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BIM Effect on the Quality of Communication in the Project Management of Smart Cities

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Affidavit

I hereby formally declare that I have prepared and written this thesis by myself without any illegitimate assistance of a third party and all the content used from the other sources have been directly or indirectly cited as such.

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3rd August 2020 Khatereh Derakhshanfar

Preface

The concept of smart cities points out the future cities, which will incorporate IoT and digitalization for facilitating the communication among people, their devices, government services, and various facilities that can provide enough services for the enormous population in the future cities.

To achieve the goal of having the ideal smart cities, it is necessary to go digital and plan for having virtual imagination for every component in the cities, including the construction facilities. BIM method as a means of having a virtual vision of each element of the construction project glows in mind as one sort of assistance to reach this target.

This thesis investigates the impact of BIM on the quality of communication in the future smart cities based on the literature review of the three smartest cities including Singapore, London, and Manchester.

Keywords: Smart Cities, BIM, Communication, Construction Project Management

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List of Abbreviations

AEC- Architecture, Engineering, and Construction

BCA- Building Construction Authority

BDDR- BIM Design Data Review

BEP- BIM Execution Plan

BIM- Building Information Modelling

CAD- Computer Aided Design

CAM- Computer Aided Machining

CATIA- Computer-Aided Three-Dimensional Interactive Application

CDE- Common Data Environment

CIMI- Cities in Motion Index

CORENET- Construction and Real Estate Network

ConSASS- Construction Safety Audit Scoring System

EIR- Employers' Information Requirements

GFA- Gross Floor Area

GUI- Graphical User Interface

IaaS- Infrastructure as a Service

ICT- Information and Communication Technology

ICTC- Information and Communication Technologies for Construction

IFC- Industry Foundation Classes

IGA- Istanbul Grand Airport

IoT- Internet of Things

IPASS- Intelligent Productivity and Safety System

ITS- Intelligent Transport System

JMA- John McCall's Architects

NIBS- National Institute of Building Sciences

PaaS- Platform as a Service

PMBOK- Project Management Body of Knowledge

PPR- Project Procurement Route

RESTful Web Services- Representational State Transfer Web Services

ROI- Return on Investment

SaaS- Software as a Service

TfL- Transport for London

UK- United Kingdom

WSH- Workplace Safety and Health

VDR- Virtual Design Reviews

1 Introduction

1.1 Problem Statement

Communication in every project is one of the vital critical factors for its success. Without efficient communication, the projects will face failure. Communication progression is essential because the interested parties need to interact with each other effectively to comprehend the projects' goals.[1] The stakeholders should exchange their information, share ideas, and develop trust through effective communication. Particularly in construction projects, communication development is desirable since the quality of communication matters for the productivity of the project.[2] Some think stricter about communication, like Zulch (2014) [3], who stated that the sole reason for the victory of a project depends on the communication ability of the project manager. The project manager should have the talent to apply the right technique to handover accurate information to the involved parties of the project in real-time. Besides, the project manager needs to have a functional plan for the communication process and design a framework for the observation of its progress throughout the project, which applies to the construction projects as well.

Construction projects are projects with a variety of stakeholders who join the project with diverse objectives. The project manager should network with all of the stakeholders systematically and steadily to exchange the information of the project with them.[4] Therefore, it is a necessity to reinforce the network with a new method to accelerate the access of all interested parties to the real-time information and progress of the project. A project manager should consider stakeholders' communication as a primary tool for project management in the areas of scope, time, cost, and many other components of the project.[5]

Communication has an ultimate function in most of the complications in the construction industry; therefore, sustaining efficient communication through the project is

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[1] Cf. Zulch (2014), p. 1001.

[2] Cf. Hoezen et al. (2006), p. 14.

[3] Cf. Zulch (2014), p. 1001.

[4] Cf. Melzner et al. (2015), p. 1.

[5] Cf. Naqvi et al. (2011), p. 5824.

fundamental for the success of the project.[6] On the one hand, Proper communication has a positive effect on team cooperation and project collaboration; on the other hand, poor communication results in misinterpretations, interruptions, and disputes along the path. According to Zulch (2014)[7], the lack of accurate understanding is the consequence of unproductive communication in construction management that causes a breakdown in the project's outcome. It is, therefore, crucial to establish a communication plan by considering the organizational structure and the organizational norms of communication.[8] As a result, the demand for a tool that can enhance the effectiveness of communication in the projects is undeniable. It seems that using new applications and tools which can incorporate different stakeholders and strengthens their network is helpful to the success of the project.

Conveying what the concluding project will look like, as well as the progress level is imperative but perplexing. Some interested parties cannot understand the aimed achievements of the projects through the documents; therefore, we need a tool that can visualize the outcome of the project. BIM, as a visualizing technique, is a new revolution in the construction industry. It is possible to use BIM to show the exact preview of inside and outside of the terminal building to the clients and stakeholders before it is built. It is a unique method that can change the communication behavior in the projects.[9] From the 2000s, contractors started using BIM in their projects; however, designers, and as a result, owners were hesitant in using it in the construction projects.[10] Year by year, BIM is moving its role from a design tool to a fundamental part of the production process because it can make more information accessible than the typical paper designs.[11] Moreover, BIM saves us time, which was being wasted in the traditional form of project communication because it can minimize the communication protocol. It also helps the parties to come to a mutual agreement on the details of the construction plan and devise solutions to the

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[6] Cf. Pérez Gómez-Ferrer (2017), p. 1.

[7] Cf. Zulch (2004), p. 1002.

[8] Cf. Ibid.

[9] Cf. Melzner et al. (2015), p. 1.

[10] Cf. Worden (2016), p. 13f.

[11] Cf. Svalestuen et al. (2017), p. 205.

problems faster than before. BIM is an ongoing process during the construction of the building, and it is a virtual presentation of the building, which shows the design and the information behind it in real-time. As a result, construction sites are going to use it for running the physical work of the project in addition to using it in the design office.[12] As mentioned before, not many of the project managers and contractors are eager to adopt BIM in their projects. It can be because of the lack of information about BIM, having no interest in making changes, and the concerns about the possible imposed costs on the projects.[13]

1.2 Aim of the Study

This study will analyze the existing empirical literature about the cases of Singapore, London and Manchester as some of the smartest cities in the world to investigate the BIM Effect on the Quality of Communication in the Project Management of Smart Cities.

BIM can provide an excellent scheme for the project manager to plan every single step of the project before the implementation and connects the AEC professionals in the project. Especially in enormous projects like smart cities, having a proper plan and method for facilitating proper communication plays a significant role. Smart city projects are massive projects which will employ enormous resources, including time, expenditure, human capital, and many other assets. If we do not plan for the details of the project in advance, there will be an enormous loss of these resources without achieving the desired outcome for the project.

BIM has the competency of displaying the construction project's diverse factors to the stakeholders, which comprises data management, design, and communication flow in the project.[14] This study aims to concentrate on the communication effect of BIM in smart city projects. Many studies have looked at BIM and its effectiveness for the projects in construction projects from the architecture and engineering point of view. This study aims to observe the impact of BIM on the communication aspect. Some studies have

[12] Ibid.

[13] Cf. Hardi; Pittard (2015), p. 370.

[14] Cf. Singh et al. (2018), p. 29

demonstrated the positive influence of BIM on construction projects; however, the goal of this study is to study the functionality of BIM in smart city projects, which are vaster than current construction projects and have more aspects than them.

1.3 Research Question

This study will observe the "BIM Effect on the Quality of Communication in the Project Management of Smart Cities" and tries to find the answer to the below questions:

1. What is the effect of BIM on the quality of communication in smart city projects?
2. Which communication problems will BIM solve in smart city projects?
3. What is the future role of BIM in improving the quality of communication in smart cities?

The general hypothesis of this study is: "BIM has a *positive and significant effect* on the quality of communication in smart cities."

1.4 Methodology

There are two general methods for conducting an academic study, which includes Quantitative and Qualitative Methods. This study does not aim to calculate the effect or find out the percentage of the impact; however, it aims to discover the likelihood of improving the quality of communication with the use of BIM in the smart city projects. Usually, the quantitative method is applied when using the numeric data to find the relationship between different variables. On the contrary, the qualitative method can use descriptive information to explain the relationship between variables and make suggestions that are more suitable for case studies. This research quality method will be coordinated with the inductive method, which can help us generalize our findings of the case as a sample to the whole population, which can be the set of cities aiming to become smart shortly.

For making a good base for the case study analysis, this study will employ the literature review to gain thorough knowledge about the related concepts as well as previous studies in similar fields. Analyzing Singapore, London and Manchester as some of the smartest cities in the world would be beneficial for analyzing and finding the answer to the questions of this thesis.

Overall, the base of the research methods for this study will be qualitative method by reviewing the literature and historical background as well as analyzing the outcome of

applying BIM in Singapore, London, and Manchester as three of the best planned smart cities of the future.

Chapter 2 will explain the research methodology in more detail.

1.5 Structure of Work

This thesis includes six chapters as below:

Chapter 1- Introduction: It consists of an overview of the topic, problem statement, aim of the study, research question, methodology, and the structure of work.

Chapter 2- Research Methodology: It comprises the description of standard research methods and approaches, including inductive versus deductive method, quantitative versus qualitative method, various types of collecting data, for instance, surveys, interviews, focus groups, case studies, and the research scheme of this thesis.

Chapter 3- Literature Review and Historical Background: It covers literature review, explains the definition of BIM and its implementation history in construction projects, the advantages and disadvantages of BIM, its various applications, communication in construction projects, BIM versus project management concepts, smart cities project management plus communication, and the relevant previous studies.

Chapter 4- Case- Study: It covers the information about Singapore, London, and Manchester as the smart cities of the future, the use of BIM in them, the smart projects, and the experience of BIM in these cities for addressing the communication problems in construction projects.

Chapter 5- Conclusion: It concludes this master thesis with the outcome of the study on the topic with reference to the information given in the previous chapters and gives recommendations to the researchers for future studies.

2 Research Methodology

2.1 Introduction

In this chapter, I will explain the various kinds of the methodology used in similar scientific research that are suitable for this study. Furthermore, I will describe why I have adopted these specific methods for running this study. Therefore, this chapter starts with an overview of standard research methods and continues with the research scheme of this thesis.

2.2 Overview of Common Research Methods

There are different methods for running a scientific study, including qualitative or quantitative research, inductive or deductive methods, implementing literature review, empirical studies with interviews or case studies, questionnaires, and many other quantitative methods that are not related to the research method of this study.

2.2.1 Inductive Method

The inductive method is when, after examining specific items of a sample, we generalize their behavior and specification to the whole members of that sample. In other words, we go from a specific logic to a general idea for the whole sample.

As also said by Tibbetts (2013): "Inductive reasoning tries to infer general laws from specific observations. For many complex problems, the only guide to gathering the relevant facts is to begin some creative musing about the cause of the phenomenon; this leads to the inductive method."[15]

It is the procedure of discovering contrasts among objects regarding their attributes and mutual relationships' similarities and diversity.[16] Not only similarities among the objects but also their differences can assist us to generate conclusions about the behavior of a group of objects. Their specific behavior with all the similarities and diversities can help with forecasting their attribute in the future. This is how the inductive method assists with anticipating future incidents.

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[15] Tibbetts (2013), p. 8.

[16] Cf. Klauer; Phye (2008), p. 107.

According to Sauce & Matzel (2017):

> "Inductive reasoning is a logical process in which multiple premises, all believed true or found true most of the time, are combined to obtain a specific conclusion or to supply evidence for the truth of a conclusion. Inductive Method is often used to generate predictions or to make forecasts"[17]

As humans, we are most of the time using inductive reasoning in the generalization of the events to foresee upcoming occasions.[18] On the other hand, inductive reasoning helps to predict new incidents by using current information.[19]

2.2.2 Deductive Method

In the deductive method, we can conclude specific characteristics for the members of a sample from a generalized idea about the whole. In fact, we go from a general idea for the whole sample to a specific logic for each member of the sample.

According to Johnson-Laird (2009)[20]:

> "Deductive reasoning is the mental process of making inferences that are logical. It is just one sort of reasoning. But it is a central cognitive process and a major component of intelligence, and so tests of intelligence include problems in deductive reasoning"

As Arthur (1994)[21] said, humans do not make proper use of the deductive method for analyzing the events; instead, they prefer using the inductive method to reach a generalized idea about events.

Regarding deducting reasoning, Tibbetts (2013) said that: "It requires that you accumulate relevant facts about a problem, carefully weigh and compare them, and deduce a balanced conclusion that will fit all the facts into a consistent framework."[22]

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[17] Sauce; Matzel (2017), p. 1.

[18] Cf. Nisbett; Krantz (1983), p. 339.

[19] Cf. Hayes; Heit (2017), p. 1.

[20] Johnson-Laird (2009), p. 8.

[21] Cf. Arthur (1994), p. 406f.

[22] Tibbetts (2013), p.8.

It seems that it has too many process steps for analysing everyday tasks; that's why people typically prefer to benefit from inductive reasoning.

2.2.3 Inductive vs. Deductive Method

Heit & Rotello (2010) argued that inductive reasoning does not allow the argument to be accurate reasonably because they are affected by the fast processes of analytical rationalizing, however, it is not the case for deductive reasoning.[23] However, in many cases, using inductive reasoning is more beneficial due to the lack of appropriate data or the case's novelty. The induction method explains the production of knowledge about unresolved issues from the recognized information.[24]

The findings of the induction method are presumable and subject to the power and persistence of the proof, while the conclusion of the deductive method is accurate.[25] However, inductive reasoning is the base of the scientific findings; its use spreads surpassing science, and many activities of the human being are based on it.[26]

2.2.4 Quantitative Research

This research method includes working with numerical data and statistical models to test the hypothesis and determine the relationship among various variables of the model. A variable is not only measured but also can be manipulated and controlled to be examined regarding its effects on the dependent variable.[27]

Apuke (2017) described quantitative method as below:

> "A quantitative research method deals with quantifying and analysis variables in order to get results. It involves the utilization and analysis of numerical data using specific statistical techniques to answer questions like who, how much, what, where, when, how many, and how."[28]

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[23] Cf. Heit; Rotello (2010), p. 805.

[24] Cf. Hayes; Heit (2017), p. 1.

[25] Cf. Sauce; Matzel (2017), p. 1.

[26] Cf. Ibid.

[27] Cf. Apuke (2017), p. 43.

[28] Ibid., p. 41.

The advantages of applying quantitative research are as below:[29]

1. Using data saves resources and time which might have been needed to be used for explaining the findings.
2. It is possible to generalize the results with quantitative data collection and analysis.

On the other hand, in the quantitative method, the researcher will look at everything from outside, which gives him/her an observer role and is separated from the participants of the topic.[30]

There are some occasions which using quantitative methods is not beneficial for us, which are[31]:

1. When we want to explore a problem in-depth, we should apply the qualitative method because the quantitative method will explore it only in breadth.
2. For examining theories and hypotheses, we use a quantitative method, but when the aim is to generate a hypothesis or theory, we should implement qualitative research.
3. For an in-depth comprehension of the issue, it is better to adopt the qualitative method because new unpredictable variables my arise, and the quantitative method has restrictions for the number of variables.
4. When we need to understand the meaning of an occurrence, it is better to use qualitative methods. On the other hand, for finding cause and effect, using quantitative methods will be more beneficial.

2.2.5 Qualitative Research

Contrariwise quantity research, different researchers have a different understanding of the concept of qualitative research; for example, a psychologist would look at a

[29] Cf. Daniel (2016), p. 94.

[30] Cf. Ibid.

[31] Cf. Muijs (2011), p.6f.

case study, whereas a sociologist will perceive a participant observation as a qualitative analysis.[32]

The advantages of qualitative research are[33]:

1. Qualitative method has adequate tools to assist in solving problems that gathers data by different means, for example, "[...open-ended questions, in-dept interview (audio or video), and field notes...]" which give a proper understanding of the issues.
2. The data collection method in the qualitative approach is unique.
3. Qualitative research observes the human attribute regarding the research topic by close interaction of the researcher and the participants as the sample of the study.

Overall, making distinction between quantitative and qualitative research is beneficial:

"Qualitative research seeks to discover new knowledge by retaining complexities as they exist in natural settings, whereas quantitative research seeks to discover new knowledge by simplifying complexities in settings that tend to be more contrived."[34]

2.2.6 Tools for Data Collection

On the basis of the nature of the research whether it is qualitative or quantitative, there are various kinds of data collection methods which I mention some of the most important and common ones in the following pages.

2.2.6.1 Surveys

Surveys, as well as questionnaires, are used to find out the trend in the population by applying them in studying the sample of that population, which is chosen randomly.[35]

Goddard & Villanova (2005) explained surveys as below:

"A survey is a method of collecting information from people for descriptive or predictive purposes. A survey can be used to gather information about the nation's population as a whole (the decennial

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[32] Cf. Tesch (2013), p.3f.

[33] Cf. Daniel (2016), p. 92f.

[34] O'Dwyer; Bernauer (2014), p.5

[35] Cf. Pribyl (1994), p. 195.

census of the United States) or to assess the reactions of a sample of consumers to a new soft drink. Surveys can take the form of a questionnaire filled out by individuals, a one-on-one interview between the subject and the surveyor, or a telephone interview."[36]

If surveys are done on a random sample of the population, it is possible to generalize them to the thorough population; however, if the sample is not chosen randomly, it is not possible to generalize it to the whole population.[37]

Surveys are useful for measuring the efficacy of some policies, decision-making, and acquiring information for a research study.[38] Surveys consist of Face-to-face surveys, telephone surveys, self-administered surveys, internet surveys, etc. which questionnaires are their main component.[39]

Surveys and interviews, including one-on-one interviews, focused group interviews, etc. can be used in a quantitative and qualitative approach. It is vital to know the correct implementation and manipulation of these tools for more meaningful data extraction.[40] The questionnaires, as well as surveys, are good measures to find out the trends; however, there are concerns related to their reliability because participants might have misunderstandings about the questions in the questionnaires and surveys.[41]

2.2.6.1.1 Interviews

Interviews can provide us enough information about the interviewee and cases for retrieving enough information to run the scientific research; however, the interviewer should possess enough skills to take proper notes, appropriate planning, proper preparation, and be a good listener to be able to make the most out of the interview.[42]

Qu & Dumay (2011) believe that:

"The research interview, one of the most important qualitative data collection methods, has been widely used in conducting field studies and ethnographic research. Even when it is not the primary

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[36] Goddard; Villanova (2005), p. 114.

[37] Cf. Navarro-Rivera; Kosmin (2011), p. 395f.

[38] Cf. Goddard; Villanova (2005), p. 115.

[39] Cf. Navarro-Rivera; Kosmin (2011), p. 404-406.

[40] Cf. Slattery et al. (2011), p. 836.

[41] Cf. Pribyl (1994), p. 196.

[42] Cf. Qu; Dumay (2011), p. 239.

method of data collection in a quantitative study, the interview method is employed often as a pilot study to gather preliminary data before a survey is designed."[43]

There is a discussion going on about the minimum sufficient amount of the interviews for having an adequate standard of qualitative research, which books and other resources suggest the quantity between 5 to 50 interviews to reach our goal.[44]

Interviews are categorized as below as Gill et al. (2008)[45] mentioned:

1. Structured: The questions which are prepared before the interview will be orally asked, which makes it easy and quick to manage the whole interview.
2. Semi-structured: They have some prepared questions as the key questions but give the interviewer the flexibility to ask more unplanned questions if necessary.
3. Unstructured: The questions are not prepared in advance, and the organization level is near zero; therefore, it will not be easy to control the interview process, and each answer to a question will be the base for the next question. This type will be suitable for in-depth analysis.

The appropriate use of in-depth interviews is as below:

"In-depth interviews are optimal for collecting data on individuals' personal histories, perspectives, and experiences, particularly when sensitive topics are being explored."[46]

Specially in in-depth interviews people can share their beliefs about a topic provided that the interviewer is prepared to be active to the causal explanations and can continue with the causal questions to find out everything in depth.[47]

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[43] Qu: Dumay (2011), p. 238.

[44] Cf. Dworkin (2012), p. 1319.

[45] Cf. Gill et al. (2008), p. 291.

[46] Mack et al. (2005), p. 2.

[47] Cf. Milena et al. (2008), p. 1279.

2.2.6.1.2 Focus Groups

It is a kind of interview in the form of a group and is in the category of qualitative research that can have a structured, semi-structured, and unstructured format the same as interviews, which were explained in the previous section.[48]

The effectiveness of focus groups is in the below case:

"Focus groups are effective in eliciting data on the cultural norms of a group and in generating broad overviews of issues of concern to the cultural groups or subgroups represented."[49]

Focus groups have less structured interviews with sharing a variety of characteristics, which were first implemented in the 1940s for market research by the Bureau of Applied Social Research at Columbia University and are mostly for retrieving data about the shared views and the concept behind it.[50]

Gill et al. (2008)[51] assumed that:

> "The composition of a focus group needs great care to get the best quality of discussion. There is no 'best' solution to group composition, and group mix will always impact on the data, according to things such as the mix of ages, sexes and social professional statuses of the participants."

In the focus group discussion, freedom of speech should be guaranteed for everybody in the group, and they should be free to share their knowledge and beliefs without any fear of being threatened.[52]

2.2.6.2 Literature Reviews

With the literature review, we can have a better opinion about the topic of the research and the related concepts and definitions related to the study. By having appropriate knowledge, it is easier to do the analysis and make the conclusion accordingly.

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[48] Cf. Boateng (2012), p. 54.

[49] Mack et al. (2005), p. 2.

[50] Cf. Gill et al. (2008), p. 293.

[51] Ibid., p. 293.

[52] Cf. Milena et al. (2008), p. 1279.

Rowley & Slack (2004) defined the literature review as below:

> "A literature review is a summary of a subject field that supports the identification of specific research questions. A literature review needs to draw on and evaluate a range of different types of sources including academic and professional journal articles, books, and web-based resources. The literature search helps in the identification and location of relevant documents and other sources."[53]

Literature review will give us an idea of the steps that has been made and the steps that we should do for the study, helps us with finding appropriate variables, brings us the right perspective to find out the real problem and many other benefits related to the methodology, data gathering tools, structuring a body knowledge and making the structure of the topic.[54]

The method for implementing the literature review should be according to the method for doing the research study as explained below:

> "When a body of literature is primarily qualitative, or contains a mixture of quantitative and qualitative results, it may be necessary to conduct a qualitative review, either alone or as a complement to a quantitative review."[55]

As we write the literature review of our study, we should decide the method we want to use for writing the review, which can be quantitative, qualitative, or a mixture of both qualitative and quantitative methods of research.[56] Efron & Ravid (2019)[57] explained these three research methods as below:

1- Quantitative Method: Quantitative researcher believes in implementing the strategy of natural science for doing the study, and they concentrate on the measurable data which is visible.
2- Qualitative Method: The knowledge for this method is out of the subjective perception of people of the reality, which can be retrieved in interviews, observations, and the analysis of the accessible documents.

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[53] Rowley; Slack (2004), p. 31.

[54] Cf. Hart (2018), p. 31.

[55] Randolph (2009), p. 9.

[56] Cf. Efron; Ravid (2019), p. 15.

[57] Cf. Ibid, p. 16-18

3- Mixed- Methods Research: The author believes in the values of both the research methods.

2.2.6.3 Case Studies

This method is generally for studying about four to five cases and is not necessarily for one case; however, in some small cases, which is for individuals, it can consist of 40 to 50 cases.[58]

According to Gerring (2008):

"CASE-study analysis focuses on one or several cases that are expected to provide insight into a larger population."[59]

Case Study research includes observing the different incidents through various sources for finding answers to challenging phenomena and make discussions over the retrieved knowledge which can be quantitative or qualitative-based depending on the data whether it is numeric or qualitative-based like text or images; however, researchers believe that there is a narrow line between the quantitative and qualitative case study which makes it difficult to distinguish these two.[60]

Swanborn (2010)[61] explained case-studies as:

> "A case concerns a specific instance or manifestation of the phenomenon to be studied. A case study may be based on one case (a single-case study), or on several cases (a multiple-case study). Furthermore, a case may involve only one actor, such as a person, an organization or a village, or it may involve several, sometimes many, interacting actors (such as in studying a conflict between organizations, a conversation between people, a riot involving hooligans and the police, or a traffic accident)."

A case study, as stated above, can be quantitative or qualitative; however, normally, in quantitative studies implementing a case study is not the first preference; therefore, the case study research should have a story within its body that starts with explaining the

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[58] Cf. Swanborn (2010), p.14.

[59] Gerring (2008), p. 1.

[60] Cf. Ramenyi (2012), p. 1f.

[61] Swanborn (2010), p. 21.

problem, continues with the methodology and literature review and ends with the conclusion over the topic.[62]

For choosing the case study, we should keep in mind to choose the one which can be a representative of other similar cases, however, in case of study research we are not sampling instead, we have to understand this case in-depth, and this case should be strong enough to help us understand the matter and find the answer to solve it.[63]

However, Mohd Noor (2008)[64] said that one of the advantages of case study research is its capability in generalization:

"Case Studies also allow generalizations as that result of findings using multiple cases can lead to some form of replication."[65]

2.3 Research Scheme of This Thesis

The first step for structuring the study schemes to decide if we want to research in quantitative or qualitative based.

The disagreement between the scholars for the effectiveness of qualitative and quantitative methods cannot make any of them beneficiary or nonbeneficiary for the research; however, the usefulness of each is subject to the research nature and the strategy of collecting data for the study.[66]

Each of these two methods, quantitative and qualitative, has its own strengths, and some believe than combining these two can bring the strengths of each of them to the research and level up the outcome of the research; however doing so needs careful consideration of the concepts of each method and the differences between these two methods.[67]

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[62] Cf. Ramenyi (2012), p. 5-7.

[63] Cf. Stake (1995), p. 4.

[64] Cf. Mohd Noor (2005), p. 1603.

[65] Ibid., p. 1603.

[66] Cf. Daniel (2016), p. 92.

[67] Cf. Morgan (1998), p. 362f.

The smart cities model is a novel concept that needs to be studied through the inductive method due to the lack of proper data. No city in the world can declare that they are smart cities; instead, some cities in the world are categorized as smartest cities because their specification is the closest to the smart cities' concept.

The idea is to choose the rare successful cases in the world, which are the closest to the smart cities' standards and generalize it to the other cities in the world. This idea is referring again to the inductive method, which is to study a case and generalize that to the other possible cases.

This study focuses on the communication performance in smart cities by implementing BIM method, therefore, the qualitative nature of the study can help us to analyse the effect easier. This qualitative method is preferred because of the lack of quantitative data about the communication performance in the smart cities which is the concept that can be fulfilled in the next 30 years.

This research is going to implement the case study of three of the smartest cities in the world with the qualitative method.

As Mohd Noor (2008) said:

> "Researchers in business related subjects sometimes limit case studies to the exploratory use. For example, pilot case study can be used as a basis for formulating questions or hypothesis testing. Descriptive case study is an attempt to describe, like what happen to a product when it is launched. Explanatory research can be useful for example to study processes in companies."[68]

Referring to the above explanation of various kind of case study analysis, the combination of explanatory and descriptive method seems to be the most reliable method for this research which enables us studying the processes of the communication and analyze the effect of BIM in communication to answer the questions and hypothesis of this study.

The case selection for the research is one of the key components which should be done correctly. Normally in quantitative research, the sample should be chosen randomly to reach accurate results. However, in a quality-based case study, the case should preferably be chosen nonrandomly.

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[68] Mohd Noor (2008), p. 1603.

According to Gerring (2008):

> "In order to isolate a sample of cases that both reproduces the relevant causal features of a larger universe (representativeness) and provides variation along the dimensions of theoretical interest (causal leverage), case selection for very small samples must employ purposive (nonrandom) selection procedures."[69]

Therefore, Singapore, London, and Manchester, as three of the smartest cities in the world with the perspective of becoming perfect smart cities until 2050, are the selected cases for performing this study.

[69] Gerring (2008), p. 2

3 Literature Review and Historical Background

Chapter 3 of this thesis will describe the definition and historical background of BIM, its application in construction projects, its pros and cons, communication in construction projects, distinguishes the BIM versus project management concepts, the communication and project management in smart cities, and the relevant literature review and previous studies in similar fields.

3.1 Introduction to BIM

Nowadays, successful project management and optimum leading of the projects within the limited time and budget to reach the desired outcome and success is critical for all the companies in different industries. One of the most competitive industries, the AEC industry, is intensively influenced by the external elements that make it harder for businesses to reach optimized, innovative success on the market.[70] The growth of each economy is not predictable, and sometimes unpredictable crisis happens that makes the economies and businesses fall. However, some industries show better performance comparing to the others in all the periods. Wong et al. (2009) [71] say that even during the period that the other industries were growing, the construction industry was performing with a non-efficient productivity level. Thus, using a new method for having optimized success and optimum quality within the budget seems essential for the AEC industry.

An alternative technique should provide a convenient method to carry out the project during the implementation and its whole life cycle. Building Information Modeling abbreviated as BIM is the method or in better words management technology behind many unique and innovative buildings all around the world. It has revolutionized the system of planning, constructing, and operating the projects worldwide. As an alternative method, BIM can give better credit and identity to the construction projects by incorporating it into their operations. BIM can assist with delivering reasonable proficiencies for architectural design in the existing industry by incorporating competitive construction

[70] Cf. Keskin et al. (2019), p. 881.

[71] Cf. Wong et al. (2009), p. 1.

information and managing sketches that advance the skills corresponding to problem-solving, better synergy, and efficiency.[72]

An example of implementing BIM is in the renovation of the Heathrow airport terminal.[73] The other examples of BIM application in the projects are the Sydney opera house, public schools in Bourgogne (France), US general services administration, the US Pentagon renovation and construction program, the Airbus restaurant in France, and the Freedom Tower in New York City.[74]

BIM is the underlying technology for most construction projects and few urban rail transport projects in smart cities in China.[75] Some examples of applying BIM in construction projects in China include Shanghai tower that was completed in December 2014[76], Beijing capital airport[77], the Shanghai Disneyland project[78], and Phoenix Media Center in Beijing.[79]

3.2 BIM Definition

There are several available definitions of BIM, or in other words, Building Information Modelling provided by diverse institutions and professionals, which I will mark out to some of them in the following lines.

3.2.1 National Institute of Building Sciences (NIBS)

US Congress established the National Institute of Building Sciences or NIBS in 1974, which carries the responsibility of supporting the improvements in the construction technology for the developments in the construction industry and performs as a connection between the government and private sector in the United States of America.[80]

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[72] Cf. Ozturk; Eraslan (2018), p. 25.

[73] Cf. Dwyer (2008), https://www.cibsejournal.com/cpd/modules/2018-11-bim/

[74] Cf. Brown et al. (2008), p. 31f.

[75] Cf. Ge; Xiong (2020), p. 95.

[76] Cf. Bi; Jia (2015), p. 1032.

[77] Cf. Ge; Xiong (2020), p. 95.

[78] Cf. Ibid.

[79] Cf. Kang et al. (2018), p. 101.

[80] Cf. NIBS (n.d.), https://www.nibs.org/page/about

According to the National Building Information Modeling Standard (2007), "A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward".[81]

National Institute of Building Sciences (2007)[82], mentioned diverse stakeholders of the projects which Figure 1 is pointing out some of the most important ones:

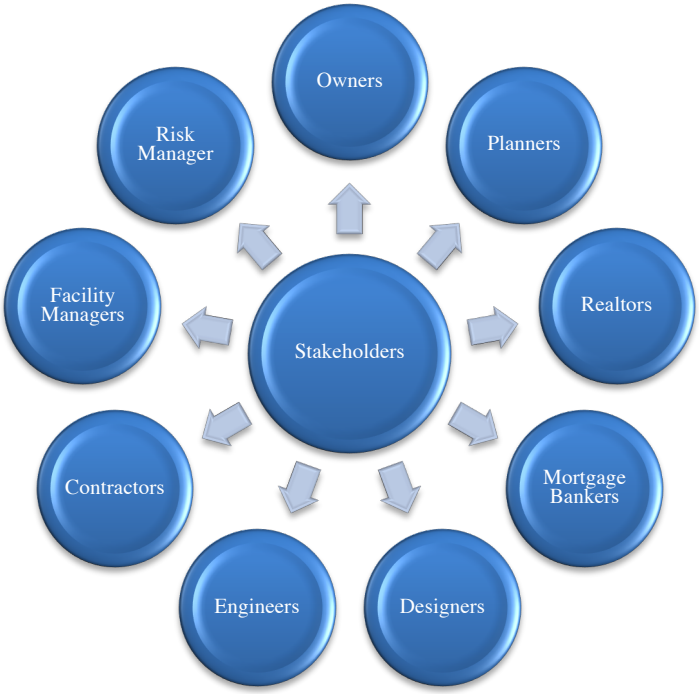

Figure 1- Project Stakeholders

(Source: Own presentation based on NIBS (2007), p. 23.)

The mentioned stakeholders in Figure 1 and many other stakeholders of the project require access to the actual data of the construction project before, during, and after the construction of the facility or the building. BIM supports the project parties with satisfying this requirement in order to reach the desired achievement of the project.

[81] NIBS (2007), p. 21.

[82] Cf. Ibid, p. 23.

3.2.2 Autodesk

Autodesk as a company active in developing applications which is famous in BIM applications with the provision of Autodesk Revit series is a preeminent developer of softwares that offers software solutions to the AEC industry.[83]

According to the website of Autodesk[84], BIM is: "a process that begins with the creation of an intelligent 3D model and enables document management, coordination and simulation during the entire lifecycle of a project (plan, design, build, operation and maintenance)"

3.2.3 Associated General Contractors of America (AGC)

Associated General Contractors of America or AGC serves the AEC industry as a pioneer association which represents several firms, general contractors, specialty contracting firms, service providers, and suppliers in the industry and is in authority for assuring the ongoing progress of the commercial construction industry.[85]

According to the website of AGC[86], Building Information Modelling is:

> "The process of generating and managing a building information model through the use of three–dimensional, intelligent design information. BIM is driving the construction industry toward a "Model Based" process and gradually moving the industry away from a "2D Based" process"

The definition of 3D BIM points out that it is a necessity to issue every detail and documentation of the construction project.[87] This electronic form of the project information assists all the partners in solving the problems of the project effectively. In other words, BIM gives access to real-time data about the project to the stakeholders during the life-cycle of the construction project, which helps with the utilization of the cooperation, optimized scheduling, cost-effectiveness, and decreasing the conflicts and

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[83] Cf. Wong et al. (2009), p. 7.

[84] Autodesk (n.d.), https://www.autodesk.com/solutions/bim/benefits-of-bim

[85] Cf. AGC (n.d.), https://www.agc.org/about-us

[86] AGC (n.d.), https://www.agc.org/learn/education-training/building-information-modeling/building-information-modeling

[87] Cf. Bryde et al. (2013), p. 2.

misunderstanding among the team players.[88] As Bryde et al. (2013)[89] affirmed, BIM is not only an application for geometric modeling but also a project management method that helps with the processes associated with managing the projects.

The BIM technique with incorporating ICT techniques is suitable for more competent construction project management, which consists of elements for better transparency and cooperation among the project players, stakeholders, and owners.[90] BIM is a virtually digitally constructed model of a building that can help from the planning and design to construction and, finally, the operation of the building.[91] There are hesitations by the project managers and owners on implementing BIM in the projects; however, some countries like the UK have already made it obligatory to use BIM in the construction projects. A reason for the unwillingness of the experts to use BIM can be because of the complications and misunderstanding in the definition of BIM. Therefore, referring to the authentic resources for understanding the definition and aim of BIM is inevitable. We should notice that BIM is not only a 3D model for planning the structure of the building but also a method for real-time cooperation of the parties. It is a method involving applications containing information concerning the geometry of the construction, data about the geographical environment, the relationship of different parts in distinctive locations, the quantity report of the components and their specifications.[92]

Besides, BIM is not only a modeling method but also a management process; that is why it is more popular to be named as Building Information Management.[93] It gives information management service to the construction projects from the implementation to the end of the life-cycle termination.[94] Overall, BIM, either as a modeling system or as management assistance, has a wide range of applications in construction projects, which will be explained in the following pages.

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[88] Cf. Keskin et al. (2019), p. 882.

[89] Cf. Bryde et al. (2013), p. 1.

[90] Cf. Latiffi et al. (2014), p. 628.

[91] Cf. Azhar (2011), p. 241.

[92] Cf. Mohammad et al. (2018), p. 959.

[93] Cf. Kocakaya et al. (2019), p. 325.

[94] Cf. Ibid

3.3 BIM Levels

BIM has four levels from 0 to 3 which starts from no collaboration to the full collaboration in the level 3.[95]

Level	Description
0	Collaboration: No Output: Paper based or electronically
1	Collaboration: Limited Output: CAD and 3D-modelling which is not shared with the entire team.
2	Collaboration: Development of 3D CAD models by facilitating data exchange within teams Output: Standard file format which enables sharing data and analyzing various model components
3	Collaboration: Complete digitalization of the collaboration of all stakeholders Output: share the project data in the cloud-based system to have appropriate synergy

Table 1- BIM levels

(Source: Own presentation based on Sielker; Allmendinger (2018), p. 15.)

However, Succar (2010) [96] explains the BIM stages as below:

1. Pre-BIM Status / Disjointed Project Delivery: All the plans, even the 3D plans, will be shown in 2D documents. The details of the plan will not be based on the model or the 2D document. The model does not include the cooperation and network among the stakeholders, focusing on linear workflow.
2. BIM Stage 1 / Object Based Modelling: The models will be made by using 3D Softwares like ArchiCAD and Revit for the automation of cooperation between 2D documentation and 3D visualization. The sharing level of the data among stakeholders and their collaboration is the same as the pre-BIM stage; therefore, there is still no appropriate network system among the project participants.

[95] Cf. Sielker; Allmendinger (2018), p. 15.

[96] Cf. Sucar (2010), p. 7f.

3. BIM Stage 2: Model Based Collaboration: The participants start collaborating with each other within one or two phases of the project actively. The software used for cooperation among the team players is based on individual choice.
4. BIM stage 3: Network-Based Integration: By using a network-based collaboration system, the models will be shared among the project stakeholders among various phases of the project.
5. Integrated Project Delivery/ Interdependent, Real-Time Models: In this stage, the focus is on the real-time connection between the n-dimensional models with the databases.

In both the above-mentioned BIM levels and stages, the collaboration and teamwork among the stakeholders start from no collaboration to complete digitalized cooperation, which is the aim of incorporating BIM in AEC projects.

3.4 Application of BIM

BIM technique includes all the components of the building, quantities of the prerequisite resources, geographical condition, geometrical connections, project scheduling, budget assessment for proficient and effective management of resources stock, scopes of work, and progressions that assist the team members cooperation more than the outdated methods.[97] It also contributes to the structural design, facilitates the connection among experts, alleviates the aberration, and facilitates the cooperation of the stakeholders, which was time-consuming in the traditional structural design and led to huge resource damage.[98]

BIM is more than a 3D CAD pattern with which only the 3D illustration of the elements and plans were available; rather it provides straightforward access to operative and execution qualities, material, supplier, preservation elements, cost and delivery time to the stakeholders and in other words, it makes all the components smart objects.[99] BIM is not only a system for simplifying the planning and design phase, but also it assists the implementation phase as well as project management, construction management, asset

[97] Cf. Azhar (2011), p.241.

[98] Cf. Ozturk; Eraslan (2018), p. 31.

[99] Cf. Ding et al. (2014), p. 2.

management, time management, and cost management which all in all helps us to benefit from the proper management of the project from the planning phase to the end of the construction project life-cycle and its demolition.[100]

BIM provides us with efficient accurateness, steadiness, fewer mistakes, and more than that, the information on the BIM can be reused later several times.[101] This is done by saving the information in databases inside the BIM platform, with which it is easier to manage the entire project and its components. [102]

According to Brown et al. (2008)[103], BIM has five phases in the lifecycle of construction projects, as shown in Table 1 below:

Stage	Phase	Function
0	Pre- Design	• Set project parameters and requirements. • Set assessment standards for the performance.
1	Design	• Document the client's demands. • Design a conceptual scheme. • Cooperation between the architect and the project manager.
2	Construct	• Create the construction according to the guidelines. • Evaluation of the project by architect/ project manager. • Architect/ project manager is the owner's representative. • The concluded project is surrendered to the owner.
3	Maintenance	• Known as facility management. • Hard Service: For example: ensure the quality of air conditioning. • Soft Service: For example: ensure the cleanliness of the building.

[100] Cf. Kocakaya et al. (2019), p. 327.

[101] Cf. Brown et al. (2008), p. 4.

[102] Cf. Bi; Jia (2015), p. 1030.

[103] Cf. Brown et al. (2008), p. 4f.

4	Renovation/ Decommission-ing	• At the end of the lifecycle. ⇒ Refurbishment: extending the usable life of the asset ⇒ Decommissioning: Dispose of the components (sale or reuse)

Table 2- Phases of a construction project life cycle

(Source: Own presentation based on Brown et al. (2008), p. 4f.)

BIM is beneficial to be adopted in several stages of the construction project; however, it is not eagerly used by the engineers, contractors, and other stakeholders. It is possible to applause them to exert and integrate BIM in their project by educating them about the rewards of BIM and showing its impact on the profitability of the project.[104]

3.4.1 Advantages of BIM

Cost minimization, time effectiveness, communication advancement, coordination, and quality development are only some of the advantages of BIM.[105] Besides, BIM assists with the enhancement of ROI or return on investment, which is one of the most necessary gauges of indicating performance quality in the AEC industry.[106]

According to Bryde et al. (2013)[107], BIM helps the project management process as in Figure 2 below:

Figure 2- BIM Assistance to project management

(Source: Own presentation based on Bryde et al. (2013), p. 2.)

[104] Cf. Wong et al. (2009), p. 1.

[105] Cf. Bryde et al. (2013), p. 3.

[106] Cf. Mohammad et al. (2018), p. 961.

[107] Cf. Bryde et al. (2013), p. 2

According to Brown et al. (2008)[108], BIM can boost the rate of data transmission, minimize the expected processing time, advance the efficiency of the collaboration, promote the quality of data by using digital databases, more reliable data visualization by proceeding 3D model into a 4D model and reinforce fault-finding as a result of up-to-date data which diminishes the misunderstandings and conflicts. BIM is capable of bringing advantages to the construction project including enhanced quality, more productivity, better design resilience, impressive partnership, lowering rework, advanced marketing, achieving desired project outcomes, diminished faults, time efficiency, more successful communication, substances assessment meticulously, and decreased scrap which all in all contribute to a pioneer project management in AEC industry. [109]

Brown et al. (2008) mentioned the advantages of using BIM in the several phases of the projects as in Figure 3 below:

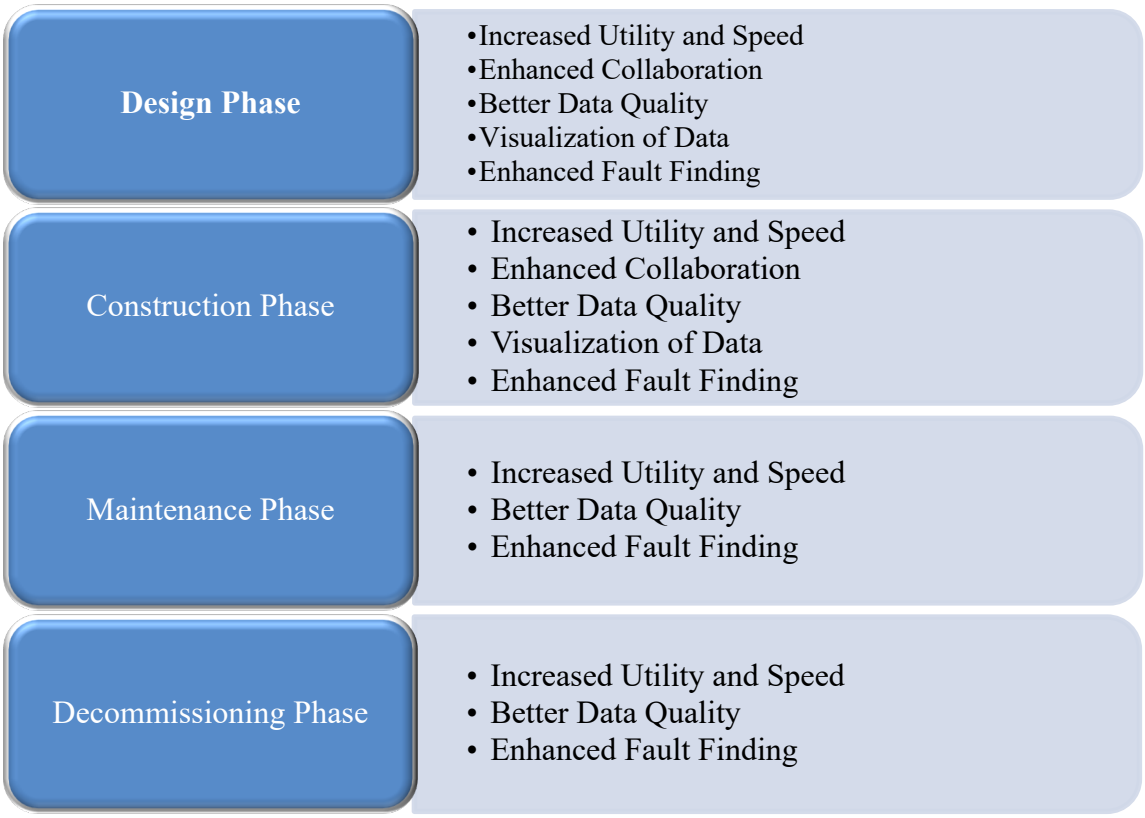

Figure 3- BIM Advantages in Different Phases of the Project

(Source: Own presentation based on Brown et al. (2008), p. 15.)

[108] Cf. Brown et al. (2008), p. 10 – 14.

[109] Cf. Ozturk; Eraslan (2018), p. 29-31.

In a new survey of 36 respondents who were involved in construction projects of public and private sectors of Hong Kong, more than 60% of the participants believed that BIM has a positive effect on design visualization, sustainable design of the facilities, and effective communication. [110]

3.4.2 Disadvantages of BIM

The negative benefits of BIM are limited to software-hardware matters and can be tackled by educating the including parties like stakeholders as well as employees who can help the efficient implementation of BIM in project management.[111] An appropriate BIM structure can grant optimum support to the parties with more successful project management and gives a better perception of the BIM application advantages in the projects.[112]

Brown et al. (2008) [113] categorized the disadvantages of BIM and addressed these barriers which I mention some of the most important ones in Table 3 below:

Disadvantages	Arguments of Opponents	Response to Arguments
Single Detailed Model	• No choice for alternative designs. • Impossible to pick the best scheme out of diverse ideas. • No possibility for what-if scenarios.	• BIM facilitates multiple design possibilities with more precise data and more authentic feedback.
Interoperability	• Various firms use different applications that limit their access to the designs in another application.	• The government should push firms to use the Industry Foundation Classes (IFC standards) in adapting the BIM method.

[110] Cf. Wong et al. (2009), p. 3.

[111] Cf. Bryde et al. (2013), p. 8.

[112] Cf. Ding et al. (2014), p. 1.

[113] Cf. Brown et al. (2008), p. 19 – 23.

Additional Workload for Designer	• More time consuming for the designer to generate the primary drawing.	• Balanced by possibilities like ease of adjustment and data richness.
The Size and Complexity	• Managing BIM's database is an organizational hurdle. • Real-time access to data necessitates high internet velocity. • More powerful security system for the firm's data records is demanded.	• Public policies for data security and the fundamentals of enormous BIM models are available.

Table 3- Disadvantages of BIM

(Source: Own presentation based on Brown et al. (2008), p. 19-23)

3.5 History of employing BIM in construction projects

The need for a new method for decreasing communication failures in construction projects was always known; however, even at the beginning of the 21st century BIM was unknown to the AEC industry members.

3.5.1 Before the year 2000

With the rise of CAD or in other words, computer-aided design in the 1950s and 1960s, BIM emerged, which was followed by releasing CAM or computer-aided machining by Hanratty in 1957.[114]

Ivan Sutherland developed CAD software by generating Sketchpad in his Ph.D. dissertation in 1963, which was a graphical user interface or GUI.[115]

BIM was presented by the Georgia Institute of Technology in the late 1970s and flourished promptly, subsequently due to the enthusiasm of construction companies in exploiting it for the management and construction of their projects.[116] The French Aerospace company, the generator of CATIA or computer-aided three-dimensional interactive

[114] Cf. Mohammad et al. (2018), p. 959.

[115] Cf. Ibid.

[116] Cf. Rokooei (2015), p. 88.

application, the famous software in aerospace, automotive, and shipbuilding industry, made the renovation of 2D to 3D construction planning.[117]

Charlie Eastman was instructing at Carnegie Mellon University in 1975 when he propositioned BIM as a tool in successful construction projects with which alteration in any design can modify all other figures correspondingly.[118]

During the 1980s and 1990s, Autodesk developed AutoCAD, making it a prominent front-runner and leader in the IT or information technology industry, however, in the same period its other competitors like Bentley offered competitive IT solutions for transmission from 2D to nD which were tremendous solutions to the construction projects problems.[119]

3.5.2 After the year 2000

As explained above, the base of BIM was established between 1950 to 2000, however, it was applied in the AEC industry since the middle of the 2000s.[120]

BIM was adjusted later in 2008 as a 3D model simulation tool for project management with making a connection to the necessary data in different phases of the projects.[121]

In 2007, including BIM necessity in the public procurement law, Denmark became one of the leaders of implementing BIM in Europe.[122] In 2014, the European Parliament recommended implementing BIM into public procurement processes.[123] The digital transition plan in the building industry (PTNB) in France in the year 2015 helped the

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[117] Cf. Mohammad et al. (2018), p. 959.

[118] Cf. Bia; Jia (2015), p. 1029.

[119] Cf. Mohammad et al. (2018), 959f.

[120] Cf. Azhar et al. (2012), p. 15.

[121] Cf. Latiffi et al. (2014), p. 627.

[122] Cf. European Construction Sector Observatory (2019), p. 9.

[123] Cf. Smith (2014), p. 484.

improvement of the focus on BIM employment.[124] Also, the Polish government has supported the implementation of BIM in its construction industry by new policies recently.[125]

3.6 Communication in construction projects

Communication is the procedure of clarifying and transferring the obtained appropriate knowledge or piece of information to the parties who have the demand for it to make decisions.[126] BIM can help the project with the condition that there is an appropriate structure for communication of the stakeholders and beneficiaries in the projects as well as integrating a proper tool for implementing BIM method.[127]

3.6.1 Communication, Combination of Factors

Communication performance is not only based on unique individual components; instead, all the different components in the project, including participants, mediating instruments, social components, cultural factors, all the tools used in the project, etc. will contribute to the efficiency or inefficiency of communication within the project.[128]

The contribution of every active member to the project is based on his role responsibilities which should be mentioned in the formal conditions of the role; however, the communication at the operational level is also dependant on the informal intercommunication between project members including trust establishment, organizational hierarchies' sustaining, integrated technologies in the project, etc. [129] In fact, the relationship between the various factors in the construction project has a more critical role than the system itself in building efficient communication.[130] The use of a tool that can unite the diverse factors in a construction project can shape more effective communication. This tool should be able to assist the project participants in accessing real-time data regarding the progress of the project uninterruptedly.

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[124] Cf. European Construction Sector Observatory (2019), p. 9.

[125] Cf. Ibid, p. 10.

[126] Cf. Zulch (2014), p. 1001.

[127] Cf. Kocakaya et al. (2019), p. 327.

[128] Cf. Gulch; Räisänen (2009), p. 166.

[129] Cf. Zerjav; Ceric (2009), p. 909.

[130] Cf. Zhong; Low (2012), p. 88.

Information loss is a result of the shortage of access to the appropriate communication instruments, which makes it challenging to reach the precise data at the accurate time when it is required; however, with the emergence of new technologies in the communication, information management to access the proper information on the construction projects is easier nowadays.[131] The deficiency of effective communication between the project parties and stakeholders, including owners, architects, constructors, suppliers, and users, can be resolved by the support of BIM using a 3D digital model of operational and construction process simulation.[132] However, the structure and the procedure of communication in the construction project should be inspected before executing any ICT technology.[133] The effectiveness of communication in construction projects is subject to sociological, managerial, and technological associated issues.[134] As a result, the structure of the communication in the project should be defined with details in a formal model which obliges everyone in the project to follow this model on a daily basis in their everyday tasks and responsibilities.[135] This formal model can assist with shaping all the sociological, managerial, and technological aspects of the project.

3.6.2 Communication Disorders in Construction Projects

Since the construction projects include a variety of communication channels among participants, consist of organizations with various cultures as participants instead of individuals, and have a long life with different tasks which will be held by ever-changing contractors in different cycles of the projects, communication is a complicated phenomenon in construction projects; therefore, it is challenging to diagnose the deficiencies.[136]

With the growth of crisis disturbances and complexities alongside the changes in technology and society, the communication system of the organizations and within the

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[131] Cf. Herstad et al. (2015), p. 391.

[132] Cf. Bi; Jia (2015), p. 1029f.

[133] Cf. Adriaanse; Voordijk (2005), p. 160.

[134] Cf. Zerjav; Ceric (2009), p. 908.

[135] Cf. Ibid, p. 914.

[136] Cf. Tai et al. (2009), p. 138.

projects is under extra pressure to react perfectly in the case of an internal or external crisis that might affect the performance of the project.[137]

Tai et al. (2009)[138], in their study about Chinese construction projects, mentioned the below reasons for the communication problems in such projects:

1. Lack of good communication mechanism: Not having a proper mechanism for communication within the project makes it easy for the participants to behave based on their own benefits and avoid sharing information with the other parties. They consider their information confidential and wouldn't intend to share the information, which results in less willingness for active communication with others.
2. Weak organizational structure of teams: There is a linear structure for communication in the traditional types of construction projects. Therefore, the long process for delivering the data makes it challenging to deliver the data accurately from the top management to the lowest construction workers.
3. Lack of uniform standards for construction information: The construction projects are gradually expanding in scope; consequently, they consist of plenty of professionals and organizations which participate in the construction of the projects. Each of these organizations has its organizational norms, language, and expressions. In the nonexistence of a united norm in the industry, the projects encounter more problems in their day to day communication.
4. Lack of support for advanced technologies: The construction industry is labor-based comparing to the manufacturing industry. Moreover, the technology which was presented in the 1960s is mostly used for CAD, information generation, and data analysis and not for information transmission during the construction process.

Overall, for improving the communication quality in the construction projects, proper structure, mechanism, and standard should exist in the construction industry, making it obligatory for all the project participants to share the data of their work and progress state at each point of time. The new computer technology can help them reach the goal of

[137] Cf. Zhong; Low (2009), p. 270.

[138] Cf. Tai et al. (2009), p. 143f.

effective and efficient communication in construction projects. The obligatory implementation of BIM in some countries can help the parties not only think about their own interest and start giving the necessary information which is required by the other project team members and contractors.

3.7 BIM and Project Management

Since it is simpler to comprehend 3D sketches of the construction facility than the traditional 2D models, BIM can enhance communication among the project beneficiaries.[139] BIM helps design new buildings based on the previous models; therefore, it is not necessary to design everything from zero point which makes BIM a more robust method than the traditional methods in which the stakeholders had to imagine the 3D model in their brain based on the 2D sketches.[140] The n-dimensional models which are provided by BIM assist the project management by helping the stakeholders and project members having a better understanding of the final outcome of the construction facility.

There is a two-way direction between BIM and project management because BIM as a system feeds the project management with managing the information among the stakeholders, which will lead to the satisfaction of them and is the goal of the project management; therefore, BIM is a matter of project management.[141] As a result, BIM is correctly named not only the Building information modeling but also Building Information Management, which can help the project management's information management need appropriately.

BIM has a positive effect on cost, time, communication, cooperation advancement, and quality of the project, while the negative impacts are only about the software and hardware factors of using BIM.[142] One might think that using BIM will impose extra management costs for training the employees on BIM concepts however one can look at

[139] Cf. Fazli et al. (2014), p. 1120.

[140] Cf. Ibid.

[141] Cf. Travaglini et al. (2014), p. 1058f.

[142] Cf. Bryde et al. (2013), p. 978.

it this way that these costs are one-time costs which can boost not only this project but also the quality of the future projects by these trained employees of the organization.[143]

3.7.1 BIM vs. PMBOK

It is possible to compare the BIM capabilities with the knowledge areas of PMBOK, as Rokooei (2015)[144] mentioned, as below:

1. Integration Management in PMBOK: BIM combines all the details of the project , including documents, plans, and development status.
2. Project Scope Management in PMBOK: With classifying various components of the construction facility and splitting it into several categories, BIM as an object-based system can resemble this knowledge area of PMBOK.
3. Time and Cost in PMBOK: BIM with 4D and 5D methods can have control over time and cost, like cost and time management in PMBOK.
4. Risk in PMBOK: BIM can decrease the risks of the construction; however, it cannot showcase all the risks.
5. Quality in PMBOK: It is similar to BIM's clash detection of soft and hard conflicts.
6. Human Resources Management in PMBOK: It resembles the collaboration and forming teams in BIM.
7. Communication in PMBOK: It has the same function as BIM's communication capability, which is the main purpose of BIM. BIM facilitates communication among various components of the project.
8. Procurement Management in PMBOK: BIM can alter cost, time, and required work for procurement as soon as any element changes in the project.

3.8 Smart Cities

With the intense rise of population and urbanization, IoT or Internet of things has been proposed as an ICT solution for the development of city administrations.

[143] Cf. Ibid.

[144] Cf. , Rokooei (2015), p. 91f.

Consequently, the smart city idea emerged as a resolution to the increase of the tendency for urbanization, which can assist with the city processes and challenges.[145]

With the representation of the smart cities to improve the quality of life in the areas besides the increase of urbanization, BIM has become a necessary known application for the management and sharing of the data of the buildings throughout their life cycle.[146]

As Internet-of-Things (IoT) concept is about connecting the physical and virtual devices, it focuses on enabling communication and the data that can be retrieved from 'Things' about other 'Things', which is, in other words, 'State of Things'.[147] Every 'Thing' will inform the system about its new state as soon as any change in its state happens; moreover, it will be clever enough to be informed about any change of any other 'Things' state right away.[148]

3.8.1 Communication in smart city projects

The idea behind the smart cities of the future is that BIM will spread the details of the building while IoT nodes should share the real-time data about the inside of the building through its life cycle. Therefore, every object in the building, even the furniture, and pieces of equipment will be connected to a virtual sensor.[149]

Smart cities need appropriate ICT solutions to facilitate communication in their project management from the planning and construction phase to facility management, traffic management, and so on. In fact, project management and communication in smart cities have a broader range than construction projects.

However, the concept of IoT in smart cities and consequently implementing BIM is not only related to the project management of buildings but also controlling the different devices and components within the smart cities. One of the most challenging tasks in smart cities is making connections among billions of devices and components without

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[145] Cf. Silva et al. (2018), p. 697.

[146] Cf. Ma; Ren (2017), p. 1072f.

[147] Cf. Isikdag (2015), p. 33.

[148] Cf. Ibid.

[149] Cf. Ibid, p. 34.

any error.[150] As Yaqoob et al. (2017)[151] illustrated, smart cities will be a combination of smart people, smart homes, smart parking systems, smart waste management, smart electricity transmission, smart ambulance, smart transportation, smart sea monitoring, etc.

Therefore, the technology and network for making the connection between the devices mentioned above in the smart cities have the features to help with the below concerns, as Theoleyre et al. (2015)[152] mentioned:

1. In Smart Cities, there is a high amount of data being created by an extremely large number of smart devices.
2. Strange interdependence among the traffic patterns exists because of huge synchronizing data among smart devices.
3. The Internet has a structured atmosphere, however, the nature of Smart Cities in which the communications are based on the wireless network is unstructured.
4. There are numerous types of technologies active in Smart Cities that coexist with each other. There should be an appropriate system to help with the caused heterogeneity among them.
5. There should be a system that can protect the security, privacy, reliability, validation, and secrecy of data among Smart devices.
6. The technology should be competent in solving coexistence matters regarding the interference made by numerous radio stations being deployed in the same area.

The below ICT features can help BIM, as Isikdag (2015) [153] mentioned, for providing appropriate communication in the smart cities:

1. **Cloud Computing:** It is based on the virtual hardware and software system and consists of SaaS or Software as a Service, PaaS, or Platform as a Service, IaaS, or Infrastructure as a Service, data centers, and data warehouses visualization. The data of BIM can be easily distributed through cloud computing platforms.

[150] Cf. Yaqoob et al. (2017), p. 2.

[151] Cf. Ibid, p. 3.

[152] Cf. Theoleyre et al. (2015), p. 1.

[153] Cf. Isikdag (2015), p. 35f.

2. **Real-Time Information:** BIM is a method that gives us not only geometric aspects of the building but also information about the material applied in each component of the structure. However, BIM cannot demonstrate the status of every segment itself. For showing the current situation, it needs the cooperation of IoT with which it can show if the elevators and escalators are running or not, if the cooling system is operating, if the door or window of a section in the building is open or close, how many people are in the different locations of the building. This information will be retrieved by the nodes and sensors set up in diverse construction facility locations.
3. **RESTful Web Services:** Using HTTP protocol systems, the shared BIM can be updated with real-time data about the project's situation right away.
4. **Big Data:** With the unification of the data which comes from distinct resources and organizing it in an appropriate way to be adjusted to the city modeling standards, it is likely to use the Big data to compare and analyze the smart city's detailed data. For example, this can be used to compare various components in a city during a particular time of the day.

3.8.2 Project Management in Smart Cities

As cities grow, they need proper management to tackle their problems with the right project management; otherwise, the disadvantages will outshine the advantages.[154]

The focus of project management and enhancing communication in smart cities is based on the use of IoT and ICT technology. Using the newest technology for smart energy management, smart traffic, and smart transport for smart project management of the city sounds vital.[155] On the other hand, the external and internal threats like hackers can threaten the security and privacy of the citizens and the data which is transmitted in real-time during the process of smart management of the city.[156]

The hurdles in the smart project management of smart cities include the shortage of awareness about the ICT systems and the chance of the systems to be hacked, demand

[154] Cf. Monzon (2015), p. 20.

[155] Cf. Bohli et al. (2015), p. 3f.

[156] Cf. Ibid, p. 2.

for notable financial support for the smart foundations, project complexity because of restrictions in the cooperation amid various stakeholders, absence of qualified management and teams which leads to wrong decisions, and the social challenges regarding educating the citizens about smart city projects.[157]

3.9 Relevant previous studies

Zulch (2014)[158] studied "Communication as the Foundation of Project Management" and concluded that communication has a primary role as a tool for incorporating cost, scope, and time to accomplish a quality outcome. Thus, the project manager should concentrate on communication quality as the first success factor of the project. According to Naqvi et al. (2011)[159], stakeholder communication should not be the second priority in project management, and its importance is significantly high compared to the other factors of the project. Therefore, there is a vital need for using BIM as a tool that can facilitate more effective communication. BIM with its six standpoints consisting of design, estimation, construction process, building life cycle, performance, and technology is a mean of a management gadget for better collaborative teamwork between the participants in construction projects in AEC industry.[160]

Azhar (2011)[161] mentioned that, BIM can lead the way through superior implementation in AEC industry by boosting teamwork and diminishing disintegrations since in the old-fashioned methods the parties would not attempt to discover the other party's errors, though, with the advantage of BIM it is possible to determine each other's failures because everybody perceives themselves as the members of the same team that can result in the least construction defeat and acquisition desirable outcome in the construction project.

As the world is going towards constructing smart cities for the future of humankind, the AEC industry is becoming more critical every day. Unfortunately, the AEC

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[157] Cf. Alshahadeh; Marsap (2018), p. 47f.

[158] Cf. Zulch (2014), p. 1009.

[159] Cf. Naqvi et al. (2011), p. 5829.

[160] Cf. Latiffi et al. (2014), p.628.

[161] Cf. Azhar (2011), p. 251f.

industry has been performing less productive comparing to the other sectors.[162] As Hoezen (2006)[163] mentioned, the communication problem between the demand and supply side in the projects in the construction industry is more severe than the other sectors. Therefore, scholars have been trying to do research and analysis to find a way to improve its performance in the latest decades. As a result, the AEC industry started applying BIM as a new method for visualizing the project progress to decrease communication barriers. As Pérez Gómez (2017)[164] said, BIM could facilitate most of the communication problems in a project, which are because of the lack of a proper documentation management system. In the beginning, it was not easy to engage the stakeholders' enthusiasm in using BIM in their construction projects. The enthusiasm for applying BIM in the projects increased after the UK Government's announcement in 2011 for the obligation of using BIM in procured public sector projects by 2016.[165]

Lindblad (2013)[166], conducted the "Study of the implementation process of BIM in construction projects" and concluded that the interested individuals in an organization could contribute effectively to apply this method in the projects when they have an impeccable understanding of BIM. A better understanding of BIM will help in having better collaboration, productivity, and insight of the project performers. As Melzner et al. (2015)[167] mentioned in their study about "The influence of Building Information Modeling on the communication management of construction projects", BIM is a crucial factor for the success of the project and the proper maintenance of the building throughout its life cycle, therefore, developing qualified technicians and BIM coordinators is vital. Keskin et al. (2019)[168], in their study about the challenges and enablers of BIM application in the case study of Istanbul Grand Airport (IGA) in Turkey, summed up that BIM has a remarkable function in facility management of the construction project in the scope

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[162] Cf. Lindblad (2013), p.1.

[163] Cf. Hoezen et al. (2006), p. 18.

[164] Cf. Gomez (2017), p. 49.

[165] Cf. Hardi; Pitard (2015), p. 366.

[166] Cf. Lindblad (2013), p. 58f.

[167] Cf. Melzner et al. (2015), p. 8.

[168] Cf. Keskin et al. (2019), p. 888.

of power exertion on the subcontractors, supervise operations in the project location, recuperate quality of operations in different phases, rapid solution for complications on-site, and boost the concerted effort. Worden (2016)[169] studied “Implementation of Building Information Modeling into an integrated project delivery contract to encourage project teams to communicate” and found out that the interested parties should mention BIM in the contract and discuss it to be able to understand the application process of BIM better. However, BIM like any other new system or device, which is applied to improve the documentation process and communication, needs training.[170]

With the growth of the population in cities, policymakers must devise new methods to overcome the challenges of population concentration in metropolitan areas. It seems that smart cities can bring qualities to the urban areas that can solve the complication caused by a high population. Smart cities are in the focus of today's media and governments planning for solving challenges in the major cities in the upcoming decades. Yamamura et al. (2017), conducted a study about "Assessment of urban energy performance through the integration of BIM and GIS for smart city planning" and stated that using BIM and GIS, in combination as a tool for suggesting solutions for future smart cities, will enable comprehensive analysis and data unification across the existing projects and the forthcoming smart cities.[171]

In a case study of BIM maturity level in Ningbo (China), Kang et al. (2018)[172] said that BIM ability for collaboration of the project stakeholders is considered more essential than traditional project elements like budget or period of the project; however, there is a gap between the expertise of the BIM users and the market requirements which should be accomplished by educating the users.

Al Sayed et al. (2015)[173], BIM can help with providing network-based models in solving the complexity in the operation phases of smart cities infrastructure projects.

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[169] Cf. Worden (2016), p. 78f.

[170] Cf. Svalestuen et al. (2017), p. 217.

[171] Cf. Yamamura et al. (2017), p. 1471.

[172] Cf. Kang et al. (2018), p. 103.

[173] Cf. Al Sayed et al. (2015), p. 1.

These complexities might arise because of imperfect communication among the project performers, which would continue to result in inefficiencies in the buildings' maintenance in the future as well. BIM has the potency of simplification the communication between the design and construction units which will result in advanced quality within less budget.[174] Every smart building will be a small part of the whole smart cities; therefore, the problems caused by ineffective communication might prevent successful functionality in future smart cities.

The effectiveness of BIM in the quality of the communication process of construction projects is undeniable; however, it is necessary to find out the effectiveness of BIM in more significant projects like smart cities. According to Shaikh et al. (2017)[175], after we prove the positive capableness of BIM in smart cities projects, we can study on BIM functionality for greater geographical regions like smart countries, smart continents and smart planets.

Kocakaya et al. (2019)[176], studied the impact of BIM via a case study of a sales-office in a construction project which will have the multi-functionality of a hotel, shopping mall, and residences and found out that BIM can reduce project costs and duration significantly.

[174] Cf. Bi; Jia (2015), p. 1036.

[175] Cf. Shaikh et al. (2017), p. 15f.

[176] Cf. Kocakaya et al. (2019), p. 331.

4 Case- Study

4.1 Singapore

Singapore is one of the advanced users of BIM and one of the four Asian Tiger economies in Southeast Asia.[177] With one of the most intense populations in the world and without having natural resources, Singapore could grow into a global commerce center and provided an environment for business, with which, was able to reach the most economic growth in Asia equal to 15% in 2010.[178]

Singapore is not only looking for building a smart city but also a smart nation and a smart state. With building up secure infrastructures, Singapore could prove itself as one of the smartest cities in the world by having one of the highest income per capita for its low population of 5 million, owning the second biggest airport in Asia, locating 6 thousand multinational companies, and occupying the first position concerning economic business in the world.[179] The idea of building up a smart city was not only limited to the building construction facilities and digitalization but also building underground facilities like commercial places, expressways, water tunnels, electrical tunnels, pedestrian spaces, highways and subways which will be all in the underground. This can be a fantastic plan for a country with the issues of facilitating the traffic in a small space.

Singapore, as a small island country which is known as the smartest city worldwide, is heavily relying upon cloud computing, the Internet of Things (IoT), digital information and communication, and multiple technologies.[180] These are the means of technology that can facilitate the proper communication needed for easing the traffic issues and complex problems in the future smart cities of the world.

The idea of helping people connect to the government's digital facilities has become vital for the aim of having a smart nation:

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[177] Cf. Sielker; Allmendinger (2018), p. 21.

[178] Cf. Lee et al. (2016), p. 3.

[179] Cf. Sanseverino et al. (2017), p. 130.

[180] Cf. Rassia; Pardalos (2017), p. 34.

"It becomes evident that digitalization is the main factor in enhancing liveability—connecting the community to government services and digital technology—and this can equally provide economic benefits."[181]

Singapore has done it successfully so far to become the smart city of the future; it is giving reality to what was being interpreted as science fiction of the past.

4.1.1 BIM Use in Singapore

In the recent decade, Singapore commenced concentrating more on the implementation of BIM by the Building and Construction Authority (BCA) program, which aimed to increase executing the management and technology systems and diminish the labour technology-based to shrink the enormous quantity of foreign workers on its construction projects.[182]

Singapore aims to shrink the number of foreign workforces from the countries of India, Bangladesh, Myanmar, and China whom their skills don't fit the standards of general contractors in Singapore; therefore, it aims to implement BIM to lessen its demands to these foreign workers.[183]

According to Ofori (2015), BIM implementation include the below items:

> "(a) the development of a national roadmap and a series of technical guides; (b) appointment of a broad-based national steering committee; (c) a series of training programmes for practitioners playing different roles in the industry; (d) incentive schemes, mainly under the BIM Fund. The fund, which is part of the Construction Productivity and Capability Fund (CPCF) for BIM adoption, covers the costs for training, consultancy services and purchase of hardware and software for businesses and projects."[184]

According to BIM regulations in Singapore, the construction projects with more than 20,000 square meters gross floor areas had to perform e-submission of their plans according to BIM modelling from 2013 and from 2015 they had to follow the e-

[181] Cavada et al. (2019), p. 298.

[182] Cf. Ofori et al. (2015), p. 11f.

[183] Cf. Kaneta (2016), p. 1306.

[184] Ofori et al. (2015), p. 12.

submission regulation of their plans for the buildings with more than 5000 square meters gross floor area.[185]

As said, the Singapore government has set BIM regulations to be applied in the construction of the projects:

> "Singapore has substantially accelerated BIM adoption with the implementation of the first BIM roadmap by BCA (Building Construction Authority). Over the past five years from 2010 to 2015, BIM has gained significant popularity in Singapore's built environment…BIM implementation in the public sector was initiated with selected projects between 2010 and 2012. Subsequently, mandatory BIM e-submissions were enforced progressively between 2013 and 2015 with specific milestones given to the architecture and engineering disciplines. By July 2015, it was stipulated that architecture and engineering BIM e-Submission be implemented to all new building projects with gross floor area (GFA) of 5,000 m^2 and above."[186]

Singapore has set the obligation for using BIM in projects; however, the drawings designed by architects and consulting engineers didn't have the standards to coordinate in different projects; therefore, the new positions of BIM manager and BIM coordinator arose for helping with the execution of BIM plan.[187] The BIM manager can facilitate the correct e-submission of BIM; thus, there will be more productivity with lessening the time that might be required for redrafting the design drawing over and over again from project to project.[188]

As Sielker & Allmendinger (2018)[189] stated, Singapore went through the below steps in implementing BIM:

Year	Step
2000	• Organized the so-called Construction and Real Estate Network (CORENET) program.
2011	• Targeted advancement of the productivity of the construction industry to 25% for the upcoming ten years.

[185] Cf. Ibid., p. 12f.

[186] Shen et al. (2016), p. 261.

[187] Cf. Kaneta et al. (2016), p. 1307.

[188] Cf. Ibid.

[189] Cf. Sielker; Allmendinger (2018), p. 21f.

	• Devised the educational BIM Specialist Diploma program.
2012	• Drove BIM Fund program for training, consultancy, hardware, and software cooperation to enhance industry integrity.
2015	• Launched BIM Awards for project and organization. • Targeted BIM level 3 development.
Example	The reconstruction project in Marina Bay Sands was developed solely by BIM. The construction challenges were addressed by BIM, which shortened the planning phase effectively. The obligatory regulations for submitting all the plans related to the construction of the project via BIM assisted the deep use of BIM in this project.

Table 4- Summarized Singapore Steps in Implementing BIM

(Source: Own presentation based on Sielker; Allmendinger (2018), p. 21f.)

Singapore has made e-submission of the plans mandatory; therefore, 100 percent of the plans are being submitted in the e-submission system, which could help with saving time and cost, plus enhanced the productivity of the employees of various teams within the organization.[190]

Like any other technology, BIM can have some barriers to being implemented. Shen et al. (2016)[191] had an unstructured interview with the members of the project management team of an organization in Singapore over the constraints for implementing BIM in the projects in Singapore and found the barriers as listed below.

1. **Cost** barriers related to the infrastructures which should be build for implementation of BIM. These costs include the costs for initialization of this method as well as facility management maintenance infrastructures.
2. **Time** required to reach the maturity to fit BIM standards for implementing BIM in facility management might be lessened in the future; however, currently, this period, which can be between 10 to 12 years, might demotivate the project owners to incorporate BIM.

[190] Cf. Mahdjoubi (2015), p. 428.

[191] Cf. Shen et al. (2016), p. 266f.

3. **Return on Investment (ROI)** can be between 6% to 8%, making it difficult to get acceptance for running BIM methods from senior management.
4. **Technical Competency** because of the lack of employees with technical backgrounds. The workforce in the entire system of the project should be therefore trained, which increases the costs for BIM implementation.
5. **Massive work** of adopting the BIM model in the entire system, which consists of a variety of sectors that are using the system, which has to be converted to the BIM integrated method. This needs extensive work.
6. **Software** offers for implementing BIM are too many, which makes it difficult for the organization to select which one can be the most beneficial to be used in the entire organization for unification purposes.
7. **Reformations** in the structure of managing documentations and assets which are complex itself. Adopting BIM needs extra changes to the structure of the organization, which will make the reformations more complicated and will be an extra burden for the organization.
8. **Priority** of the organization budget is for investing in the other business functionalities instead of the facility management area.
9. **Intangible assets** should be presented in tangible form or in dollars to persuade the senior management to use BIM, which can be an intangible asset for the organization.

According to Mahdjoubi (2015), Singapore issued 300,000 work permits to the foreign labours to work in the AEC industry in June 2013, which can be a sign of deminishing productivity.[192] This workforce is not an IT knowledgeable workforce and cannot contribute to the enhancement of BIM implementation.

However, the AEC industry could perform almost successfully after the implementation of the BIM roadmap by Building and Construction Authority (BCA), which targeted 80% of the industry to use BIM by 2015 and is supported by strong economic considerations and education in Singapore.[193]

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[192] Cf. Mahdjoubi (2015), p. 429.

[193] Cf. Ibid.

4.1.2 ITS Projects in Singapore

Singapore is implementing the latest ICT advancements for better control of the state-city and making the smartest state-city or, in other words, the smartest nation in the world, while the other countries are struggling to make some of their cities smart.[194]

With the advancement of ITS or Intelligent Transport System, Singapore has been able to help with transportation management by providing citizens with the below transportation services[195]:

Transportation and Urban Mobility Services	
ONE.MOTORING	A platform that provides citizens with traffic images every 5 minutes. It also advises repairing, buying, or selling the citizen's vehicles. Available parking spaces can be seen on this portal to prevent extra traffic while looking for a parking space.
EMAS and VRS	In the case of an accident, the recovery team will be on-site in 15 minutes and transfer the crashed vehicles out of the main road right away.
Your Speed Sign	To encourage drivers to stay in the limited speed, this application warns them if they pass the quota in real-time.
Bus Information system	Via the MyTransport.SG App, it is possible to access real-time information about the buses as well as available seats and available standing spaces on the bus.

Table 5- Transportation Apps in Smart Singapore

(Source: Own presentation based on Lee et al. (2016), p. 8 - 10.)

The above-mentioned available apps are only a few examples of Singapore's future plans for the next 40 years to have a smart city-state. These and many other cloud-based plans help the future implementation of IoT in Singapore and support the connection of different stakeholders in the smart nation.

[194] Cf. Lee et al. (2016), p. 6.

[195] Cf. Ibid., p. 8.

4.1.3 Intelligent Productivity and Safety System (IPASS)

This intelligent service uses BIM as its platform and helps the construction industry diminish the problems regarding the productivity and safety of the construction projects.[196] The idea of IPASS is to recognize the safety issues before the beginning of the project based on the Construction Safety Audit Scoring System (ConSASS), which incorporates BIM as a precious tool for advancing the safety of the project.[197]

This system can bring new opportunities to the AEC industry with providing the solution for the projects' problems using the advantages of implementing it with BIM modeling which can boost the cooperation and communication among the stakeholders and enable them to recognize the safety challenges and risks in details and reduce them before starting the project.[198]

BIM can help the IPASS system with recognizing the hazards in the design phase; therefore, IPASS will be able to take proper actions in advance to diminish the amount of unwanted dangerous incidents and decreases the rework of the various stakeholders cooperating in the construction project.[199]

IPASS can play the role of a solution alternative for problems related to the low productivity and poor safety performance by improving the information flow, enhancing the communication and advancement of collaboration among the stakeholders which help them to have knowledge about any changes in the decisions or factors of the project as well as the pre recognized safety risks.[200]

4.1.4 Addressing Communication Challenges by BIM in the projects in Singapore

Lack of proper communication in construction projects can lead to various disadvantages in the projects in Singapore, diminishing the productivity. Some of the

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[196] Cf. Lin Toe et al. (2016), p. 8.

[197] Cf. Tjandra et al. (2016), p. 1.

[198] Cf. Lin Toe et al. (2016), p. 9.

[199] Cf. Tjandra et al. (2016), p. 14f.

[200] Cf. Lin Toe et al. (2016), p. 9.

negative effects of inefficient communication which can be addressed by BIM are explained as below:

1. **Rework:** Various stakeholders can cause rework, mainly because of the lack of proper communication among them in the project.[201] Nonsufficient information exchange among them about the project's details, the decisions modifications, and the changes in materials can lead to misunderstandings and increase the rework load for various stakeholders in the project.[202] Hwang et al. (2019) believed that the BIM framework could diminish the failures which cause rework, which is a top benefit of using BIM.[203]
2. **Productivity:** The Singapore government aims to diminish the workforce on the construction site and enhance the relative technology. Singapore government requested the designers to develop buildable designs and technology, which can decrease the need for the massive labor force.[204] Therefore, the use of BIM as a means of facilitating communication and coordination among the stakeholders for increasing productivity is vital to the construction projects.[205]
3. **Workplace Safety and Health (WSH):** Singapore aims to decrease the number of accidents that happen to the workforce while working on construction sites.[206] Fatality Rate in the Construction industry in Singapore is surprisingly high.[207] It is common in Singapore that the contractor transfers the work to subcontractors and they give it to another subcontractor or company to finish it; therefore, employees from different companies will work on the same site, and most of the times it is not possible to make proper communication and collaboration among them which can affect the safety performance.[208] The workers and supervisors on the site come from different countries and speak various languages; therefore,

[201] Cf. Hwang et al. (2019), p. 04018125-3.

[202] Cf. Ibid.

[203] Cf. Ibid. p. 04018125-5.

[204] Cf. Ai Lin Teo et al. (2017), p. 5.

[205] Cf. Ibid.

[206] Cf. Ai Lin Teo et al. (2015), p. 10.

[207] Cf. Ling et al. (2009), p. 717.

[208] Cf. Ibid. p. 718.

sometimes they don't have a common language to build up effective communication, and the messages cannot be transmitted from one to another correctly hence increases the effect of the danger on the workers which is not known to them because of the lack of efficient communication and knowledge.[209] It seems that having a common system among the diverse workforce of the project to alert them in the case of danger in advance can save their lives and increase the project's safety performance. This can bring enough collaboration and communication to the project. BIM helps with simplifying the communication and coordination among the design team contractors and clients and even workforce to work according to the real-time information and changes to the plan.[210] Many of the projects should be done at a fast speed, which can make conflicts. BIM can help the safety manager and project manager by alerting them of upcoming safety issues on the site and helps them to manage the workforce and the project safely to reach rough deadlines.[211]

4.2 London, United Kingdom (UK)

There are various cities in the UK that the government has planned to make them smart like London and Manchester; however, London is glowing on top of the list. London could get a top rank based on the CIMI or Cities in Motion Index for successive years.

Cities in Motion Index is the measure based on 10 dimensions introduced by the University of Navarra for assessing the city smartness level following the smart city's standards.[212] Based on the CIMI measure, London could have the smartest city's position in 2015 and the second smartest city in 2014, 2016, and 2017.[213]

London has a high population equal to almost eight million people who speak beyond 100 diverse languages with a combination of ancient and modernity in its city

[209] Cf. Ibid. p. 725.

[210] Cf. Ai Lin Teo et al. (2015). p. 15.

[211] Cf. Ibid. p. 16.

[212] Cf. Sorin-George; Andrea (2018), p. 112.

[213] Cf. Ibid., p. 114f.

structure.[214] Looking at the mortality and fertility rates, the population might increase to around nine or ten million between 2030 and 2050.[215] For being able to manage this population and control the traffic, which is caused by everyday movements of the people within the city, the city governors need to think of advancements to reach the smart cities' standards to overcome the issues caused by this enormous population.

> "Nevertheless, London has a very long way to go in retrofitting its ancient housing stock into „smart" uses, upgrading its Victorian infrastructure - sewage, water mains, public transport, waste disposal, and to reuse waste heat, increase efficiency in energy use, and supply digital broadband and wifi facilities which are much more advanced with wider coverage in many other cities."[216]

According to what Ryser (2014) said in the above quotation, London needs deep renovation in its construction facilities and houses to be able to comply with the standards of a smart city. As any smart city needs more digitalization and implementing IoT in its everyday activities, a digital system for improving communication in its construction facilities is an inevitable issue.

Watson (2013) believes that by 2050 enormous renovation for the strengthening of the buildings in London will be taken; however, 50% of the buildings remained from the 2000s will still be available in which their energy consumption will be lowered with tremendous renovations.[217]

4.2.1 Smart Projects in London (UK)

The smart projects in London are all endeavors on the track of making a smart London which is mainly focused on the cloud-based digitalization and incorporating IoT for facilitating the real-time data collection and making it accessible by the citizens. However, these all need some infrastructures which can be made by building up necessary construction facilities by the AEC industry.

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[214] Cf. Bell et al. (2013), p. 1.

[215] Cf. Mateos (2013), p. 15.

[216] Ryser (2014), p. 453.

[217] Cf. Watson (2013), p. 50.

4.2.1.1 Smart Parking Service

This facility is offered by London to overcome the pollution and massive traffic issues, which helps with saving 68 pounds on petrol per driver and decreases 238.14 the emission of CO2 per car every year. Overall, London can save 183.6 million pounds of petrol and diminish 642,978 tons of CO2 emission per year.[218]

London is a city with so many cars which are making high traffic jams on the roads and streets. Therefore the Westminster City which is a city in Central London started running the pilot program for smart parking in 2012 by setting up 189 wireless sensors which could help with the data collection to be used in an app called ParkRight to give accurate real-time information to the drivers to have enough knowledge about the available parking spaces.[219]

4.2.1.2 FixMyStreet Service

The UK provides its citizens with this service so that in the case of any issues in the city's infrastructures, the citizens can register their complaints.[220] It was first issued as a website in which the residents could report the problems; however, today it has expanded its form to mobile applications that can be included in the website of each city in the UK which enable the app to send the issues received from the citizens directly to the responsible authorities of the same city for further follow-ups and maintenance.[221]

4.2.1.3 Smart Building Management Service

It includes the systems which are connected to the sensors in the buildings and helps the facility management team to manage the heating system, cooling system, electricity, and lighting control systems, safety mechanisms, and the other facilities of the building.[222]

4.2.1.4 Smart Waste Management Service

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[218] Cf. Peng et al. (2016), p. 845.

[219] Cf. Ibid., p. 853f

[220] Cf. Walrvens (2013), p. 27.

[221] Cf. Ibid., p. 28.

[222] Cf. Peng et al. (2016), p. 848.

It consists of the idea to position smart trash cans in buildings, public areas, commercial facilities, houses, and other construction facilities to manage the waste system smart.[223]

4.2.1.5 London Bike App

This app gives service to the users to find the available bikes for transportation in London under the system of Transport for London (TfL), which is the relative organization for managing transportation in the Great London.[224] This app is only available on iOS developed by Big Ted Ltd to offer real-time data of London to residents.[225]

4.2.2 BIM Use in UK

For becoming the pioneer in adopting BIM fast, UK set the Government Construction Strategy in 2011 to make BIM obligatory in all governmental projects from 2016.[226] UK endeavored to reach level 3 of BIM; however, it was successful in reaching level 2 by April 2016 and restated its aim to reach level 3 in Government Construction Strategy 2016 – 2020.[227]

Since 2016 the implementation of BIM level 2 is obligatory in all projects that are funded publicly in the UK, which gave BIM the role of a necessary concept of the projects.[228] Accdording to a semi-structured interview with 15 participants in the UK, not only the obligatory nature of BIM but also its benefit for the project, which encourages applying it in the construction projects.[229]

Watson (2013) imagined UK in 2062 as below:

"Building Information Modelling (BIM) is now ubiquitous for capital construction in the public and private sectors, applying from design visualisation and co-creation with

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[223] Cf. Ibid., p. 848.

[224] Cf. Walravens (2013), p. 30f.

[225] Cf. Ibid.

[226] Cf. Sielker; Allmendinger (2018), p. 14.

[227] Cf. Ibid., p. 14f.

[228] Cf. Dakhil et al. (2016), p. 2.

[229] Cf. Ibid., p. 10.

clients through computer-aided off-site manufacture, to real-time performance optimisation. "[230]

However, using BIM in the AEC industry has some challenges as well which was mentioned by Ghaffarianhoseini (2016) as below:

> "[… major challenges in BIM implementation in UK include high initial investment, lack of knowledge, lack of time, information retention across multi-software platforms, security issues, cultural change, lack of collaboration and extensive management skills.]"[231]

BIM was first used by organizations because of its mandatory nature by the UK government; however, the companies started to use it later for other projects rather than only public-funded ones.[232] According to a survey by Eadie et al. (2015), 91.30 of survey participants used BIM as it was obligatory to use, and 8.70 percent implemented BIM for their other projects as well.[233] It shows that the users of BIM will be more eager to use it in all their projects after they understand the benefits of BIM for facilitating coordination and communication in their projects to boost positive outcomes. According to Eadie et al. (2015), the project stakeholders have found BIM useful for designing 3D formats of the models, analysis of the spaces, planning for the projects, plan for the number of materials to be used in the projects, and recognizing the conflicts within the project.[234]

4.2.3 Addressing Communication Challenges by BIM in the projects in UK

4.2.3.1 Implementing BIM in Hospital Construction (London)

In the projects of Saint Bartholomew Hospital and the Royal London Hospital, BIM was used to fulfill the gaps among the designer and contractor as well as the construction site and the design office.[235] BIM could play its role as a method to show the construction steps for the project's accurate implementation.[236]

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[230] Watson (2013), p. 50.

[231] Ghaffarianhoseini et al. (2016), p. 9.

[232] Cf. Eadie et al. (2015), p. 13.

[233] Cf. Ibid.

[234] Cf. Ibid., p. 17.

[235] Cf. Harty et al. (2010), p. 1.

[236] Cf. Ibid.

The problem with the construction of the hospitals is that large medical pieces of equipment come as the complete setup and cannot be dissembled and assembled again.[237] Therefore, previously the construction team had to destroy the walls or partitions to be able to open area for locating this equipment, but BIM could help with the virtual modeling of the construction plant before delivery of the types of equipment with which all relative parties will be involved from the design phase until the delivery of the equipment which can simplify the successful implementation of the project and saves cost and time.[238]

According to Harty et al. (2010):

> "The BIM model started as a method of ensuring spatial coordination but turned out to be a tool to improve quality, reduce costs and waste, save time and improve Health and Safety for the end user. Importantly, it is not the technology which has driven these innovations, but the appropriation of these tools into new ways of working, managing and collaborating across the project."[239]

4.2.3.2 Implementing BIM in a Remote Construction Project (Manchester)

This specific case is about John McCall's Architects (JMA) and its remote cooperation with its contractor.[240] The purpose was to implement BIM in their correspondence to find out its effect on the outcome of the project, which was done under the supervision of 5 members consisted of experienced BIM knowledgeable supervisors, researcher, company director and an architect in the company as the supervisor of the project.[241]

This case is especially novel because of the diversity of locations of its stakeholders. While the construction site was in Manchester, the contractor was working from Cheshire, architects were in Liverpool, and the subcontractors were working on the project from diverse regions.[242]

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[237] Cf. Harty et al. (2010), 5f.

[238] Cf. Ibid.

[239] Ibid.

[240] Cf. Arayici et al. (2012), p.78.

[241] Cf. Ibid., p. 79.

[242] Cf. Ibid., p. 86.

JMA as the architecting company shared the BIM model-based design and the project's data with the contractor and, consequently, the subcontractors.[243] During this pilot project, the staff of JMA and the other stakeholders were receiving training about BIM and JMA standards and methodology for designing the model.[244]

By implementing BIM and transferring the knowledge database, sharing information with stakeholders, email automation, project review to avoid the unwanted issues, the discovery of procurement demands, the advancement of quality, utilizing time and cost, real-time correction of the shared knowledge among stakeholders, and real-time information distribution was simplified.[245]

All in all, the implementation of BIM in the remote project could prevent the inconsistency that might have happened in the collaboration and advanced the quality of communication to have the desired outcome of the project.

4.2.3.3 Uncertainty about the BIM Level

As the UK has regulated the implementation of BIM level 2 in all public projects in the entire country, the project stakeholders need to assess if the level of BIM they are using complies with the level 2. The BIM level is absolutely important regarding the level of data sharing throughout the project, which is one of the aspects of the communication quality within the construction project. Here Arup solution can help the companies in the United Kingdom.

Arup BIM Maturity Measure is an application which was exhibited in 2013 by Arup company in the UK and can help the project stakeholders to find out their maturity level by measuring 11 areas as below[246]:

1. **Employers' Information Requirements (EIRs):** It is based on perceiving the client's requirements and preparing designs accordingly, which helps the project

[243] Cf. Ibid., p. 87.

[244] Cf. Ibid., p. 88.

[245] Cf. Ibid., p. 89.

[246] Cf. Azzouz; Hill (2017), p. 50f.

leader surrender the correct data at the desired time with a valid purpose and enables him to reply accurately to the client's needs.

2. **BIM Design Data Review (BDDR):** It concentrates on thorough reviews to assure that the clients' requirements are being considered accurately and consists of various BIM goals, including data sharing, which assists with the preparation of the plan for executing the project. This is a prepared plan as an aid for simplifying the communication and transferring data throughout the project.
3. **BIM Execution Plan (BEP):** It is also called a Digital Design Plan, which helps with preparing a digital plan for aims, standards, processes, and data sharing procedures, which includes all the stakeholders of the project. This is another means for ensuring the quality of communication for an appropriate data share in the project.
4. **Project Procurement Route (PPR):** It refers to taking BIM concepts into account when discussing procurement with clients and other project participants to be able to have the maximum benefit of BIM in the project.
5. **Common Data Environment (CDE):** This is a shared system among the project stakeholders for better data sharing, which the design documents and all other details of the project can be shared on it. In the primary stage, SharePoint can be used, but it is recommended to use another sharing platform later for uniting the communication within the project.
6. **Document /Model Referencing, Version Control and Status:** This enables the project participants to know about any changes and prerequisites of any step within the project.
7. **Marketing Strategy:** This function is to encourage the stakeholders who are not familiar with BIM's concept and its benefits for the project by using case studies about BIM functionality.
8. **Virtual Design Reviews (VDR):** It assures the design models' compliance with the team, client, and contractor's quality requirements before their issuance.

9. **Open Standards:** Like Industry Foundation Classes (IFC), these standards can help with better coordination in the projects and sharing data within various tools and even being used for future softwares.
10. **BIM Contract:** It can help with the adequate permissions to share the data and models on a common platform, which can be a mutually agreed plan for implementing BIM within the projects, which gives information to the stakeholders about the allowed purposes of the shared knowledge.
11. **BIM Champion:** A BIM Champion performs as a knowledgeable technical leader who assures the accurate application of BIM in the project. This person can be a participant directly in the project or a third party.

All the above 11 areas of analyzing the project's BIM level can be graded on a scale of 0 to 5.[247]

[247] Cf. Ibid., p. 51f.

5 Conclusion

5.1 Summary of results

This thesis's focus was to implement a literature review for studying the case of Singapore and the United Kingdom as two countries that are having restrict regulations for mandatory adopting BIM modeling in their construction industry.

Both the United Kingdom and Singapore are thinking of reaching the standards of smart cities. The choice of Singapore for studying in this master thesis was because of its aim to become a smart state and not only a smart city that is showing success on its path in Asia. The United Kingdom was chosen because of its very good performance in advancing London and Manchester conditions to the international standards of a smart city.

However, it is not easy to conclude the results of Singapore's actions for making a smart nation because it just started the program in 2014.[248] The same conditions apply to the UK because a smart city is still a concept, and no country in the world can declare that they have smart cities. The countries are still trying to reach the standards of the smart city concept.

As mentioned in chapter 4 of this thesis, UK mandated the use of BIM in the publicly funded construction projects from 2016; however, BIM is being used in the designing phase of the projects mostly. Therefore, there is a long way to go to encourage the projects' stakeholders to implement BIM in the other phases of the projects and specifically the facility management phase, which is a sort of assistance to the digitalization of smart cities.

After setting the obligatory regulations of BIM by the Singapore government, its implementation in construction projects was accelerated; however, Singapore still has a long path to implement it in the whole project's lifecycle successfully.[249]

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[248] Cf. Lee et al. (2016), p. 28.

[249] Cf. Shen et al. (2016), p. 262.

The study of both Singapore and the UK cases showed the positive experiences of implementing BIM in reducing the communication and collaboration problems in the construction projects.

The successful examples were the solution of BIM to rework, insufficient productivity and WSH issues in Singapore construction projects, inadequate quality of communication in Saint Bartholomew Hospital and the Royal London Hospital, and the communication issues in the remote construction projects which the latest was tested in Manchester which is known as one of the smartest cities in the UK. After implementing BIM in the above-mentioned projects, the communication quality was improved, and the problems caused by improper communication among the stakeholders were solved.

The future smart cities will consist of these construction projects, which we are building today. The digitalization of each construction plant will help with the IoT and digitalization infrastructures of the future smart cities. The services like Smart Bike App, Smart Waste Management, FixMyStreet, and Smart Parking Service, which were explained in chapter 4, need adequate construction infrastructures as well as setting sensors on the site which are connected to a digital platform. BIM can help today with the construction of the infrastructures and might help us with the facility management in the future.

5.1.1 Findings of the Questions

1. What is the effect of BIM on the quality of communication in smart city projects?

The future of smart cities can be remote construction in which the architect company is in one city while the construction plant, contractors, and subcontractors are in other regions. As explained in chapter 4, the experience of JMA in Manchester showed that BIM could increase the quality of communication and collaboration in a remote construction system and prevent the unforeseen issues.

2. Which communication problems will BIM solve in smart city projects?

The case of hotels in London in chapter 4 can demonstrate that BIM can help us with preventing the waste of time and cost, which can happen because of no access to the virtual design of the location of every component in the building. With BIM, it is possible

to anticipate everything in the design phase and coordinate appropriately with the different stakeholders in the design phase without wasting extra time and budget.

3. What is the future role of BIM in improving the quality of communication in smart cities?

The case of smart cities is different from the traditional form of cities which we have experienced so far. In smart cities, people are connected to the different facilities and the government services with nodes and sensors, which are located on the street and in the buildings. All of these will be connected to each other with IoT and digital platforms, which helps the authorities with the maintenance of the facilities as well.

Although it is not possible to predict anything in the future precisely, one can imagine that in the future, BIM can help the facility management by demonstrating the location of everything in the construction facilities and warns the facility manager about the issues.

All in all, this study comes with this outcome that yes, BIM has a *positive and significant effect* on the quality of communication in smart cities.

5.2 Further Research Recommendation

As cities are growing, and the concept of smart cities is becoming more popular year by year, the concept of digitalization and IoT becomes more important.

Today for each construction project, the stakeholders are dealing with too much data on BIM application, which is time-consuming for a human workforce to deal with all of it that is sometimes complicated for a human brain and can make errors.

The future researcher can study the effectiveness of Artificial Intelligent based BIM by using Machine Learning method for a better quality of the construction projects outcome as well as making fewer errors in the facility management.

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