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BIM in Construction Project Planning, Building Sustainability, and its Current State in Turkey

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BIM IN CONSTRUCTION
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List of Abbreviations

BIM	Building Information Modelling
BEM	Building Energy Modelling
AEC	Architectural, Engineering and Construction
CAD	Computer-aided Design
ERP	Enterprise Resource Planning
LOD	Level of Development
IPD	Integrated Project Delivery
ROI	Return on Investment
IES	Integrated Environmental Solutions

I declare that this final thesis paper is the result of my own original work and I confirm that all of information and data provided in this research study is in accordance with the academic rules. I further confirm that this research study has not been submitted or published in any other place. I declare that I have cited and used information that is not belong to this study in accordance to the ethical and academic laws.

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Signature:

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Abstract

BIM in Construction Project
Planning, Building Sustainability,
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Although Building Information Modelling (BIM) has emerged immensely in recent years, some issues regarding the full use of BIM remains unsolved. As the advantages of BIM is well recognized in construction industry, there is an urgent need to address the remaining issues regarding the full use of BIM. This research study was performed to address four different issues in construction industry. Outlining challenges and pathways for BIM adoption in Turkish construction industry, challenges and pathways for better utilization of BIM in project planning and sustainablitiy, analysing the challenges and advantages of determining the ideal level of BIM in different construction projects and last but not the least analysing BIM application in building performance was analyzed and interoperability was examined between BIM-based software and Energy Modelling software. Research methods used in this study was exploratory research based on the available literature. This paper outlines important key points for industry practionaries for enhancing the utilization of BIM.

Keyword: Building Information Modelling, Building Perfomance, Sustainability, Project Planning, BIM Level of Development

Öz

Proje Planlama, Sürdürülebilirlik, Bina Performansı ve Türkiye'de Daha Hızlı Uyuma Yönelik Bina Bilgi Modelleme Uygulamasının Kavramsal Çerçevesi

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Bina Bilgi Modellemesi (BIM) son yıllarda oldukça ortaya çıkmış olsa da, BIM'in tam kullanımı ile ilgili bazı sorunlar hala çözülememiştir. BIM'in avantajları inşaat sektöründe iyi tanındığından, BIM'in tam kullanımı ile ilgili kalan sorunları ele alınması için acil bir ihtiyaç vardır. Bu araştırma inşaat sektöründe dört farklı konuyu ele almak için yapılmıştır. Türk inşaat sektöründe BIM'in uymasına yönelik zorlukları ve yolları özetlemek, proje planlama ve sürdürülebilirlikte BIM'in daha iyi kullanılması için zorlukları ve yolları özetlemek, Farklı inşaat projelerinde ideal BIM seviyesini belirlemenin zorluklarını ve avantajlarını analiz etmek ve son olarak bina performansında BIM uygulamasının analizi ve BIM tabanlı yazılım ile Enerji Modelleme yazılımı arasında birlikte çalışabilirlik incelenmiştir. Bu makale, endüstri uygulayıcıları için BIM'in kullanımını artırmak amacıyla önemli anahtar noktaları ana hatlarıyla açıklamaktadır

Chapter One

Introduction

1.1 Building Information Modelling and Filling the Gaps

Construction projects are increasing in size, complexity, and scope. Project risk, whose management is fundamental for success of any project, is also increasing. On the other hand, budgetary and time constraints are increasing and making a push towards increased efficiency all around. While the design process should be flexible enough to match the needs and requirements of the clients, unforeseen changes due to lack of coordination, planning, or careful attention during the design phase are likely to create unavoidable delays and increased costs. Building Information Modeling (BIM) is a process of creating 3-D based model, which stores all the data related to the project and enables project participants to manage those data, coordinate, cooperate and collaborate during the project's life cycle. BIM is a tool geared towards identifying and minimizing errors during design, implementation, and operation of a building, thus improving efficiency of construction projects.

BIM is not a software but it is a process, which can build, view and test a structure in 3D. BIM contains architecture models, structure models and MEP models, which uses those models in pre-design, design and construction phases.

BIM is a novel information modelling methodology that allows the pre-construction, construction and post construction process to move faster and easier for all the stakeholders involved in project. It allows stakeholders of the project to have access to multiple sort of information type graphical and non-graphical regarding the project through its databases. As the information and data produced in modern construction industries are significantly complicated, the need for managing those information flows has been recognized.

BIM enhances working efficiency for all project participants as it consumes less time and prevents potential delays on project sites. In BIM, clash detections are taking place during design phase unlike the past, which were taking place at the construction sites and were causing days of unexpected delays in construction timeline.

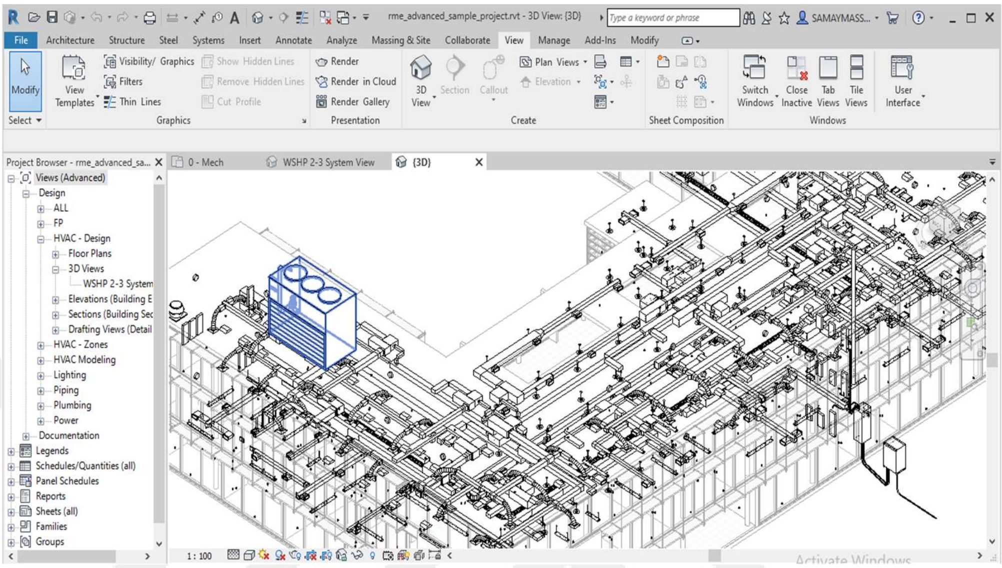

Figure 1. Example of a project within BIM software

BIM offers engineers and other project participants a digital representation of building project as shown in (Figure 1) before the construction period begins, which allows project managers and other project participants to have a better understanding of how the building will look like. BIM is responsive to changes; it allows the engineers and other project participants to regenerate the model any time they want.

BIM process involves different stakeholders of the project in different phases of the project and it helps them to communicate and avoid further possible conflicts during project's life cycle. On the other hand, most of the time buildings do not match the original aspirations of engineers and designers; this leads to bad building performance with higher energy usage and emissions.

Improved efficiency has direct benefits to sustainability as defined by its three pillars: environment, economy and society. As Motawa et al. (2013) suggests that using BIM technology to monitor building performance can also be used in designing suitable scenarios to maximize energy savings in order to match design and performance of buildings.

The implementation of BIM in construction industry was not as fast as it was expected due to some factors such as lack of skilled professionals, lack of national standards etc.

Admittedly, projects are increasing in size, complexity and scope rapidly, which manifest even more constraints to the projects. Managing building data and using them during the pre-construction and construction period has been a difficult job for years. Many construction projects are facing serious cost overrun and delay problems that can be referred to traditional and complex working and planning methods. The importance of developing a constraint-free, fast and reliable working environment has long been recognized by the construction industry and adapting BIM as fast as possible is essential for both construction industry and all project stakeholders.

1.1.1 Levels of BIM in industry adaptions

There are different levels of BIM implementation in construction projects. Over time, it was deemed necessary to be able to identify the extent of BIM use in project management. There are different definitions for levels adopted by various organizations. Government Construction Client Group BIM (2011) state the levels of BIM as:

Level 0: Unmanaged CAD probably 2D, with paper (or electronic paper) as the most likely exchange mechanism.

Level 1: Managed CAD in 2D or 3D using BS1192:2007 with a collaboration tool providing a common data environment, possibly some standard data structures and formats. Commercial data managed by standalone finance and cost management packages with no integration.

Level 2: Managed 3D environment held in separate discipline ‘’BIM’’ tools with attached data. Commercial data managed by Enterprise Resource Planning application (ERP). Integration based on propriety interfaces or bespoke middleware could be regarded as ''PBIM'' (propriety). The approach may utilize 4D program data and 5D cost elements as well as feed operational system.

Level 3: Fully open process and data integration enabled by web services compliant with emerging IFC/IFD standards, managed by a collaborative model server could be regarded as IBIM or integrated BIM potentially employing concurrent engineering process.

1.2 Sustainability and contribution to science and technology

Since the industrial revolution, the construction industry as well as other industries has grown immensely. As construction industries are big consumers of natural resources, it is understood that construction industries has a big impact on climate change by producing emissions and consuming natural resources. The finite amount of natural resources and the emissions, which were produced by the industries, caused the world to think about the term sustainability to reduce the environmental impacts of industries as well as other factors.

Sustainability and sustainable development finally came to prominence in 1987, when the United Nations World Commission on Environment and Development, chaired by Norwegian prime minister Gro Harlem Brundtland, (1988). In mentioned report, the term sustainable development was introduced and the defined it as a process of change in which the consumption of resources, the direction of investments and the scope of the technology development should be compatible with present and future needs or in other word, a development that meets the needs of the present without compromising the ability of future generations to meet their needs is sustainable development.

The effects of climate change on health provide evidence that social sustainability hinges on environmental sustainability. As the World health organization indicates, "The net effect of climate change will be negative" meaning that use of sustainability in a right manner is necessary at the moment.

Construction industry has been long accused of causing damages to the environment for consumption of natural resources during construction period and unsustainable design of the buildings, which causes direct and indirect damages to the environment.

A sustainable construction usually focuses on reducing energy consumption and waste, creating an environmentally friendly construction site and saving natural environment.

BIM has direct impact on improving the efficiency of construction projects by reducing time spent, cost and overall energy use. Improved efficiency has direct benefits to sustainability as defined by its three pillars: environment; economy and society. Sustainability research on using building materials and other methodologies to minimize environmental impact is essential since sustainability is a key factor for having a healthy and non-toxic environment plus adding value to the customers by reducing additional costs and increasing building efficiency.

Gordon (2008) stated that in recent years, BIM application has become wider in construction industry in both design and construction fields.

One of the reasons for its rapid emergence in the past few years is that it offers many advantages to stakeholders as well as to the environment. It is claimed to save time and money, improve building performance in term of sustainability, and avoid possible misunderstandings during construction period and project life cycle.

This dissertation aims to provide a formalized system for application of BIM in building sustainable and energy efficient buildings and to research useful methods and procedures while implementing BIM in project planning to get more benefits out of it as well as to find pathways for faster adaption in Turkish construction industry.

1.3 Motivation for the study

There is lack of research on possible pathways for faster adaption of BIM in Turkish construction industry. While most of the developed countries around the world has started to adapt BIM in their construction industries, Turkey is yet to adapt despite the facts on advantages that BIM offers to the construction industry. Migilinskas et al. (2013) stated that obstacle in BIM implementation is the lack of information about BIM implementation standards and rules for certain project participants, contract obligations in certain countries or unified documentation for regions such as European Union, Americas, Asia and others.

There may be a difference between hypothesized building performance and actual performance, and buildings do not always match the original expected outcome of engineers and designers despite using BIM, The divergence mostly leads to poor building performances with high-energy usage and emissions. This is usually because of the unplanned changes during construction period and building energy modelling problems.

It is understood that software alone are insufficient for a better implementation of BIM. Project participants are mostly used to work with particular tools (software and hardware) and often data transfer is limited due to incompatibility and transmission of inconsistent information to other participants. Migilinskas et al. (2013) suggests that Extra efforts need to be made to add information for other particular tools. The importance of project teams and coordination among them are yet to be recognized. This causes the projects to not fully benefit by BIM, which leaves a gap in BIM implementation in project planning and project management.

Migilinskas et al. (2013) also indicated that getting the maximum benefits from BIM technology is directly correlated with the ability to maximize collaboration in project. No matter who is leading, when all key participants are involved offers most benefits for the whole project team. The current research study will contribute to filling an important gap where the projects mostly benefit from using BIM plus adding value to the projects and environment in terms of sustainability and building performances. Reduction in time, cost and energy is essential for every project, this project also aims to quantify building performance and energy reduction in the buildings by using BIM.

1.4 Goal of the study

The goal of this study is to develop a formalized system for application of BIM in building sustainable and energy efficient buildings and to research useful methods and procedures while implementing BIM in project planning to obtain the most benefits.

A sustainable building or green building is an outcome of design philosophy, which focuses on increasing the efficiency of resource use of energy, water and material while reducing building impacts on human health and the environment during the building life cycle, through better sitting, design, construction and building's life cycle. A good building performance is critically important for a sustainable environment. As the role of BIM in sustainability and climate change is obvious, a fast adoption of BIM in construction industry, all around the world and specifically in Turkey in this period of time is a must.

The objective of the current study is to provide a comprehensive review of literatures and industry practices in relation to BIM application in project planning and sustainable buildings designs, building performance and faster adaption of BIM in Turkey. In addition, outlining a conceptual framework for BIM application in project planning and sustainable/green buildings. Analyzing building performances with BIM and BIM to Building energy modelling (BEM) combinations through showing different building models.

Particularly the research will address these sub objectives:

1- Analyzing the challenges and outlining a conceptual framework for faster adoption of BIM in Turkish construction industry.
2- Provide a comprehensive review of BIM application in project planning and in sustainable buildings, adoption of BIM by the construction industry and its challenges, and building performance with BIM.
3- Provide a comprehensive review and analysis of BIM level advantages, challenges and determining the ideal level of BIM while applying it into different project size.
4- Analyze building performance and energy reductions by using BIM and to see the coordination between BIM and BEM or building performance.

Chapter Two

Literature Review

2.1 Building Information Modelling

BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle; defined as existing from earliest conception to demolition. BIM simulates the construction project in a virtual environment it assists the architects to design the schematic models with elements. Presentation of the building models can be made through rendering and walk-throughs of the building model to the owners and important changes and revisions can be made in accordance to the building owner's decision.

In design stage, usually the scheduling, planning and estimation using BIM occurs. Project parameters and necessary information are given to the model during this stage, schedules and plans are correctly supervises in order to optimize scheduling. According to BWAIL (2018) Usually coordination and collaboration meetings in accordance to BIM are taking place between architects, engineers, schedulers, cost estimators and project managers during the design phase of the project. In construction, phase clash detection is run on all the works in order to reassure the construction is simulated and work is completed according to the scheduled time and cost.

In a study, Li et al. (2014) stated that BIM provides a material database for all the structural elements and site layout facilities in which during the projects material lists can be linked to the objects within model and it can be renewed or updated anytime easily in BIM. This will enhance the material management process in material planning, material control and quantity take-off.

Sacks et al. (2018) stated that with BIM technology, an accurate virtual model of a building, known as a building information model, is digitally constructed. When completed, the building information model contains precise geometry and relevant data needed to support the design, procurement, fabrication, and construction activities required to realize the building. BIM has become an essential process for AEC industry, most of the developed countries are benefiting from BIM and they have developed their own strategies for it.

Cassino et al. (2014) states that technological change is modernizing construction industry, Project teams are benefitting from faster communications, smaller, more powerful and mobile computers, robust digital modeling tools and a transformative shift toward integrated delivery processes, all of which are generating positive outcomes. Since BIM illustrates the whole project through digital model and it contains almost all of the data related to the project, it offers an undeniable advantages and it improves the information flow of the project. By BIM, information flow is accessible to all project stakeholders and it helps all parties to reduce misunderstanding, better coordination, it reduce potential failures.

BIM helps project cost estimators to estimate the whole project easily, since building information modelling contains almost all the information related to the project and it prevents waste of time.

To benefit the most out of BIM all the stakeholders of the projects should work accordingly. The benefits of BIM adoption depend on all parties being able to engage and collaborate in a well-informed way. Boukara et al. (2015) stated that in the BIM world, all participants depend on each other to succeed. There may be a lot of focus on technology, but BIM is also about people and processes. People need to understand the opportunities offered by technology and make choices about how to use it. With BIM it is possible to create different scenarios for projects in terms of cost and time in order to be predictable.

BIM enhances collaboration and communication between project participants by providing a platform in which all of the related project participants in different project phases are involved in the process and necessary data are being shared among them. According to Autodesk (2019) BIM allows related project participants to access and work with project documents, checklists, daily logs and issues on their mobile devices. This will enable better collaboration and communication between the project teams to avoid potential misunderstanding during the project.

There is many BIM software solutions available in the current construction industry. Some of the most important BIM software are explained in Table 1.

Table 1 Popular BIM Software

Software	Capabilities
Autodesk Revit	Architectural, engineering, structural and construction modelling
ArchiCAD	2D & 3D architectural, engineering, structural and construction modelling
Vectorworks	BIM based sketching, modelling 2D & 3D models plus site information models and rendering
SketchUP	3D modelling for architectural, interior design, landscape architecture, civil and mechanical engineering.
Civil3D	Infrastructure design and documentation software
BIM object	BIM content platform, defines product and its geometrical characteristics to assist the designers
BIM360	Construction management, design collaboration, documentation, simulation
Navisworks	Navigation, combination of design and construction data into an integrated model, project review and coordination
Tekla BIMsight	BIM based construction project collaboration and communication, effective clash management.
AECOsim Building designer	Creation of information rich models with analyzing documenting and visualizing tools
Trimble Connect	Collaborative tool to make projects traceable, accessible and transparent.

2.2. BIM Advantages

As a new technology development in construction industry BIM offers many advantages to the AEC industry. From designers to the all project participants including engineers and contractors BIM provide a platform in which they share data between each other, the construction works are being coordinated, clash detections are being reported and many other advantages. A study by Azhar (2011) suggests that after gathering data from almost 32 projects, which were using BIM in their projects, there was up to 40% elimination in project changes that usually occurs in construction projects, there was a cost estimate accuracy of 3% compared to the traditional system. Additionally there was an 80% reduction of time in estimation time, plus up to 10% of savings in construction cost due to clash detections and 7% reduction in project duration.

In addition, BIM provide better visualization of the project through its digital model before the building is constructed; it gives the project participants the ability to react and interact with the building before its construction in order to avoid misunderstanding. BIM is assisting the MEP engineers by providing them visualization and clear understanding of the design before the construction starts. As Wilkins et al. (2008) stated that despite the challenges towards BIM, there is a great opportunity for MEP firms and MEP engineers to benefit from the advantages that BIM provides.

Building performance is another important characteristic of a building, while most of the time BIM is considered as a vital tool in design and construction phases, its potential value for facility and operational management is also strongly recognized. Lu et al. (2017) suggests that BIM could facilitate data exchange and integration, provide visualized building performance analyses, and enhance the communication and collaboration of various stakeholders during the lifecycle of green buildings. According to another study by Bazjanac (2010) BIM can simplify and improve the accuracy of energy analysis because the data required to perform such analysis is resident in the digital building model.

Building information modelling provide enormous advantages to the post construction phase through life cycle of the buildings. Since BIM stores all the information and data related to the buildings, during the life cycle of the building when a building component fails to work appropriately, BIM has the capacity to detect the failed component in building and ease the repairing process. Lee et al. (2006) stated that in case of revision in design of the buildings, BIM can be used to redesign MEP systems and it assists the designers and engineers in detection of MEP objects before the construction of the building.

Research by Hergunsel (2011) suggests that reduction in construction failures during the construction phase while producing high quality products in less amount of time increases the construction labor's productivity. As the construction, industry uses BIM more coordinately and collaboratively, the benefits of using BIM will be optimized and the labor productivity gap between construction and manufacturing industry will be reduced.

2.3 Sustainability and BIM

Construction industry plays an important role in protecting a sustainable environment. As it is understood, the Earth has limited natural resources and a growing human population. The need to control the ecological balance has long been recognized. In a study Wong et al. (2013) stated that BIM provides a system for designer in which the designers can optimize the building design efficiently and it enables improved design and better building performance. Buildings are responsible for 40% of global energy and carbon dioxide emissions. While using traditional construction methods, some construction companies considered sustainability as a key factor in their construction projects. They have look to develop strategies to reduce CO_2 emissions created by those companies and to reduce energy consumption during the construction period and building life cycle. On the other hand, Motawa et. al (2013) explained that sharing information/knowledge about the use of energy-efficient technologies will improve the means to reach occupants expectations and improve their working conditions. Using BIM technology to monitor building performance can also be used in designing suitable scenarios to maximize energy savings in order to match design and performance of buildings.

According to another study by Bonenberg et al. (2015), BIM is an effective tool for the integration of natural and technical system in architectural design. Multi-dimensional digital models gives the opportunity for efficient multidisciplinary project coordination, in accordance with the principles of green design.

Moreover, another study by Liu et al. (2015) suggests a BIM-based building design optimization method with the aim of improving the sustainability of buildings. It is applicable by integrating BIM-based simulation system and PSO-based optimization system. The authors suggests that it is a much more reliable, effective and efficient method than traditional methods. This method gives the designers and clients a general view of their projects and increases the probability of being successful.

A research study survey by Bynum et al. (2013) suggests 63% of those who were interviewed strongly agreed that sustainable design and construction practices were important factors for their companies. Many of them also believed that sustainability is not the primary application of BIM. 77% of those who were interviewed believed that design build and IPD are the optimal project delivery methods to integrate BIM as a sustainability tool. 91% of survey respondents also believed that schematic design, predesign/program, and design development phases were the optimal phases in which to implement BIM in sustainable design and construction.

2.4 Characteristics of BIM and Construction

2.4.1 Adoption of BIM by Construction industries

A research by Gu et al. (2010) suggests that there are both technical and nontechnical issues that needed consideration in BIM adoption. There were numerous factors affecting BIM adoption, which mainly fall into two areas: technical tool functional requirements and needs, and nontechnical strategic issues. The need for guidance on where to start, what tools are available and how to work through the legal, procurement and cultural challenges have been evidenced.

Some countries have created their own strategies for faster implementation of BIM. Singh (2017) stated that in the UK it is mandatory for government ventures to use Level 2 of BIM in their projects, if the current trend in UK construction industries continues they will become leaders in BIM adoption.

J. Woetzel et al. (2017) stated that Scandinavian countries are the current leaders of BIM adoption in the world. While US has not mandated using BIM in their construction industry, it was stated that BIM implementation was expected to increase to 70% of US construction industry within the next three years. For Germany, the goal is to adopt BIM in their construction industry by 2020 and the Digital Building Platform was created to develop a national BIM strategy in 2015. As Jack, (2016) stated, in December 2015, the German transportation minister announced that BIM process will be made mandatory for German road and rail projects beginning with the end of 2020.

In a study by Jensen et al. (2013), there are recommendations for the Icelandic building industry to improve the utilization of BIM. These recommendations are both for national level and individual organizations in the construction industry. For the national level, authorities are recommended to increase the general knowledge of BIM through public initiatives, considering that public clients order simple building models of existing buildings, entering cooperation with the Nordic countries regarding the development of standards and guidelines. The individual organizations are recommended to start the implementation of BIM immediately but slowly, choose the right pilot projects, finding the super-users meaning those who shows interest in finding new, more efficient ways of doing things.

2.4.2 BIM and Building performance

Minimizing the gap between predicted and actual building energy performance has been a need for years, BIM helps the designers and engineers to examine the building energy performance before the construction by analyzing energy models and facilitating data exchange between BIM software and building performance software (BEM software). According to a study by Azhar et al.

(2009) BIM facilitates the designers in solar and daylighting analysis as well as project planning and cost estimations.

In another research by Gerrish et al. (2017), it is stated that data management during design and operation must be more carefully considered to support effective use of BIM. Without a standard data structure, the time taken to sort and structure that data to make it usable, is too long and costly to be effectively implemented for projects. Usually, the effectiveness of BIM depends on the accuracy and type of information, which is given to the model. Lack of detailed and accurate information will lead to bad building performance design.

Asl et al. (2015) reported that generally in traditional designing system, the practitioners create one or few design models before selecting one to construct which leads to underperformance of buildings. BIM assists the designers with automated design methods to develop number of models and optimize building performance.

Chapter Three

Challenges and Pathways for Faster Adoption of Building Information Modelling in Turkey

3.1 Introduction

This chapter's main objective is to analyze BIM challenges in Turkey's construction industry as well as outlining pathways for faster adaption of BIM in Turkey's construction industry. The use of BIM has increased exceptionally since 2002 when BIM was just a theory on the paper and the idea of BIM was starting to get attracted by the software vendors. Since then BIM has replaced the traditional 2-dimensional drawings and paper based construction documents by offering an intelligent 3-dimensional model that contains all the data related to the buildings. BIM enables the users to access to the related information from pre-construction phase to the building life cycle, it assists the users for better coordination during the construction period, better project planning and to experience sustainable construction environment.

Generally, BIM adaption in construction industry failed to be as fast as it was expected due to several factors, which will be discussed later in this chapter. As BIM offers many advantages from pre-construction phase through building life cycle, the value of implementing it is well understood. By taking into consideration BIM adaption advantages, governments and different construction industries are being pressured to adapt BIM as fast as possible. BIM offers so many advantages to the construction industry both from technical point of view and economical point of view. According to a study by Criminale et al. (2017) BIM is an innovative concept in construction industry. BIM enhances design, operation and maintenance process. Its perceived value is not only for the designers but also for all project stakeholders.

BIM adaption differs across the different construction industries around the world. While some of the countries have made BIM usage mandatory for their construction industries after understanding the benefits of utilizing BIM. Some countries are in the process of adopting BIM in their construction industries while some countries has failed to adapt BIM yet.

BIM offers tremendous advantages to the firms and industries, it helps the automation process in construction and it helps to reduce time wasting during the construction projects. There has been always an issue to gain maximum benefit out of utilizing BIM. As BIM is a teamwork tool, the better understanding and coordination between the teams, the better performance by BIM. It is also believed that the more accurate and detailed information stores in BIM software the more the outcome will be desirable.

The effective and feasible use of BIM has remained a serious issue for construction industries. The goal of this study is to analyze the challenges and obstacles which are undermining BIM implementation in Turkey's construction industry and to investigate the pathways which are being used by the countries who are the leaders in using BIM in their construction industries and finally to outline conceptual framework for faster adaption of BIM in Turkey's construction industry.

Construction industries plays an important role in economy growth of each country, different countries have different strategies towards their construction industries. Some countries focuses more on development of their construction industry while some countries show less attraction towards their construction industry. Luckily, construction industry is one of the leading industries in Turkey. The growth of Turkish construction industry has started since almost 30 years where Turkish contractors have undertaken projects both nationally and internationally. According to an overview report of real estate and housing industry by Emlak Konut (2018) over the last 45 years, Turkish contractors have taken on 9300 projects worth $355 billion dollars. The main driver of Turkish construction industry has been the domestic operations such as domestic housing, building and renewing infrastructures, repair works etc.

In summary, in order to keep their growth and development in construction industry both in domestic and international markets Turkey needs to adapt to the latest technologies and developments in construction industry. The adaption of

BIM is yet to be implemented in majority of the construction projects in Turkish construction companies due to some factors, which we will discuss about it in the next part.

For the Turkish companies and contractors, in order to keep their competitive advantages with their competitors and in order to have a common language in their joint operations and projects with other international contractors, the need for adaption of BIM as soon as possible is essential.

3.2 Building Information Modelling and its Adoption Challenges in Global Construction Industries

Despite the development of construction industry in the recent years, the expected delivery outcome have always been an issue for construction companies and contractors. As a study by Latham (1994) suggests that lack of co-ordination and interoperability between the designing and construction teams results bad project delivery. According to another study Callistus et al. (2016) suggests that lack of communication between planning, budgeting and evaluation departments are the main reasons for unexpected project deliveries. The necessity for a sustainable environment and sustainable construction process was well recognized before. As defined before, BIM is solution to the problems mentioned above by providing virtual 3-D model of objects as well as storing all the data related to the building. BIM assists project participants by giving them access to the data, high quality data integration, ease in collaboration and communication between project participants, and improved visualization etc.

BIM adoption differs from country to country, some of the countries made BIM mandatory for their construction industries and some of the countries are in the process of mandating BIM usage in their construction industry. Scandinavian countries are the current leaders of utilizing BIM in their construction industry, According to a report by Singh (2017); Denmark, Norway and final were the early adapters of BIM in their construction industry.

According to a study by B Zakaria et al. (2013) the Malaysian government strives to improve construction productivity and implementing BIM is one of

their key agenda however, lack of knowledge about BIM and lack of interest resulted low BIM application in Malaysian construction industry.
BIM is not mandated in all states of U.S. yet but according to Cassino et al. (2014) Wisconsin was the first U.S. state that mandated BIM on all government and public projects with a budget of $5 million or more. According to another study by Woetzel et al. (2017), the digital technology including BIM is expected to be implemented in majority of the construction industry in the next three years. Germany is another demanding country towards BIM; report by McGraw hill Construction (2014) suggests that the BIM implementation by contractors has witnessed an increase from 2013 to 2015 by 35% (from 37% to 72%). Another study by Takashi et al. (2016) indicates that Japan is not always encouraged and motivated enough towards BIM, as the client of the project is not aware of the advantages and enhancement of their construction industry's quality by BIM to express BIM use into the contracts of the projects. In Australia according to a study that was done by Alabdulqader et al. (2013) only 32% of the firms, which was interviewed, was not using BIM, some of them indicated that 2-D CAD software fulfill their expectations while some of them indicated that BIM is too expensive to operate.

According to a study by Navendren et al. (2014), generally the key challenges towards BIM adoption and implementation particularly from the perspective of designers are as follows: cost of deployment especially in the case of small design firms. Eadie et al. (2014) suggested that changes to traditional process of designing, experiencing lag and loss of time due to the creation of the BIM model and passing it between other project participants, lack of BIM understanding by clients, lack of learning feedback; issues of interoperability, lack of supply chain integration, and lack of clear guidelines and standards. Scale of culture change required, lack of flexibility, lack of supply chain buy-in, doubts about return on investment (ROI). lack of vision of benefits, cost of software, cost of training, literacy of staff, lack of technical expertise, staff resistance, legal uncertainties, other competing initiatives and lack of senior management support are the key challenges for BIM adaption in UK. In a study by Alabdulqader et al. (2013) Firms which were using BIM in Australian construction industry, addressed some issues and challenges regarding the implementation of BIM, which are data ownership, unclear responsibilities, selecting appropriate software for specific projects and challenges like the lack of interoperability, upfront cost of system setup, resistance to change, lack of BIM understanding, fragmented industry and adversarial culture, lack of visions; and inadequate training and education. In another study which was done by Langar (2017) analyzed BIM challenges in 5 different countries and it suggests: Time needed for training people, cost of training, lack of responsibility for data ownerships, lack of responsibility for errors, software license and update expenditures lack of standard for contractual BIM document and cost of acquiring BIM for small firms were the key challenge addressing BIM adoption in construction industry.

3.3 Cost of BIM:

Since each project has its own complexity and scale, cost of implementing BIM also differs in between different projects. Major weightings of BIM cost in a project are the cost of hardware, software, training cost, personnel salaries and the duration of the projects.

Project type and use of BIM is another important factor while calculating cost of BIM. For instance, the company may want to use different level of BIM, which automatically requires additional software, and training, which directly affects cost of BIM. If we compare the modelling of a large building with so many empty space with a building with so many industrial facilities, we understand that the building with many building facilities requires additional work and time.

If we assume a small and a bigger company who wants to implement BIM in their company, the BIM cost modelling for each of the company will be like this:

If the small company plan to have 4 BIM employees, and the project duration is 12 months then the BIM cost according to the recent market price in Turkey will be:

Software cost – AutodeskRevit = 15374 TL per year

BIM 360 = 5355 TL per year

Hardware cost – computer and its components = 10000TL x 4 = 40000 TL

Training cost – BIM software training in Turkey = 2800TL x 4 = 11200 TL

Employees' salaries – in 12 month duration of project = 12 x 4 x 4000 TL = 192000 TL

Total cost of BIM = 264000 TL.

For the companies in order to have a positive net BIM savings, the total cost of BIM should not exceed the net BIM savings. If we compare the total cost of BIM with the highest net BIM savings percentage that was 1.7%, which we have, done in Meta-analysis in (4.2) part, we can assume that the project's overall cost should be 15.5 million TL in order to have a positive net BIM savings.

For the larger company:

Software cost – AutodeskRevit = 15374 TL per year

BIM 360 = 5355 TL per year

Hardware cost – computer and its components = 10000 TL x 6 = 60000 TL

Training cost – BIM software training in Turkey = 2800 TL x 6 = 16800 TL

Employees' salaries – in 24 month duration of project = 24 x 6 x 4000 TL = 576000 TL

Total cost of BIM = 674000 TL.

In this case, according to Meta-analysis 1.7% BIM savings percentage we can assume that the project's overall cost of the project should be 40 million TL in order to have positive net BIM savings.

3.4 Analysing BIM Challenges in Turkey:

As we mentioned earlier in this chapter, for Turkey in order to keep its competitive pace with international contractors Turkish construction industry need to adjust themselves with the latest development in construction sector as well as reducing time and cost during construction process. Additionally, as the attraction toward sustainability and green buildings increased in Turkey the desire to implement BIM, which has direct relation with sustainability and building performance, is also increased. Aladag et al. (2016) stated that legislations and laws about energy efficiency have been strictly implemented in Turkish construction industry since 2007 (Energy Efficiency Law no. 5627; Regulation of Energy Performance of Building).

In general, we can divide BIM challenges and obstacles in Turkey into 5 different fragments, which are from academic perspective, legal perspective, resource perspective, standardization perspective and finally organizations perspective.

a. **Academic issues:** Lack of skilled individuals in utilizing BIM in Turkish construction industry is one of the most challenging problems. Since BIM software are completely different from traditional 2-D CAD software the lack of knowledge on how to draw, store the data and use different levels of BIM has remained a key issue.
b. **Legal issues:** Unlike other countries, which mandated BIM usage in their construction industry, Turkey is yet to mandate BIM usage in Turkish construction industry. Legal regulations for BIM are not created/applied for Turkey yet that might be one of the biggest reason why the BIM adaption is slow in Turkey.
c. **Resource issues:** Lack of available resource for small companies, high cost of training and educating BIM principles, high initial cost of setting up BIM, stakeholders and sub-contractors disabilities in understanding BIM, software errors, software update and upgrade expenditures, inability for buying and setup BIM software are the main challenging issues for adapting BIM in Turkish construction industries.
d. **Standardization issues:** Lack of standard for evaluation of BIM, lack of standard for contractual BIM documents in both before and after construction period, lack of industry standard for BIM in Turkish construction industry are the main standardization challenges for Turkey.

e. **Organizational issues:** Lack of motivation towards using and benefiting from BIM by Turkish construction companies, differences with traditional systems, lack of information about the advantages that BIM offers, lack of information about the high return of BIM and traditional organization cultures are the main organizational challenges toward BIM adaption in Turkey.

3.5 Pathways for faster adaption of Building Information Modelling in Turkey

This part focuses on outlining conceptual framework for faster adaption of BIM in Turkish construction industry. As a consequence of the challenges and obstacles of BIM in Turkey, which we mentioned in the previous part, a conceptual framework that would tackle those challenges and obstacles and enhance the adaption of BIM in Turkish construction industry is outlined.

As the research methodology used in this study is observational and exploratory we have investigated countries with similar challenges for adaption of BIM in their construction industries, how they overcome those problems, what are unresolved problems, and what should be done to enhance BIM adaption in Turkish construction industry.

The points deemed important to enhance BIM adoption in Turkey are presented in Table 2.

Table 2. Pathways for Government and Private sector

For Government	For Private Sector
a. More investment on research and development of IT applications in construction industry may be supported by government policies, either directly through incentives and subsidies, or indirectly through	a. Training programs may be offered to professionals to ease and facilitate the transition through higher education institutions or professional societies. Construction companies should identify

making it priority for research funded by public funds.	technical requirements before adopting BIM in their construction projects.
b. Turkish government may support increased collaboration among BIM related institutions, academic research or professional, in order to provide consistency in both national and international standards.	b. Culture change of an organization in construction industry is another key factor; by adopting BIM, the need to adapt to a new organization culture is always felt in international construction industries. The role of leadership and commitment for change is essential in cultural change of an organization.
c. Policies may make BIM implementation mandatory for public works and projects above a certain budget and project size due to reported significant positive return on investment from other countries.	c. Private companies may start utilizing BIM by starting from a trial project, choosing the right project is crucial for new BIM users. Knowledge on different levels of BIM and choosing the appropriate level is also necessary for project success.

3.6 In Summary

The goal of this chapter was to analysis challenges and obstacles of BIM implementation in Turkish construction industry as well as to outline pathways for faster adoption of BIM in Turkish construction industry. Cost of BIM for primary adapters of BIM in Turkey was explained based on recent market prices and assumption. After the exploratory research on available literature, it was found that there are five main challenges for BIM in Turkish construction industry which are academic challenges, legal challenges, lack of resource challenges, standardization challenges and organization challenges which each of them was briefly explained.

Important procedures and framework were outlined for enhancing BIM adoption in Turkish construction industry for both government and private sector.

Chapter Four

A Comprehensive Review of Building Information Modelling in Project Planning and Sustainable Buildings

4.1 Introduction

In construction industry, BIM has a great impact on sustainable construction environment, sustainable, project planning and project managements. From perspective of designers, BIM reduces possible time waste, which is likely to happen in traditional 2-D CAD system due to clash detections etc. From project manager perspective, BIM reduces delays that are likely to happen in traditional systems due to lack of coordination, communication and misunderstandings since BIM offers an outstanding tool which let the project participants a clear vision of the BIM before the construction process begins and to have access to all information related to the project.

As construction projects became more complex in recent years, the need to challenge and fulfil the expectations also arise. BIM was introduced to the industry in order to fulfil those expectations and tackle complex challenges of the projects. In project management and planning during construction projects there is always a well-recognized need for better understanding and better cooperation between project participants. On the other hand, environmental sustainability and sustainable construction are other important factors that are needed to take into consideration during construction projects.

BIM enhances environmental sustainability, sustainable construction and project managements tremendously by offering advantages like better accuracy in cost estimations, which improves the project managers, cost estimating challenges, it reduces time wastes created by estimating the project before the construction period, which helps the projects managers to manage their project timeline. Safety risks are another critical characteristic of project management, unexpected delays often occurs during construction period due to accidents, injuries, building object clashes etc. that affects the project timeline.

Malekitabar et al. (2016) stated that BIM can support the detection and interpretation of safety signals, as they include almost all the objects and their relations in a project. In addition, Martínez et al. (2018) suggested that BIM increases safety through an automated safety code checking and simulation tools.

Controlling the environmental performance of the building throughout the building life cycle, accurate visualization before construction for designers etc. A research by Wong et al. (2013) suggests two main beneficial features of BIM in relation to sustainable building design are those of integrated project delivery (IPD) and design optimization. In a study, Motawa et al. (2013) stated that using BIM technology to monitor building performance can be used in designing suitable scenarios to maximize energy savings in order to match design and performance of buildings. In a study Bonenberg et al. (2015) stated that BIM is an effective tool for the integration of natural and technical system in architectural design. Multi-dimensional digital models gives the opportunity for efficiency multidisciplinary project coordination. In accordance with the principles of green design.

In recent times, the attraction toward BIM increased as people are understanding the advantages that BIM offers, but unfortunately in some cases the construction industries has not benefited from BIM’s capabilities towards project planning and sustainable buildings very well due to some factors which we will discuss about it later. A Study by Ghaffarianhoseini et al. (2017) indicates that many companies experience low return on investment because of BIM engagement issues and their experience level.

Another research study by Smith (2014) found that the quality of BIM model, automated quantities, lack of standards and software incompatibility, sharing cost data information, business changes and legal issues are the main concerns on cost estimations in construction projects which has direct effect on project cost.

This research study aims to review BIM role in project planning, sustainable buildings and sustainable environment as well as to outline potential challenges, which prevents the full utilization of BIM capabilities in Construction industry plus outlining a framework for better use of BIM in project planning and sustainable buildings by using observational and exploratory research method.

4.2 Meta-analysis

The goal of this part is to analyse the benefits generated by BIM in contrast with project size, study analyse the link between project size and BIM savings by using real life project data. This study has great impact since the structure of this analysis is to integrate data from different projects and come up with a single result regarding the tentative research topic.

Data of six different projects were collected as shown in (Table 3) after reviewing the available articles through internet. However, there was limitations accessing BIM-based project data and the majority of the available data was not a complete project data.

Table 3. BIM-based project data

Author's name	Project COST ($ millions)	Duration	Cost of BIM ($)	Net BIM saving ($)
Gilligian (2017)	46	30 month	90000	600000
Giel et al. (2019)	11.79	14.6 month	53510	201125
Giel et al. (2019)	44.4	652 days	222000	665700
Azhar (2011)	47	-	4288	495712
Azhar (2011)	58	-	3800	196200
Giel et al. (2019)	8.84	270 days	44220	7138

The data was extracted from articles by (Azhar, 2011; Giel et al., 2019; Gilligan, 2017) and Meta-analysis was performed to enable the comparison between the scope of the project and the net BIM savings in respect to the scope of the project.

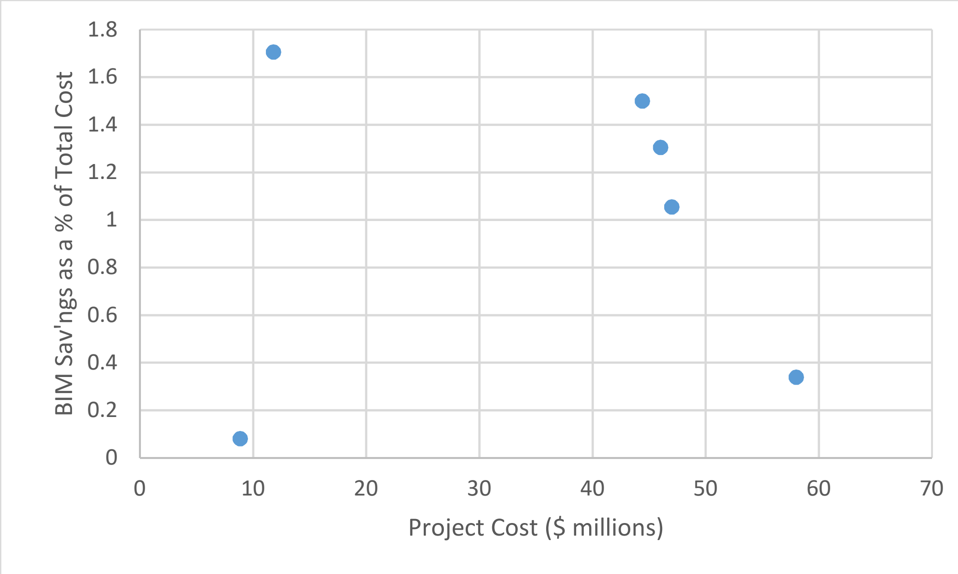

Figure 2. Comparison between project cost and BIM savings

In this comparison the x-axis corresponds to project cost in million and in y-axis corresponds to the BIM savings as a percentage in the mentioned projects.

BIM saving percentages according to the project cost has a variation between 0.08% and 1.7% in these six projects with an average of 1.18% BIM savings.

No correlation was identified between BIM savings and project cost. Different use of BIM scope in projects, different BIM levels, data limitations for further investigation and variation in scope of the study may effect this analysis. However, the full and appropriate utilization of BIM functions will directly effect BIM-based cost savings.

4.3 BIM in project planning

Project managers are using BIM broadly from the start of the projects (pre-construction phase) until the last phase of construction and project delivery. By providing digital 3-D visualization for project managers and project planners, which gives them the opportunity to see how the building will look like at the end of the project, what should be changed in order to enhance project performance, project timeline and prevent potential misunderstanding between project managers and other project participants?

Building information modelling provides a platform in which all the information related to the project stores and it assists project managers in sharing information to the other project participants. This will help the project managers in better planning, collaboration, and coordination and will prevent potential future misunderstanding and conflicts. BIM will help project managers in saving time and accuracy by estimating the project cost.

Compared to 2-D and traditional systems, BIM is faster and more accurate. Giving the cost information to the model, it will generate the cost estimations and adds lots of value to the working process by saving time and money. In a research study by Azhar (2011) the return on investment (ROI) was analyzed in some BIM-based projects which shows significant (ROI) for the projects.

In addition, trust between the project participants is another key factor in success of a project. While many project conflicts occurs when there is lack of trust between the project participants in an organization, BIM is a tool which provides better collaboration, coordination and cooperation by giving the project participants the ability to exchange data and share information related to the project. Despite this some of the BIM users has failed to utilize this privilege due to lack of trust and legal issues. According to a study by Bryde et al. (2013) in order to solve inter-organizational issues project participants should understand and agree common IT platforms, cooperating with each other, not restricting the flow of information related to the project, protecting ownership and intellectual property rights of the generated BIM model of the related project.

BIM plays an important role in construction projects, which uses prefabricated materials, as prefabrication needs site management, accuracy of the construction site and design. BIM can provide better accuracy, better coordination and better visualization before the construction starts, which gives the designers, and project managers a clear vision of how to project will look like and to reduce clashed between prefabricated objects during the installation phase.

As a research, study by Hergunsel (2011) reported that some difficult steel connections generated in BIM can be welded offsite. The welding of these small complex elements in advance of steel erection can save time and money. Saving time and money directly effects project planning.

4.4 BIM in sustainable buildings

In recent years, construction industry has become one of the biggest producer of emissions in environment. As construction industry become bigger, the projects also became more complex and the previous methods to succeed and finish construction projects were not enough. The new technology development, which BIM is a big part of, in construction industry provides new methodologies to deal with the different and complex projects and to minimize the impact of construction and buildings to the environment. Wong et al. (2015) stated that BIM has been advocated for its potential to support environmentally sustainable building development through integrated design information and collaboration.

BIM is a vital tool for sustainable buildings and sustainable construction; it provides visualization for building performance analyses before the construction of the building during the design phase. This gives the designers and engineers the ability to see the building performance model and to revise or change it before construction phase. A research study by Lu et al. (2017) states that 7 major BIM functions for green analyses are energy performance analyses and evaluations, carbon emission analyses, natural ventilation system analyses, solar radiation and lighting analyses, water usage analyses, acoustics analyses and thermal comfort analyses.

In recent years, one of the challenging issues for construction industry is construction waste and inconsistency in estimating. Construction wastes and inaccurate estimation has been the main reasons for high-lost budgets. In the meantime, construction wastes has direct effect on sustainability defined by its three pillar (environmental, social and economical). Luckily, BIM provide such a platform in which wastes and inefficiencies during construction projects reduces by the lowest level if used perfectly. In a study by Wonget al. (2015) the contribution of BIM to sustainable building design demonstrated from the two perspectives which are integrated project delivery method and design optimization method.

4.5 Framework for Better Utilization of Building Information Modelling in Project Planning and Sustainable Building

It is commonly known that project planning and sustainability are essential for every construction project; the role of BIM in enhancing project planning and sustainability tools is well understood as a research by Azhar et al. (2011) indicates that BIM-based sustainability tools generates sustainable design analysis data faster than the traditional system which saves time and resource.

After an exploratory study on better utilization of BIM in project management and sustainable building, it was found that:

a. Focus on data management and accuracy of information that is stored in BIM models will help designers to reduce inconsistency and errors during design of building energy analyses.

b. Education and experience of designers on BIM software has direct effect on performance of BIM and utilization of BIM's capabilities during BIM usage for sustainability and project planning.

c. Importance of data sharing is well recognized, and a framework for data sharing and intellectual property rights of the project should be set during the initial phase of a project in order to define each project participant's responsibilities.

d. Time and fund investment to improve interoperability between BIM software and other software may be needed depending on project scope, and the decision to pursue such interoperability needs to be set initially.

e. Improved strategies for better communication will lead project managers to reduce potential time waste, additional costs and construction wastes that have direct impact on sustainability and project management.

4.6 In Summary

As the aim of this chapter was to analysis the role of BIM in project planning, sustainable buildings and to outline framework for better utilization of BIM in project planning and sustainable buildings. Challenges and obstacles which prevents full utilization of BIM were recognized and important actions and pathways were outlined for better use of BIM in project planning and sustainable buildings which are briefly explained in previous part. A Meta-analysis on correlation of BIM-based projects cost, BIM savings was done, and it was found that there is no correlation between BIM savings and project cost in analysed projects, which is most probably due to variation in the scope of the study, data availability, different BIM levels etc.

Chapter Five

A Comprehensive Review on Challenges and Advantages of Determining the Ideal Level of Building Information Modelling Implementation for Projects

5.1 Introduction

The utilization of BIM in construction industries has become a critical factor in productivity and efficiency of the construction process. As discussed in the previous chapters, the implementation of BIM has failed to be as much as it was expected due to factors, which we will discuss about it later in this chapter. While the need to search new techniques and ways for better implementation has always been felt, to ease the implementation of BIM researchers divided BIM processes into different levels that are explained in the first chapter.

In order to successfully implement BIM, Construction firms should consider some important criteria's. Levels of BIM, organization culture, type of construction activities, project stakeholders, decision of which software to use etc. A study by Abanda et al. (2015) suggests investing in two or more BIM software for the same project phases are not helpful and efficient. Another study by Alreshidi et al. (2017) suggests that in order to have an integrated and collaborative BIM environment, governing the collaborative process and data process supported by BIM cloud technologies are essential.

Successfully implementing BIM offers many advantages to the project team such as reduction in cost and time, better quality of the project, ease in collaboration and coordination, and many more advantages, which mentioned in the previous chapters. This chapter review the challenges and advantages of determining the ideal project size for different levels of BIM, which has long been a challenge for BIM adaptors. This chapter reviews the available literature for the countries that adapted BIM successfully and will outline the challenges and advantages of determining ideal project size while implementing BIM.

5.2 Fundamentals of Building Information Modelling levels

The decision on which level of BIM is ideal for a specific type of project is essential for every firm that wants to adopt BIM. As emphasized in the first chapter The BIM Industry Working Group in United Kingdom divided levels of BIM into 4 different levels. However, there is another specification called level of development, which shows the degree of the geometrical and informative data attached to the model that will be using by the project participants from pre-construction phase through building life cycle. Comparatively, there is not much difference between BIM maturity level and BIM level of development as both describes the state of developed model. For instance, it shows how developed a model is and how much information is given to the model. It enhance coordination and communication between project participants.

According to American Institute of Architects, (2013) the level of development can be divided and defined as follows:

LOD 100: The Model Element may be graphically represented in the Model with a symbol or other generic representation, but does not satisfy the requirements for LOD 200. Information related to the Model Element (i.e. cost per square foot, tonnage of HVAC, etc.) can be derived from other Model Elements.

LOD 200: The Model Element is graphically represented within the Model as a generic system, object, or assembly with approximate quantities, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.

LOD 300: The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of quantity, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.

LOD 350: The Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, orientation, and interfaces with other building systems. Non-graphic information may also be attached to the Model Element.

LOD 400: The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of size, shape, location, quantity, and orientation with detailing, fabrication, assembly, and installation information. Non-graphic information may also be attached to the Model Element.

LOD 500: The Model Element is a field verified representation in terms of size, shape, location, quantity, and orientation. Non-graphic information may also be attached to the Model Elements.

Although possible approaches regarding the decision on which level of BIM to use have been made but construction firms often fails to adopt the right level of BIM in their firms. A study by Alwan et al. (2017) suggests that the expectation of BIM users will remain unfulfilled concerning full use of BIM potential if there is unsupportive system level.

As Abanda et al. (2015) suggests a firm should think of its supply chain partners and the type of construction activities they are involved and then decide to invest in software systems compatible with those used by it supply chain partners, large firms should consider the lifecycle of projects and purchase software that align with the project life cycle. According to a study by Olatunji (2013), it was clear that different organizational models will require slightly different modules of training; different category of staff in these business models will require different technical supplies such as software, hardware and services. Additional to these it has stated that other costs such as the cost of recruitment and contingencies could also become necessary during BIM implementation. Understanding the right level of BIM to use in an organization will have a direct effect on project deliverables and will increase the project quality.

The most common and constructive level of BIM is BIM level 2; it contains both geometrical and non-geometrical data in context of same data environment for a specific type of project. The geometrical data contains 3D models of the buildings, which helps project stakeholders to have a clear vision regarding how the building will look like and to reduce potential building object conflicts, which are likely to happen in every construction project. The non-geometrical data asset help the project managers to save cost and time by easing the estimation process. It will help the construction process by offering an environment in which the quality of collaboration, coordination and cooperation increases immensely.

The technological change in each organization can be either transformational or a complete system change from the basement. Adopting each level of BIM will require different methods and different strategies. For instance, when a company wants to implement BIM level 1, they do not need to change the entire system since BIM level 1 only offers 3D based model and visualization for the project participants.

The process of adapting new technologies to the construction industries is progressive, as it cannot be done immediately; the UK government recognized levels of BIM, which is mentioned in the first chapter. BIM level 0 carry out only the 2D drafting with output of both soft and hard print of the drawing. It is generally used by the small firms and for the small projects, which are not complex, and the system is used just for drafting and drawing.

5.3 Challenges and Advantages of Determining Ideal Building Information Level for Projects

As the purpose of this chapter is to review and analyse challenges and advantages of determining ideal BIM level for different project type we have done an observational and exploratory research and have come up with multiple challenges and advantages.

5.3.1 Challenges:

Cost of deployment for small firms: For some countries, which mandated BIM Level 2 for construction firms, the purpose for utilizing BIM may only be the drafting function and digital 3-D visualization. In such cases, BIM Level 1 may sufficiently fulfil expectation of these firms. Hence, deploying BIM Level 2 might be costlier for such firms.

Organizational culture: Organizational culture is another important factor in adapting different levels of BIM. Organizational culture change needs either transformation or fully replacement which some of the firms fails to adapt to the new culture and new technology easily that makes the BIM adaption challenging.

Uncertainty: While implementing different levels of BIM, the project teams should consider common data environment or collaborative environment in which brings the ease in exchange of information. Some of the firms do not take this into context and faces difficulties later.

Level of Detail: Generally when implementing different levels of BIM, the project managers should clarify the level of detail for each model. It shows how much detail is included in the model. Unclear information about the level of detail will lead project managers into serious problems such as estimation problems, poor quality models, unmatched client expectation from the project deliverables and unexpected delays.

Lack of Standardisation: As mentioned about lack of standardisation in previous chapters, it is likely to affect implementing BIM different levels in construction industry.

Lack of Legal Responsibilities: Lack of responsibility taking among project teams is one of the important challenge in adapting levels of BIM. For instance in BIM level 2, lack of responsibility on who should be responsible in data entry, who will be responsible when an error occurs etc. are important points which are needed to be taken into consideration.

5.3.2 Advantages

Since in each project large amount of information is being generated during design and construction phase, the decision on how much information should be used during generating BIM models and how detailed the models should be are critical. The following advantages of BIM levels are outlined:

1. To help teams and project stakeholders understand how the deliverables will look like and to prevent misunderstanding in expectations.
2. Increased quality in communication between the design teams, ease in explaining different parts of the project in detailed and informative way.
3. To help firms select the level of BIM that best suits the projects and organizational culture.
4. To help firms prevent extra costs and expenditures on wrong type of software and BIM levels.
5. From the owner's perspective, improved efficiency of asset operations is another advantage of BIM Level 2 and above, which will lead to cost savings during the use phase of facility.
6. BIM level 2 offer a platform in which the procurement system is faster and smoother for both suppliers and clients.

5.4 In Summary

As the goal of this study was to analysis, the challenges and advantages of determining the ideal BIM level for different project size, the challenges and advantages of determining BIM level was successfully outlined which is explained briefly in previous part. Main outlined challenges are cost of deployment, organizational culture, uncertainty, lack of detail in model, lack of legal responsibility and standardization.

Chapter Six

Analysing Building Information Modelling Application to Building Performance

6.1 Introduction

This chapter will contribute to analysing BIM application in building performance. As construction industry has been accused of CO2 emissions, one of the main goal of industry practitioners in recent years is to develop a framework in which the building performance increases and the CO2 emissions decreases. Wong (2013) stated that because of global environmental concerns, sustainability and an improved designing system has become essential. BIM application is found to be ideal for delivering improved design and building performance.

BIM assists designers to optimize the building performance and reduce energy needs and errors during design and construction phase. BIM helps the design teams to reduce the difference between planned and actual outcome of building performance. BIM can ease data exchange, provide visualized building performance analyses, and enhance the communication and collaboration of different project teams plus using BIM technology to monitor building performance can also be used in designing suitable scenarios to maximise energy savings in order to match design and performance of buildings (Lu et al., 2017; Motawa et al. 2013). Research by Aksamija (2012) suggests that interoperability between BIM and simulation tools will enhance the workflow between design documentation and analysis application, which have direct effect on building performance.

In a study, Gerrish et al. (2017) stated that the practical application of BIM in optimizing building energy performance is less widespread. BIM application to building performance and interoperability between BIM and energy modelling software is imminent as it helps designers to enhance building energy optimization process and reduces energy wastes.

6.2 Interoperability between Building Information Modelling and Building Performance

The design phase of each construction project is imperative in terms of building performance as in this phase the decision on how the building should be designed is being made. The goal of BIM-based building performance is to minimize the difference between the designed building performance and the actual building performance behaviour.

As the technology in construction industry developed, the utilization of BIM has also increased. BIM offers a platform in which the ability to extract, exchange and revise the data in every phase of the project is possible. At the same time, building performance analysing tools allow the design teams to have a better understanding of how the building performance will be in cooperation with BIM. In a study by Wong et al. (2015) it is stated that traditional designing systems have offered less support to designers and engineers in contrast with new designing systems. A study by Aksamija (2012) suggests that interoperability between BIM-based design and building performance analysis tools will enhance workflow between design documentation and analysis applications, where the design information contained in the models can be used for performance analysis. It is important to track what type of information is needed for a particular analysis. Moakher (2012) stated that the BIM-based design and documentation system is ideal in terms of using the stored information for optimizing building performance and design process.

According to the current literature review on application of BIM in building performance, the challenges on application of BIM in building performance is not addressed yet.

As Gerrish et al. (2017) points on several issues which prevents the fully and ideal application of BIM in building performance which are as follows:

Dis-integrated information on the model, problems in information exchange, problems in information access, skill base issues and etc.. Most of the time not managing data well enough will lead to dis-integration in dataflow, which will lead to errors during the project. Using different type of formats between BIM software and non-BIM software is another important issue that is likely to cause errors during data exchange. Information accessibility plus the decision on how much information should be included in the models is other issues which needs to be addressed.

6.3 Interoperability between Building Information Modelling Software and Energy Analysis and Performance Modelling Software

In this part of the study, interoperability between BIM software and Energy analysis and performance modelling software is examined by using Autodesk Revit 2019 as a BIM software and IES Virtual Environment 2019 as Energy analysis and performance modelling software.

Firstly, the BIM model of a residential house was generated using Autodesk Revit 2019 (Figure 3). To perform interoperability between BIM software and Energy analysis and performance modelling software a supported file format is needed for both of the software. The Autodesk Revit 2019 file was converted to gbXML file format (Figure 4), which is an industry, supported standard for software.

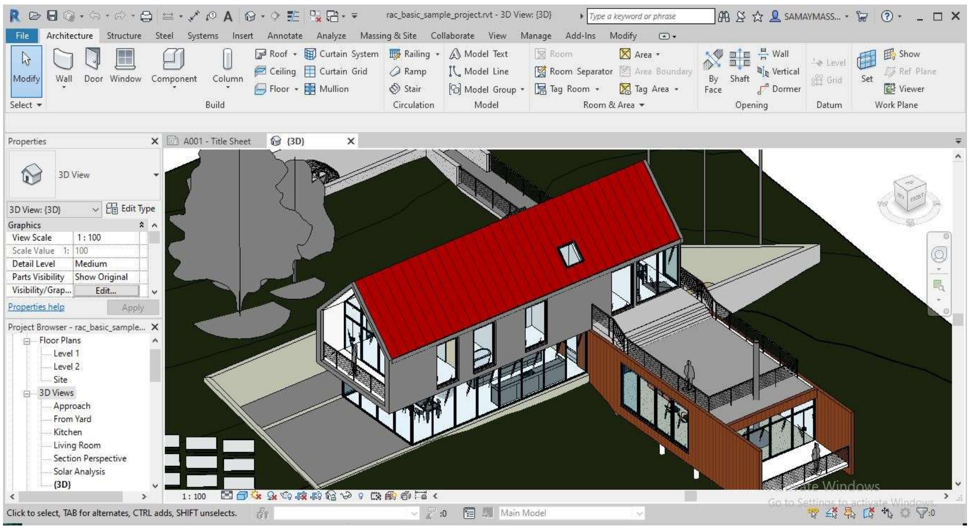

Figure 3. Residential Building Model Autodesk Revit 2019

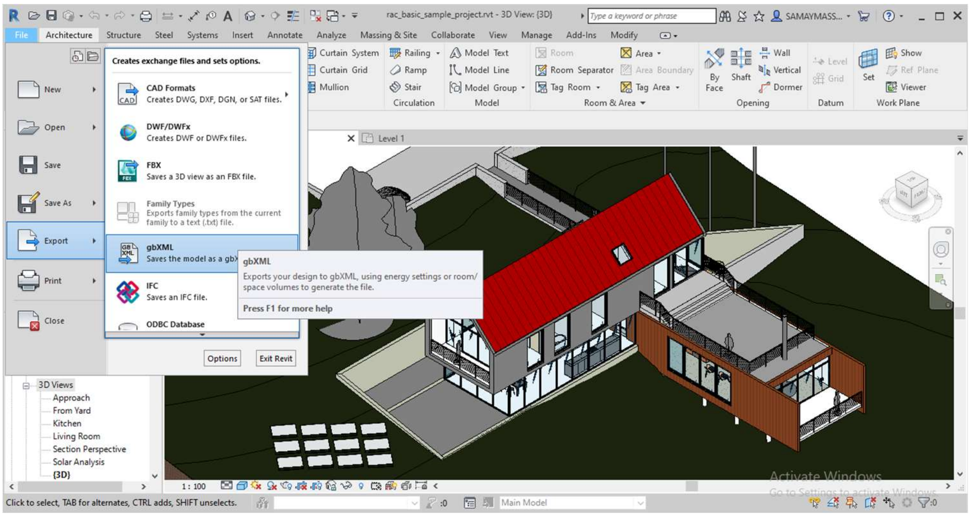

Figure 4. Converting Autodesk Revit file to gbXML file format

If the BIM-based model contain energy settings, then the BIM-based model can be converted to the gbXML file containing all the energy analytical model created by Autodesk Revit. If not then the room and space volumes will be converted to the gbXML file format. The room and space volumes defined by the model may not be as accurate as energy analytical model.

The Accuracy of Energy analysis model depends on the amount and accuracy of information on BIM-based model, errors were recorded due to lack of detailed information given to the model and missing parts of building object in BIM-based model. (Figure 5) shows the error sign on lack of information in model which was created in Autodesk Revit software.

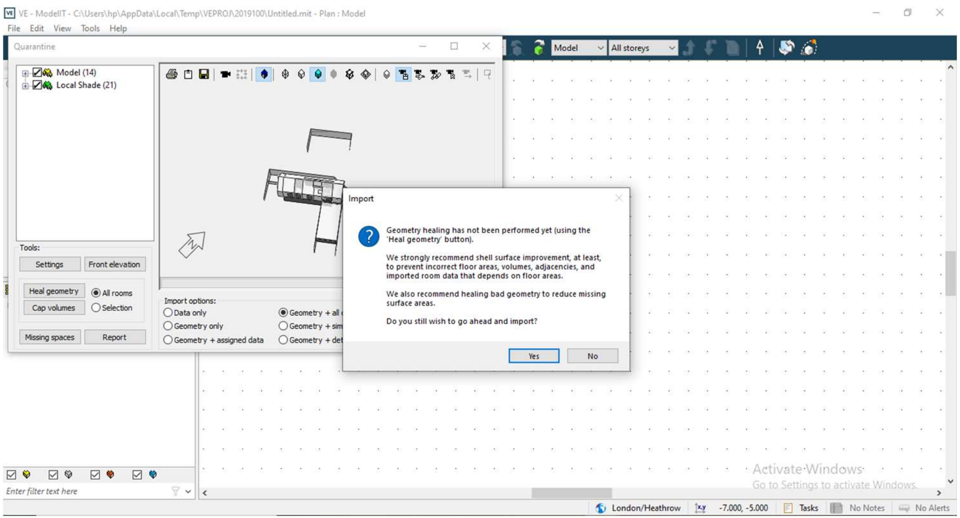

Figure 5. Error sign during convertion process

The gbXML file was succefully imported to the IES Virtual Environment software as shown in (Figure 6) in which the data is simulate and analysis. It gives the designers the visualisation to make decision regarding the design of buildings in consideration of energy consumption and sustainability.

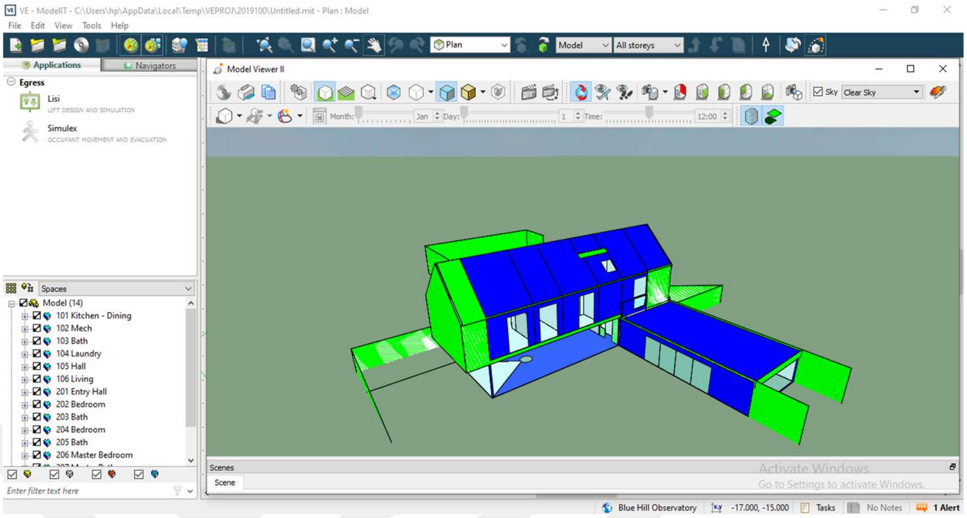

Figure 6. Building Energy Model in IES Virtual Environment Software

IES Virtual Environment Software assists the designers to visualize building energy models and gives them the ability to understand how the building will react before the construction phase. As shown in (Figure 7) IES Virtual Environment software facilitates the designers and engineers to perform solar analysis as well as thermal condition analysis shown in (Figure 8) and many other features.

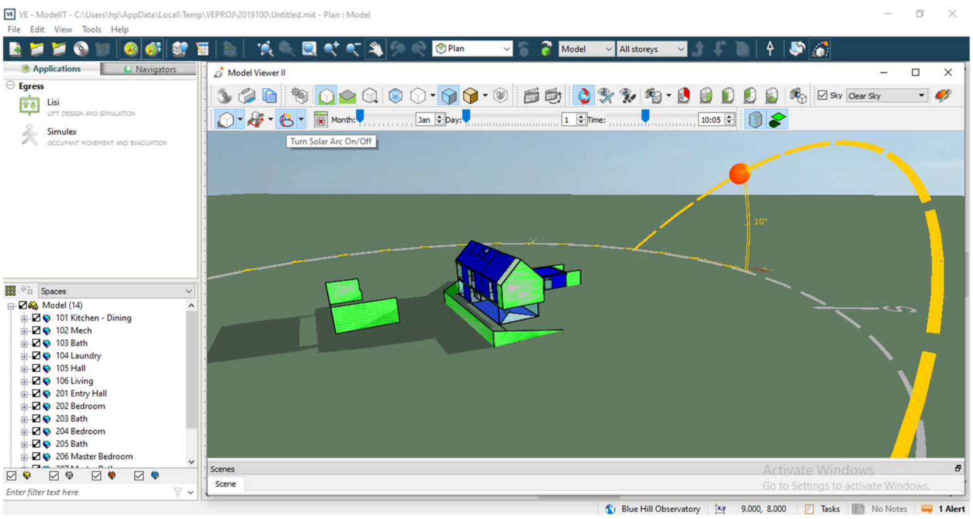

Figure 7. Solar analysis in IES Virtual Environment Software

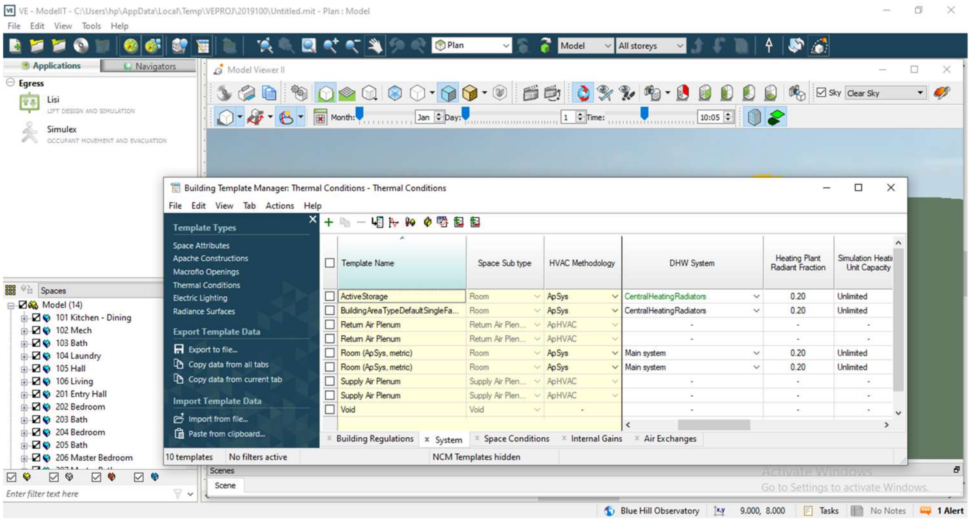

Figure 8. Thermal Condition Analysis in IES Virtual Environment Software

6.4 In Summary

In this chapter, the application of BIM in building performance was analysed and the interoperability between BIM tools and building performance was analysed based on available literature. Challenges that prevents fully utilization of BIM in building performance was outlined and the relation between BIM based software and building performance software (BEM software) was analysed using Autodesk Revit 2019 as a BIM software and using IES Virtual Environment software as a building performance or BEM software.

Chapter Seven

Conclusion

As construction projects become more complex in recent years, the demand of governments and contractors to deliver the project faster and at a more economical cost also increased. On the other hand construction indutry has been acused of being the high producer of waste in the world and causing negative impacts to the environment. Additionally, construction industry known to be one of the expensive industries in the world and it is said that 1 out of 3 dollars is wasted in construction process.

More efficient use of construction methods is more felt nowadays than any other time. Increased profitability in projects, satisfaction of clients and stakeholders, efective excecution of construction from pre-design phase through building life cycle are what caused the emergence of BIM.

BIM is more than just a physical presentation of a building as it includes and stores information related to the building and it uses those information to enhance and assists the project process from pre-construction through building life cycle.

Unfortunately, despite the benefits it offers BIM implementation was not as fast as it was expected to the construction industry. More efficient utilization of BIM plus the implementation obstacles and competitive pressure in some countries remains a serious concern.

This research aimed to formalize a conceptual framework towards the better utilization of BIM in project planning, sustainability, to analys the challenges of BIM in Turkish construction industry and outlining pathways for faster adoption, to analys the challenges and advantages of determining the ideal BIM level for different project size and to analys BIM application in building performance.

After performing an exploratory research on available literature it was found that academic challenges, legal challenges, lack of resource challenges, standardization challenges and organization challenges were the main challenges in adoption of BIM in Turkish construction industry. Pathways for both government and private sector was outlines as more investment on research and development of IT application in construction industry, supporting the collaboration among BIM related institutions, policies on mandating BIM for specific projects, role of leadership and commitment in organization and offering training programs were recognized the most important factors in adopting BIM. In addition, cost of BIM for new adaptors of BIM in Turkish construction industry were explained based on the recent market price and assumptions for small and larger companies.

In the other part of the research, the role of BIM and its challenges in project planning, sustainable building was analyzed, and a framework was outlined for better utilization of BIM in project planning and sustainable buildings. As the most important actions, which are needed to be done are focusing on data and accuracy of information, education and experience in using BIM software, better framework of data sharing among project participants, time and fund investment in improving interoperability between BIM software and other software and improved strategy for better communication. Meta-analysis was done to analysis the correlation between BIM-based project costs and BIM savings, it was found that the BIM saving percentage variates from 0.08% to 1.7% with an average of 1.18%. However, it was found out that there is no correlation between BIM-based project cost and BIM savings in the analyzed projects which may be the result of different utilization of BIM scope in different projects, data limitations etc.

Furthermore, this research analyzed the challenges and advantages of determining the ideal BIM level for different project size. Cost of deployment, organizational culture, uncertainty, lack of detail in model, lack of legal responsibility are the most important challenges for determining ideal BIM level for different project size. Determining the ideal BIM level prevents possible misunderstandings, increases the quality in communication between the project teams, prevents extra costs and expenditures, improved efficiency of asset operations and improved procurement system.

The role of BIM in building performance was analysed, the interoperability between BIM software and Energy Modelling software was examined. According to the examination and research results, the more accurate and detailed the information, the more the building energy model is accurate. It was testified that if BIM model lacks an information, the outcome of Building Energy Model will not be accurate and trustable.

Chapter Eight

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APPENDIX A

Tez Fotokopisi İzin Formu

Anabilim Dalı: Mühendislik Yönetimi Yüksek Lisans Programı

YAZARIN

Soyadı : Massum

Adı : Samiullah

Bölümü : Mühendislik Yönetimi

TEZİN ADI: BIM in Construction Project Planning, Building Sustainability, and its Current State in Turkey.

TEZİN TÜRÜ: Yüksek Lisans ☐ Doktora ☐

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir. ☐

2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir. ☐

3. Tezimden bir bir (1) yıl süreyle fotokopi alınamaz. ☐

TEZİN KÜTÜPHANEYE TESLİM TARİHİ:

APPENDIX B

Curriculum Vitae

PERSONAL INFORMATION

Surname, Name: Massum, Samiullah
Nationality: Afghan
Date and Place of Birth: 07.03.1994 - Panjsher, Afghanistan
Phone: +905380204683
email: samay.massum@icloud.com

EDUCATION

Degree	Institution	Year of Graduation
Bachelor of science in Civil and Industrial Construction	Kabul Polytechnic University	2016
Master of science in Engineering Management	TED University	2020

WORK EXPERIENCE

Year	Place	Enrollment
2014 – 2016	Kabul, Afghanistan	Admin Assistant Smart Vision Construction Company

FOREIGN LANGUAGES

Dari/Persian – Native Speaker
Pashto – Expert, Interpreting
Turkish – Expert, Interpreting
English – Expert, Interpreting
Hindi – V/good Speaking

SKILLS & ABILITIES

Able to work with all Ms. Office.
Able to create project schedules with Ms. Project Planner and Primavera
Able to work with Autodesk Revit.
Able to work with Autocad
Able to communicate effectively with superiors, colleagues and staff.
Able to work under pressure.
Able to work organized.

HOBBIES

Team sports (Football, Table tennis, Cricket)

Games

Reading

Travelling