study results denote a need for change regarding employee commitment and development. However, change emerges from the top management. Perhaps the company should dedicate monthly awards to its employees and praising a selectee as **The Employee of the Month** who has done something innovative for the company, not for his or her own salary.

7.2.2 Adaptation of BIM Role Titles

By conducting a comparative analysis between OfficeBIM and the literature based on the international community about BIM roles, it is visible that the BIM role titles in some cases are incompatible. However, the company CEO already stated they strive for matching the BIM role titles with the international ones. A key role here is the one of the BIM manager. OfficeBIM calls it "*Business Area Responsible in 3D/BIM*"

which is also referred to as "*BIM Responsible"* more commonly at the company. This role title is totally unmatched with the internationally recognized title of the BIM manager, even though their responsibilities are compatible. From a rational point of view being a BIM Responsible actor can be anyone with any role as all BIM roles are responsible for BIM. Hence, this role title at OfficeBIM is highly irrational and incompatible with the literature and should be changed after its responsibilities, which are the ones of a BIM manager. It would be highly beneficial for OfficeBIM to adapt its role titles after the international community. It has already the role title of BIM coordinator as it is, but not the BIM manager, which should be added as the two normally work in a close range to each other.

7.2.3 More Student Studies

Such a study is advantageous for the company to review and compare itself with the international community through the theoretical research inside this study concerning the same issue under enquiry. Thus, the company should enable more opportunities for students annually to conduct similar thesis studies in association with it. Each study will be an endeavor towards the company's innovation, development and connection with the outside world. As pointed out during the observations at the company, this thesis is the first one to be conducted with the company. Thereby, the company should proceed with this path for mutual benefits.

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9 Appendix I: Interview Questions

1) Personal Background: What is your educational background and role in the company currently?

2) BIM Actor Role Definition: The employees have different views about how well the BIM role responsibilities are defined in the company. A significant number believes that they are poorly defined, while others think oppositely. Can you explain or speculate on why the answers were so diverse? How does the company actually define the BIM role and responsibilities, through which channels?

3) BIM Utilization: Most of the employees believe that a BIM actor has a profound role during the design phase mainly, followed by the delivery phase. We guess that since this is a consultancy company, certainly respondents from here think BIM is mostly useful for design, but how do you think? Is BIM not that useful during production, renovation or later phases when clients are using it? Why do you think so?

4) BIM Models: How do you use the BIM models? Is it only you using the BIM model for yourself, or do you work on a BIM model together with other actors, like contractors? If you are using it only for yourself and not collaborating with others, does this mean you are ignoring other phases which harms total production?

5) Barriers: Regarding barriers leading to the development BIM roles, the employees believe that the lack of economic resources, followed by unclear responsibility allocation and time are the main barriers. What do you think are the barriers to the development of a BIM role? Why? How is it in the company specifically?

6) Future Development of BIM Roles: The employees state that there are some unclarity in relation to BIM role responsibilities, especially for the BIM-Coordinator and time deficiency but emphasize and expect positive development of BIM roles currently and in the future. How do you see the BIM role in the future? How is this difference in opinions possible? Are there new BIM roles emerging in the company based on needs? Also, one employee states that the company has introduced a "*VR-Technique*" to develop BIM further, how is that assistive?

7) BIM Actor Personal Characteristics: What are the most important three characteristics a BIM actor should have in your opinion? Your colleagues thought a BIM actor should be *co-operative* above all, can you explain why?

8) BIM Actor Education, Competency and Experience: BIM is related to construction. Yet, a number of employees believe being educated as a building engineer is not important but also simultaneously believe being educated in design and 3D-modelling is important. How is that possible? Furthermore, the majority believes having experience in 3D-modelling is more important than education. Does experience precede relevant education in the company or not?

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