BUILDING INFORMATION MODELLING ADOPTION IN JORDANIAN ARCHITECTURAL PRACTICE

AHMAD JALAL AHMAD ALJAMAL

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Philosophy

Faculty of Built Environment and Surveying
Universiti Teknologi Malaysia

NOVEMBER 2020

DEDICATION

This thesis is sincerely dedicated to my beloved father, who always supports me and has taught me to persevere for the better and that your value and reputation in this life are measured by the extent of your knowledge. Also, to my beloved mother, who continues to inspire me to be persistent, patient, and to seek God's guidance in reaching my goals. I would like to present this thesis as a little token of appreciation for the endless love and encouragement that both of you have showered me throughout this journey. There is no amount of gratitude that could match the sacrifices that you have made for me and so I will forever be grateful to have you as my backbone.

ACKNOWLEDGEMENT

First and foremost, I would like to express my special thanks and appreciation to my research supervisor, Assoc. Prof. Dr. Lim Yaik Wah for his encouragement, guidance, constructive criticisms, and valuable advice which have helped me complete this thesis successfully. Without his continued support and professional feedbacks, this study might not have achieved its objectives.

Besides, I would also like to convey my deepest gratitude to my dear father, especially for his financial support during my Master's undertaking. Also, not to mention that I am eternally grateful to all my beloved family members for their love and understanding along this journey.

My fellow postgraduate students should also be recognized for their support. My sincere appreciation extends to all my colleagues and dear friends who have selflessly provided much-needed assistance to me, on various occasions. Their views and tips are tremendously useful and significant, indeed. Unfortunately, it is difficult for me to mention all of them specifically in this limited space.

Also, to the staff of the Academic Office at the Faculty of Built Environment and Surveying, thank you for your support throughout the year. I truly appreciate your kindness and patience in handling my requests and making sure that all process go smoothly for me, every step of the way. Last but not least, many thanks to all the personnel at University Teknologi Malaysia (UTM) for their great service in facilitating the educational process, directly or indirectly, throughout my entire program.

Thank you, all, from the bottom of my heart.

ABSTRACT

Building information modeling (BIM) has been a global evolution of building technology due to its advantages and performance in the architecture industry. BIM can assist in achieving performance optimization: improving quality, saving time and cost, as well as sustaining architecture projects. In Jordan, in line with the industry's initiatives and requirements to deal with sustainability and performance, architectural firms in Jordan need to adopt innovative methods of design, cooperation, and documentation. Particularly, with the use of BIM and sustainable design tools, these firms can perform better and thus gain more credibility in the industry. However, BIM is a recent and newly emerging technology in Jordan, whereby very few studies on its adoption are available and the factors affecting this adoption by architects have not yet been explored. Investigating the current status, acceptance, and aptitude for BIM adoption in architectural firms is critical to effective implementation. An essential step is undertaken towards the effective use of BIM and facilitating its implementation, with the aim of studying the current status and the prospects for using BIM technology and its integration with sustainability in the architectural community in Jordan. Ultimately, this leads to the research objective of providing recommendations to boost BIM intake into the Jordanian architecture industry. To this end, this study used a quantitative approach for data collection technique and analysis procedure. A structured questionnaire survey was conducted targeting architects in Amman, the capital of Jordan. A web-based questionnaire was distributed by emails to a total of 249 registered Jordanian engineering and consulting enterprises. Then, an empirical statistics and analyses with a comparison between BIM users and non-BIM users were applied. Results showed that firms are progressing slightly in adopting the BIM system with a slow pace spreading. About 52% of respondents knew and used BIM software for at least some of their projects. However, only 14% of enterprises were familiar with BIM and used it in a large number of their projects. There is no resistance on the part of users. Four factors control the widespread of BIM in architectural firms in Jordan, and they were discussed sufficiently in the study. The users' attitude lies largely in three factors; drivers, i.e. personal and external motivation, management support, and BIM capability. The research also concluded that there are many barriers to the adoption of BIM among design firms, i.e. a lack of knowledge about the utility and sustainable integration of BIM, firms' preparedness, BIM promotions, management support, and resistance to change. Subsequently, the study identified the most prominent obstacles to integrating BIM and sustainability, and the results suggested improvements to their integration. It is also deduced that there is a critical relationship between sustainability and BIM, i.e. Green BIM practitioners use BIM in their projects more than non-Green BIM firms, so the strong growth of the green building market can boost BIM adoption. Finally, the research suggested some recommended strategies to enhance BIM adoption in Jordan. This examination is expected to give a more solidified status of BIM among architects in Jordan, to enable and motivate stakeholders to focus on addressing the critical barriers investigated in this study and to reach to a more effective BIM implementation.

ABSTRAK

Pemodelan Maklumat Bangunan (BIM) telah menjadi revolusi global dalam teknologi pembinaan disebabkan oleh kelebihan dan prestasinya dalam industri seni bina. BIM berupaya membantu mencapai prestasi optimum; meningkatkan kualiti, menjimatkan masa dan kos, serta melestari projek seni bina. Di Jordan, sejajar dengan inisiatif dan keperluan industri dalam mencapai kelestarian dan prestasi, firma seni bina perlu menerapkan kaedah reka bentuk, kerjasama dan dokumentasi yang inovatif. Terutama, dengan penggunaan BIM dan kaedah reka bentuk yang lestari, firma ini dapat menunjukkan prestasi yang lebih baik dan oleh itu dapat membina kredibiliti yang lebih teguh. Walau bagaimanapun, BIM adalah teknologi baru dan baru muncul di Jordan, di mana kajian terhadap keberkesanannya masih terhad serta faktor-faktor yang mendorong pelaksanaannya oleh arkitek masih belum diterokai. Mengkaji status terkini, penerimaan dan kebolehan menggunakan BIM dalam firma seni bina sangat penting untuk pelaksanaan yang efektif dalam industri ini. Melalui kajian ini, suatu langkah penting diambil ke arah penggunaan BIM yang efektif serta bagi memudahkan pelaksanaannya, dengan tujuan untuk mengkaji status terkini dan prospek penggunaan teknologi BIM dan integrasinya dengan kelestarian dalam komuniti seni bina di Jordan. Hal ini membawa kepada objektif kajian ini iaitu memberikan cadangan untuk mendorong penggunaan BIM dalam industri seni bina di Jordan. Untuk tujuan ini, kajian ini menggunakan kaedah kuantitatif sebagai alat pengumpulan data serta prosedur analisis. Tinjauan soal selidik berstruktur dijalankan dalam kalangan arkitek di Amman, ibu negara Jordan. Soal selidik berasaskan laman sesawang diagihkan melalui emel kepada 249 syarikat kejuruteraan dan perundingan berdaftar di Jordan. Kemudian, statistik empirikal dan analisis dengan perbandingan antara pengguna BIM dengan bukan pengguna BIM telah diaplikasikan. Kajian menunjukkan perkembangan yang perlahan terhadap penerimaan dan penggunaan sistem BIM. Kira-kira 52% responden mengetahui dan menggunakan perisian BIM untuk sekurang-kurangnya dalam salah satu projek mereka. Namun, hanya 14% organisasi yang mengetahui dan menggunakan BIM dalam projek mereka. Di dapati bahawa tiada penolakan daripada pihak pengguna. Terdapat empat faktor yang mengekang penggunaan BIM dalam kalangan firma seni bina di Jordan, seperti yang dibincangkan dengan terperinci dalam kajian ini. Sikap pengguna dipengaruhi oleh tiga faktor utama; pemacu, iaitu motivasi peribadi dan luaran, sokongan daripada pihak pengurusan, dan keupayaan BIM. Kesimpulannya, terdapat banyak halangan terhadap pelaksanaan BIM, seperti kurang pengetahuan dan pendedahan terhadap penggunaan dan kelestarian BIM, kesediaan firma, promosi BIM, sokongan pihak pengurusan serta penolakan terhadap pembaharuan. Selanjutnya kajian ini mengenal pasti halangan untuk mengintegrasi BIM dan kelestariannya serta beberapa penambahbaikan turut dicadangkan. Juga disimpulkan bahawa terdapat hubungan penting antara kelestarian dan BIM, di mana pengamal BIM Hijau lebih kerap menggunakan teknik BIM berbanding firma bukan pengamalnya, justeru pembangunan pesat dalam bangunan hijau berupaya menggalakkan penggunaan BIM. Akhirnya, kajian ini turut mencadangkan beberapa strategi bagi meningkatkan penerimaan BIM di Jordan. Penyelidikan ini dijangka dapat meningkatkan status pengunaan BIM yang lebih mantap dalam kalangan arkitek di Jordan, serta menggalakkan para pemegang kepentingan untuk lebih fokus dalam menangani kekangan kritikal, lantas dapat mencapai pelaksanaan BIM yang lebih efektif.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AEC	Architecture, Engineering, and Construction
AIA	The American Institute of Architects
BAM	BIM Acceptance Model
BCA	The Building Control Authority
BDS	Building Description System
BIM	Building Information Modelling
BIMTG	BIM Task Group
BIS	Business Innovations and Skills
BPA	Building Performance Analysis
BREEAM	Building Research Establishment Environmental Assessment Method
CAD	Computer Aided Design
CASBEE	Comprehensive Assessment System for Building Environmental Efficiency
CORENet	The Construction and Real Estate Network
EDGE	Excellence in Design for Great Efficiencies
ERP	Enterprise Resource Planning
FM	Facility Management
GBC	Green Building Council
gbXML	Green Building Extensible Mark-up
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GGBC	Global Green Building Council
GHG	Greenhouse Gases
GIS	Geographic Information System
HVAC	Heating, Ventilation, and Air Conditioning
IAI	The International Alliance for Interoperability
ICT	Information and Communication Technology
IEQ	Indoor Environmental Quality
IES	Integrated Environmental Solutions

IFC	The Industry Foundation Classes
IPD	Integrated Project Delivery
IT	Information Technology
JEA	Jordanian Engineers Association
JEDCO	The Jordanian Enterprise Development Corporation
JGBC	Jordan Green Building Council
KM	Knowledge Management
LEED	Leadership in Energy and Environmental Design
LOD	The Level of Detailing
ME	Middle East
MENA	Middle East and North Africa
MEP	Mechanical, electrical and plumbing
MER	Ministry of Energy and Resources
MHC	McGraw Hill Construction
MOE	The Margin of Error
MoE	Ministry of Environment
MPS	Model Progression Specifications
MPWH	Ministry of Public Works and Housing
NBS	National BIM Standard
NIST	National Institute of Standards and Technology's
NRC	National Research Council
PCA	The Principal Components Analysis
PEU	Perceived Ease of Use
PRS	Pearl Rating System
PU	Perceived Usefulness
ROI	The Return on Investment
RWCM	The Readiness for Workplace Change Management
SMEs	Small and Medium-Sized Enterprises
SDGs	Sustainable Development Goals
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TAM	Technology Acceptance Model
USGBC	US Green Building Council
XML	Extensible Markup Language

LIST OF SYMBOLS

$Z\alpha/2$	-	The Normal Distribution at α/2
p	-	The Sample Prevalence
d	-	The Margin of Error MOE
KMO	-	Kaiser-Meyer-Olkin
α	-	Cronbach's Alpha
r	-	Pearson Correlations
IRA	-	Inter-Rater Agreement
WS	-	Weight Score
SD	-	The Standard Deviation
RA	-	Rank Agreement
RII	-	Relative Importance Index
M	-	Mean Rating
n	-	Number Of Raters
PA	-	The Percentage Agreement
PD	-	The Percentage Disagreement

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

The construction industry is one of the cornerstones of the social and economic growth of countries around the world, whether developed or developing countries. Throughout the years, the building industry has faced countless challenges like low performance and productivity improvements, where the main problem lies in failure to deal with teamwork; poor inter-disciplinary communication, lack of collaboration, as well as the disjointed structure of the industry and its flow of services (Aouad and Wafai, 2002). Moreover, among the significant reasons that hinder this industry from the improvement are clinging to old methods of working, industry's slow changes or ineffective and weak response to emerging technologies (Analysis *et al.*, 1988; Dulaimi *et al.*, 2002). The construction projects over the years have seen an increase in complexity and become sophisticated with more extensive information, as the projects rely on the consumption of high volumes of data throughout the various stages of the building, from planning to operation.

There is a large amount of information involved in project construction, and dealing with this information and its flow traditionally in a manual manner barely meets such demand. Doloi *et al.* (2012) identified that weak coordination consequently leads to reworks, whereby changes in scope in construction projects are identified to be due to several issues; the most significant of which is the inappropriate flow of information among the parties involved. Indeed, this correspondingly results in a schedule delay (Hwang *et al.*, 2013). The construction industry is wasting $ 15.8 billion a year due to inefficient interoperability, as reported in The National Institute of Standards and Technology's (NIST) publication in 2004 (Lee *et al.*, 2015).

A growing number of scholars funded by the industry are beginning to recognize and highlight the issues that lead up to the poor performance of the building industry and weak organizational integration within the sector, thus seeking solutions through information technology (IT) as a key tool for an integrated industry environment. Over the last decade, the evolution of IT has been significantly affecting the development of the Architecture, Engineering, and Construction (AEC) and Facility Management (FM) industries. The industries have been experiencing a qualitative leap; such as progress in knowledge management (KM), enterprise resource planning (ERP), and supply chain management for its information systems (Lin, 2014; Rezgui *et al.*, 2010). As a result, an increase in productivity, efficiency and infrastructure value has been perceived, where the quality and sustainability are enhanced through decreasing the project costs, time limits and unnecessary duplication of tasks, through effective cooperation and communication among AEC players in construction projects (Arayici *et al.*, 2012).

The National Research Council (NRC) concentrates on providing a strategy to enhance the competitiveness, efficiency, and productivity of the construction industry in the United States. NRC has conducted a study to explore the gap between the building industry and IT, where they have found that the interoperable technology applications i.e., Building Information Modelling (BIM) is a sound solution and is considered a promising technology to improve the quality, timeliness, and cost-effectiveness as well as the sustainability of construction projects (Matarneh and Hamed, 2017).

1.1.1 Building Information Modeling (BIM)

BIM is one of the tools that emerged as a solution to the lack of integration and collaboration in the building industry and has been considered to be a vital solution for addressing multidisciplinary deficiencies in construction projects. As construction becomes complex and sophisticated, the need for BIM technology will be more necessary. Its importance in facing the challenges of information management in the building industry cannot be overemphasized (Acquah *et al.*,

2018; Jung and Lee, 2015). BIM is quickly turning into the next IT trend and innovation that may influence AEC and FM participants, both public and private (Azhar, 2011).

BIM is defined as a systematic process of managing and distributing the whole information created throughout the entire project life cycle from planning, design, construction, operations, and maintenance. Most definitions of BIM primarily describe the exchange, management, coordination, simulation and use of metadata surrounding an intelligent 3D model, and BIM's role in serving as an aid in accomplishing a variety of tasks for different stakeholders from the AEC in the construction process (Gerrish *et al.*, 2017). Sun *et al.* (2017) stated that BIM has profoundly affected the building industry from its beginning.

Researchers from previous studies have observed numerous benefits of BIM's implementation on design performance in design firms worldwide, such as a decrease in design errors, cost, time, conflicts in construction, as well as improved customer service, and enhanced product quality (Bozoglu, 2016; Love *et al.*, 2011; Zhao *et al.*, 2017). Hundreds of architectural organizations have gained significant benefits from BIM when properly implemented. Consequently, these organizations have witnessed their productivity and quality increased, project cost decreased, while project delivery duration and construction waste are also significantly reduced. In addition to that, they have also begun responding to smart building requirements appropriately, and when design teamwork and supply chain are integrated, they have managed to achieve customer and users' satisfaction, increased in profits, and also gained significant competitive advantage in the market, as well as improvement in the sustainability of the construction projects (Azhar, 2011; Eastman *et al.*, 2011; Elmualim and Gilder, 2014; Sebastian, 2011).

Other than that, BIM is also capable to support sustainable design in the areas of orientation and massing of the building, daylighting analysis, energy modeling, sustainable materials, water harvesting, site and logistics (Krygiel and Nies, 2008; Lu *et al.*, 2017; Razkenari *et al.*, 2016). BIM facilitates an opportunity to incorporate sustainability gauges all through the design procedure (Autodesk, 2012). With the

assistance of these BIM applications, architects and engineers can share sustainability information more efficiently, such as daylighting and energy consumption, which can seamlessly integrate sustainability analysis into the design process. BIM can also help designers to use existing building datasets to improve the default configuration to simulate building performance during the early stages of new building design (Hiyama *et al.*, 2014). According to Lu *et al.* (2017), the majority of Green BIM applications are designed for building performance analyses and simulations, such as analyses of the energy performance (Kim and Anderson, 2013; Schlueter and Thesseling, 2009; Shrivastava and Chini, 2012; Wong and Fan, 2013), analyses of CO2 emission (Basbagill *et al.*, 2013; Knight and Addis, 2011), and simulations of the lighting (Welle *et al.*, 2012).

Specifically, the architecture industry has been greatly affected since the introduction of the computer and related technologies in the practice (Ibem *et al.*, 2017). The study conducted by Celento (2007) revealed that architects mainly use BIM because it enables them to visualize their designs before starting the actual construction work on-site; thus contributing to reducing ambiguity and errors that help prevent potential loss of money for their customers as the changes that are made to either the model or the database are automatically updated and coordinated throughout the entire model.

The following benefits for architects who use BIM in the design process are particularly evident, including document errors and omissions reduction, reduced rework and cycle time for the design process (Construction, 2012). However, the benefits of BIM were not fully realized even during its implementation. According to the SmartMarket Report, only 3% of the entire respondents stated that they were experiencing BIM full benefits (MGH Construction, 2009). The discrepancy between the expected benefits and the benefits accrued from BIM could be explained by its low adoption rates by architects (Deutsch, 2011).

1.1.2 Sustainable Design as BIM motivator

One of the major contributors to global unsustainable development is the building industry. At present, global energy demand keeps growing steadily in almost every part of our lives; such as transport, communications, agriculture, and construction. With rising energy costs, there is an increasing focus on energy conservation and the promotion of sustainable design and construction through policies and programs. Moreover, with the trend that limited resources are scarce and increasingly costly, and the risk of pollution that harms human health, researchers have increasingly recognized that using renewable energies and upgrading existing energy sources are among the best ways forward in dealing with the many energy challenges the world is facing, day by day. Given the fact that the high cost and immaturity of most renewable energies such as solar power, or having a negative potential to destroy the world if it is out of control such as nuclear, this means that at the current level of technologies and conditions, rising the energy efficiency is considered as a sound, affordable and reliable solution for these challenges (Chan *et al.*, 2017; Malek *et al.*, 2016; Petri *et al.*, 2017; Saidan, 2012).

There is a growing worldwide realization that the earth cannot continue to absorb the harmful impact of human activities on the environment for a long time. The relationship between the architecture industry and sustainable development is essential to save the environment, due to the significant environmental, social, and economic impact that this industry possesses. Improving building practices are also necessary to minimize the adverse effects of the construction industry on the natural environment (Sev, 2009). It is worthy to note that most of the energy used in a building is expended in the operation phase or during the post-occupancy phase of the building's life cycle (Surahman *et al.*, 2015). There are multiple guidelines, for achieving sustainable building design available to architecture stakeholder. This is what the Global Green Building Council "GGBC" is about; maximizing the benefits of going green, which include economic benefits, health benefits, welfare, etc. One of its main goals is to make all buildings net-zero by 2050, particularly because buildings are one of the most influential factors affecting climate change (Asfour, 2017).

The achievement of green and sustainable buildings is in line with the objectives of energy efficiency and the reduction of greenhouse gases GHG for governments worldwide. One way to achieve this goal; reducing energy consumption and CO2 emissions, is through the expected improvement of energy efficiency in all areas of the AEC industry, by reducing energy demand in the building. However, to attain this, both design and operation processes must be facilitated effectively. It is, therefore, this thesis addresses environmental sustainability and it worth the attention of the Jordanian government and will certainly be socially and financially beneficial to the development of the country.

BIM as a process of building design information management is becoming standard practice in the architecture industry. Applying this technology outside the design development zones and using BIM data for the optimization of building performance has managed to draw the attention of the industry members due to the perceived positive effect throughout the building life-cycle. The optimization of building energy performance can be a highly complex process, given the number of factors contributing to the overall construction performance (Gerrish *et al.*, 2017). Recently, BIM has become one of the most effective techniques and monitoring innovations in the architecture industry (Succar and Kassem, 2015).

1.1.3 The Architecture and Construction Industry in Jordan

The construction industry is amongst the major productive activities in the country and it has a significant spot in the national economy. The industry features by highly skilled experiences and has recently been strengthened as The Gulf and international organizations enter the market, and that requires a higher level of technical knowledge, i.e. the new high-rise towers in the capital city Amman (Al Awad, 2015). Due to rapidly rising opportunities in property investments, Jordan is currently experiencing a spurt in construction activities, primarily in the capital (Amman), Aqaba port on the Red Sea, and the Dead Sea (JCCA) (2018). This sector requires a lot of effort to confront numerous issues of construction projects that are related to the contracting and execution systems. Among the key issues, the building

sector have to be properly organized in the project management field to keep pace with the strong advancement of construction projects and growing complexity of its activities (Al-Azhari and Al-Najjar, 2012; Al Awad, 2015).

El-Mashaleh (2007) surveyed the use of IT in construction firms in Jordan and affirmed that Jordan would witness an aggressive plan to take full advantage of IT capabilities. Furthermore, he found that the engineering drawings production depends primarily on AutoCAD in most organizations that utilize the software most of the time. Even though BIM has been leading development worldwide for a long time, its related technologies in Jordan are still within the emerging stages, and traditional CAD vendors such as Autodesk, Bentley, and Archicad are the most popular among users (Matarneh and Hamed, 2017). The World Bank (2019) has classified 137 developing countries in the low and middle-income categories. These countries face significant gaps in knowledge and limited technological innovation (Bui *et al.*, 2016). Similarly, Jordan as a developing country faces various challenges in the construction sector, like its other counterparts, particularly in the Middle East. Parts of the challenges faced by the building sector in Jordan are the many obstacles and barriers in adopting BIM technology due to the lack of clear guidelines and studies on best practices, through which to improve their ability to implement BIM (Bouguerra *et al.*, 2019; Khalid, 2017).

Jordan is one of the major Arabic-Islamic countries that are witnessing unprecedented construction developments. It has become an international arena in which architects from around the world compete to exhibit their design excellence. Most of these designs are controlled by real estate developers and are global and standardized (Jarrar, 2013). The process of design has received only empirical attention in recent years. A Focus on practice can have a direct impact on policymaking, architectural education, and future research not to mention the practice itself (Merriam, 1988). Furthermore, research in professional practice is crucial in building an area for professional practice research that exposes the complex layers of action, dynamics, and the intervening parties responsible for the various decisions (Macpherson *et al.*, 2004). However, there has been very little research on the process of professional practice of architecture in Jordan.

Such an inductive approach to professional practice research has its own challenges. The world of practice, and in this particular case design and architectural practice, is complex and highly reflexive in nature and usually involves continuous interactive encounters (Hall and White, 2005). Moreover, the most important obstacle to affecting the contemporary architectural practice scene in Jordan and the world in general is the dominance of real estate developers and the proliferation associated with fashion-based architecture (Jarrar, 2013).

The Jordanian construction sector makes up 39% of the national power consumption and witnessed a momentous growth of around 16% in this field through 2018 across the country (Ali and Alkayed, 2019). The Jordanian construction market devours a huge amount of resources in order to produce outputs and demands a great expense throughout the procedure of construction and operation (Du Plessis, 2002). This implies that there is a wide gap between the ideal concept of sustainable construction and how it is practiced. To bridge the gap, we are initially looking at the causes behind the existence of this particular issue so as to create rational solutions towards achieving the ideal utilization of sustainable design practices (Al-Momani, 2000; Flynn, 2012). In order to overcome the growing competition either domestically or abroad, and thus being able to stay ahead of the game, architecture companies must turn their focus to innovative solutions. One of the proven ways to be innovative is through technology improvements.

Undoubtedly, the architectural organizations in Jordan need to prepare for these challenges which will oblige them to adopt recent and effective approaches of design, cooperation, and documentation. Therefore, under these circumstances, the Jordanian architects cannot neglect the utilization of BIM. According to Arayici *et al.* (2011a); Navendren *et al.* (2014), and Ramilo and Embi (2014) studies, BIM adoption results in efficiency gains that help eliminate waste and generate value in small and medium-sized architectural firms. Furthermore, mandating BIM leads to the effective development of the building by improving design coordination, as well as design and operational information management (Tuohy and Murphy, 2015). Therefore, this thesis intends to outline the current practices for implementing BIM

in Jordanian architectural organizations as well as to identify the most relevant factors that control and boost BIM implementation in the architectural industry.

1.2 Problem Statement and Research Rationale

As in the aforementioned scenarios, the Jordanian building sector has witnessed such a rapid growth recently, which sparked the interest of the investors and encouraged investment in the construction projects, therefore making the integration and use of technological developments like BIM a more substantial solution. In June 2011, an initiative towards promoting BIM in the Jordanian construction industry was launched, by signing an agreement among the Jordanian Ministry of Public Works and Housing (MPWH), the Jordanian Engineers Association (JEA), BuildingSMART Middle East and North Africa (MENA), BuildingSMART Middle East (ME), and BIM Journal, to establish a BuildingSMART Forum, to improve the construction process and performance in Jordan (MEConstructionNews, 2011). In addition, in August 2018, the BIM committee was formed by a group of volunteer architects in the Architecture Division board in an effort to keep pace with technological developments in the field design and construction, and to promote and enrich BIM adoption in Jordan. One of the most notable achievements has been the lunch of the BIM design templets for engineering firms.

However, with a varying BIM adoption rate globally, Jordan was among the lowest and lagging in the use of BIM, with only 3-5% of the BIM adoption rate as compared to other countries in middle east and worldwide, as found by the BuildingSMART ME survey (Sharif, 2011), and a few recent studies by Al Awad (2015), Gerges *et al.* (2017), and Matarneh and Hamed (2017). There is still a lack of use of such technology in this county, mainly because of various social, financial, legal and technical elements. In the pursuit to change the condition of the existing state of the design and building sector, initially, the process; design technique and application must change, which then leads to the result being more efficient (McLennan, 2004). Despite the great importance of BIM's successful adoption by

design firms, an understanding of the factors affecting this accreditation by architects in Jordan has not yet been explored. Hence, it is important to study the question of the impact of these factors on the architect's decision to adopt BIM. Although there is an increasing body of research on BIM being used in the design process by construction professionals, very few studies on its adoption in a developing country like Jordan are currently available.

It is noted from the literature that some fragmented studies have been conducted on BIM in the context of the Jordanian construction industry. Some of these available studies such as those carried out by Al Awad (2015) and Matarneh and Hamed (2017) attempted to explore the level of awareness and BIM adoption in the Jordanian AEC industry. Such is also the case found in the studies conducted in the Middle East region in general. Unfortunately, most of the research was designed to assess BIM adoption in all AEC industry categories, whereas more accurate results will be obtained if the target population is narrowed. Thus, surveying the company's particular role in the AEC industry could lead to more robust outcomes. Moreover, architects play a prominent role in the design of construction projects and initiating BIM adoption; as they are the key players in creating information models for project integration. Investigating the current state, acceptance, and preparedness to adopt BIM in architectural firms is crucial to ensure effective BIM implementation (Arayici *et al.*, 2011b) and therefore, sufficient knowledge on the level of BIM adoption in the architecture industry is required.

Although previous research has explored a broader aspect of BIM in the context of the construction industry as a whole, focusing on the acceptance or penetration such as; Hwang *et al.* (2013), Enegbuma *et al.* (2014), and Lee *et al.* (2015), only a small number focus specifically on design firms and local architects and thus formed a knowledge gap that needs to be explored. On top of that, the increasing cost of energy and building materials, and the economic challenges facing Jordan, as well as the negative effects of construction projects on the environment, have required the population to consume alternative energy sources more widely and to develop techniques to reduce energy consumption in addition to developing materials and new methods of design, implementation, operation, and maintenance

(Malek *et al.*, 2016). Therefore, it is necessary to place more focus on specific areas in ensuring that the industry constantly seeks to adopt sustainable and innovative building methods throughout the value chain.

The main aspects of this study are the need for sustainable building industry practices, and the need for innovative technology to eliminate the performance problems of the design and building sector in Jordan. Consequently, this study concentrated primarily on addressing the negligence of BIM implementation among architects, by investigating its current use, awareness, benefits, driving forces, as well as industry readiness. On the other hand, there was a lack of studies exploring the use of BIM in achieving sustainable design. Therefore, this study focuses on trying to uncover the potential relationships between BIM and sustainable building practices as they relate to the built environment. On the whole, it is necessary to examine how various elements can either boost or forestall BIM implementation in the Jordanian AEC sector, particularly among architectural organizations. In an effort to address the above-mentioned gaps, this study examines the factors that are influencing BIM accreditation in Jordan within the architectural practice.

1.3 Research Goal

The main goal of this study is to evaluate the current perceptions and the state of utilization of BIM technology and its interrelations with sustainable design among architectural design professionals in Jordan.

1.3.1 Research Objectives

Under the research goal, the followings are the objectives of this investigation:

(a) To examine the current situation of BIM adoption and processes in Jordanian architectural firms.

(b) To assess the perceived factors influencing the BIM adoption in Jordanian architectural practice.

(c) To evaluate the sustainable building design as a driving factor for BIM adoption.

1.4 Research Question

The study will attempt to answer the following research questions:

1. What are the current practices, attitudes, and awareness of BIM implementation in the Jordanian architecture industry?

2. What are the perceived effects of BIM adoption on Jordanian design firms' performance and sustainability management?

3. What factors influence and impose BIM adoption in the architectural industry in Jordan?

4. Given that sustainable design as prime motivator for BIM, what are the challenges facing users in implementing BIM, and how ready are the firms to adopt it?

1.5 Significance of the Study

The study attempts to contribute constructively to the knowledge base in this field by investigating where BIM is placed in daily practices of the architectural enterprises in Jordan. Also, this study provides further insight and results regarding BIM adoption, which is a significant reference point for architects in assessing the changes and impacts that are critical in determining BIM progress in Jordan. Consequently, it is expected that the research findings benefit the community of architects and designer through enhancing their understanding regards the influences that affecting BIM acceptance and its effect on the performance of architectural firms.

This study would provide the stakeholders, especially the Architecture Division Board in Jordanian Engineering Association (JEA), with an insight into the current situation that would help them to promote and mandate BIM adoption among the architecture industry and sustainability practices in the country. Moreover, it enriches the understanding of user acceptance of BIM in the Jordanian architectural industry. If the determinants are considered, this will lead to significant acceptance and subsequent accreditation of BIM in the industry.

1.6 Limitations of the Study

BIM is a fairly recent technology, and there is a shortage of experts with extensive experience in this field. Merely 10% of the participants had over 10 years of involvement in BIM. In addition, the survey was conducted in the capital, where most of the participants were based in Amman, Jordan. As BIM is growing in popularity in the coming years, future research is expected to survey more experienced respondents with a broader range of cities and regions. Another limitation of the research is related to how the study variables are evaluated at the firm level; where the respondents evaluated their performances by themselves and these responses are not objectively measured against genuine datasets from authorized records. However, this may not necessarily be the situation. A more

precise evaluation should be considered in future research. Lastly, several constraints need to be recognized, namely, time constraints and relatively small sample sizes, which may lead to concerns regarding the generalization of research findings.

1.7 Thesis Organization

The thesis is divided into five chapters; the structure of each of the chapters is as follows:

- **Chapter 1 - Introduction**: The first chapter entails an introduction to inform and guide the reader through the background of the research, problem statement, the rationale for the research, and it outlines the goal and objectives of the study. In addition to the research questions, this chapter then lays out the importance of the study followed by the limitations and delimitation of the study.

- **Chapter 2 - Literature Review:** The chapter proceeds with an insightful discussion of relevant literature and previous research studies related to BIM practices and its adoption, to form a deep understanding of the BIM concept and use with an emphasis on architectural practices. Subsequently, sustainable development and sustainability in construction were discussed. It then continues to explore the potential impact of BIM on sustainable design and its contribution to providing sustainable design practices and improved quality.

- **Chapter 3 - Research Methodology:** This chapter elaborates the intention of the research study to attain its purpose and objectives. It discusses the research approach, design, and methodology that embodies an overview of the quantitative research method, scope, survey instrument, and the selection criteria. In addition, the method of data collection was described by reviewing the survey questionnaire conducted among architects from Jordanian engineering firms of varying sizes, types, and structures. This is followed by a detailed description of the procedure and methods used to analyze the data.

- **Chapter 4 - Results and Discussion:** The fourth chapter provides a comprehensive analysis of the results deduced from the data collected through the investigation of the literature and the survey questionnaire distributed among the architects in Jordan. The analysis concludes the reliability of the results, BIM's relation to architectural design and sustainable practices. The chapter ends with the development of a SWOT analysis, where the findings from this evaluation provide valuable answers to the research objectives.

- **Chapter 5 - Conclusion and Recommendation:** In this final chapter, the research concludes with a review of the main research findings with integrated recommendations to assist stakeholders, i.e. Jordanian government and other key players in the architecture sector, to swiftly switch to BIM in order to achieve high performance, sustainable design, and sustainable building industry in Jordan. This chapter also describes how to overcome the barriers of BIM implementation as well as some recommendations and opportunities for improvement for future research.

REFERENCES

(JCCA), J. C. C. A. (2018). Annual Report 2008. from http://jcca.org.jo/Default.aspx

Abbasnejad, B., and Moud, H. I. (2013). BIM and basic challenges associated with its definitions, interpretations and expectations. *International Journal of Engineering Research and Applications (IJERA), 3*(2), 287-294.

Abubakar, M., Ibrahim, Y., Kado, D., and Bala, K. (2014). Contractors' perception of the factors affecting Building Information Modelling (BIM) adoption in the Nigerian Construction Industry. In *Computing in civil and building engineering (2014)* (pp. 167-178).

Acquah, R., Eyiah, A. K., and Oteng, D. (2018). Acceptance of Building Information Modelling: a survey of professionals in the construction industry in Ghana. *ITcon, 23,* 75-91.

Adamus, L. W. (2013). BIM: Interoperability for sustainability analysis in construction. *Central Europe Towards Sustainable Building: Integrated building design BIM*, 1-4.

Adriaanse, A., Voordijk, H., and Dewulf, G. (2010). The use of interorganisational ICT in United States construction projects. *Automation in construction, 19*(1), 73-83.

Ahuja, R., Jain, M., Sawhney, A., and Arif, M. (2016). Adoption of BIM by architectural firms in India: technology–organization–environment perspective. *Architectural Engineering and Design Management, 12*(4), 311-330.

Akadiri, P. O., Chinyio, E. A., and Olomolaiye, P. O. (2012). Design of a sustainable building: A conceptual framework for implementing sustainability in the building sector. *Buildings, 2*(2), 126-152.

Aksamija, A. (2012). BIM-based building performance analysis: Evaluation and simulation of design decisions. *Proceedings of the 2012 ACEEE Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA, USA*, 12-17.

Al-Azhari, W., and Al-Najjar, S. (2012). *Challenges and Opportunities Presented by Amman's Land Topography on Sustainable Buildings.* Paper presented at the Proc. ICCIDC-III Conf.

Al-Momani, A. H. (2000). Construction delay: a quantitative analysis. *International journal of project management, 18*(1), 51-59.

Al-Waked, R., Nasif, M. S., Groenhout, N., and Partridge, L. (2017). Energy Performance and CO2 Emissions of HVAC Systems in Commercial Buildings. *Buildings, 7*(4), 84.

Al-Yami, A. M., and Price, A. D. (2006). A framework for implementing sustainable construction in building briefing project.

Al Awad, O. (2015). *The uptake of advanced IT with specific emphasis on BIM by SMEs in the Jordanian construction industry*. Unpublished PhD, University of Salford.

Ali, H. H., and Alkayed, A. A. (2019). Constrains and barriers of implementing sustainability into architectural professional practice in Jordan. *Alexandria Engineering Journal, 58*(3), 1011-1023.

Alsayyar, B., and Jrade, A. (2015). *Integrating Building Information Modeling (BIM) with sustainable universal design strategies to evaluate the costs and benefits of building projects.* Paper presented at the 5th international/11th construction specialty conference, 1-10.

Amoako-Gyampah, K., and Salam, A. F. (2004). An extension of the technology acceptance model in an ERP implementation environment. *Information & management, 41*(6), 731-745.

Analysis, N. R. C. P. o. S. H., Aki, K., Seismology, N. R. C. C. o., Sciences, N. R. C. B. o. E., Sciences, N. R. C. C. o. P., Mathematics, et al. (1988). *Probabilistic seismic hazard analysis*: National Academies.

Anderson, J. C., and Gerbing, D. W. (1982). Some methods for respecifying measurement models to obtain unidimensional construct measurement. *Journal of marketing research, 19*(4), 453-460.

Anker Jensen, P., and Ingi Jóhannesson, E. (2013). Building information modelling in Denmark and Iceland. *Engineering, Construction and Architectural Management, 20*(1), 99-110.

Aouad, G., and Wafai, M. (2002). *Implementation of information technology in the construction industry: the conceptual methodology approach.* Paper presented at the 2nd International Postgraduate Research Conference in the Built and Human environment, University of Salford.

Aouad, G., Wu, S., Lee, A., and Onyenobi, T. (2013). *Computer aided design guide for architecture, engineering and construction*: Routledge.

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., and O'Reilly, K. (2011a). BIM adoption and implementation for architectural practices. *Structural survey, 29*(1), 7-25.

Arayici, Y., Coates, P., Koskela, L., Kagioglou, M., Usher, C., and O'reilly, K. (2011b). Technology adoption in the BIM implementation for lean architectural practice. *Automation in construction, 20*(2), 189-195.

Arayici, Y., Egbu, C., and Coates, S. (2012). Building information modelling (BIM) implementation and remote construction projects: issues, challenges, and critiques. *Journal of Information Technology in Construction, 17*, 75-92.

Asfour, M. (2017). Views on wellbeing research, policy and practice: An interview with Mohammad Asfour. *Middle East Journal of Positive Psychology, 3*(1), 47-51.

Ashcraft, H. W. (2008). Building information modeling: a framework for collaboration. *Constr. Law., 28*, 5.

Assaf, S., and Nour, M. (2015). Potential of energy and water efficiency improvement in Abu Dhabi's building sector–Analysis of Estidama pearl rating system. *Renewable energy, 82*, 100-107.

Autodesk. (2019). DESIGNING AND BUILDING BETTER WITH BIM. Retrieved September, 2019, from https://www.autodesk.com/solutions/bim

Autodesk, E. (2012). Autodesk Ecotect Analysis. *Sustainable Building Design Software*.

Awwad, R., and Ammoury, M. (2013). *Surveying BIM in the Lebanese Construction Industry.* Paper presented at the ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction, 1.

Ayarkwa, J., Acheampong, A., Wiafe, F., and Boateng, B. (2017). *Factors affecting the implementation of sustainable construction in Ghana: the architect's perspective.* Paper presented at the ICIDA 2017-6th International Conference on Infrastructure Development in Africa, 12-14.

Azhar, S. (2011). Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry. *Leadership and management in engineering, 11*(3), 241-252.

Azhar, S., Carlton, W. A., Olsen, D., and Ahmad, I. (2011). Building information modeling for sustainable design and LEED® rating analysis. *Automation in construction*, *20*(2), 217-224.

Azhar, S., Khalfan, M., and Maqsood, T. (2012). Building information modelling (BIM): now and beyond. *Construction Economics and Building*, *12*(4), 15-28.

Azhar, S., Khalfan, M., and Maqsood, T. (2015). Building information modelling (BIM): now and beyond. *Construction Economics and Building*, *12*(4), 15-28.

Azmi, N., Chai, C., and Chin, L. (2018). *Building Information Modeling (BIM) in Architecture, Engineering and Construction (AEC) Industry: A Case Study in Malaysia.* Paper presented at the Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate, 401-412.

Barlish, K., and Sullivan, K. (2012). How to measure the benefits of BIM—A case study approach. *Automation in construction*, *24*, 149-159.

Basbagill, J., Flager, F., Lepech, M., and Fischer, M. (2013). Application of life-cycle assessment to early stage building design for reduced embodied environmental impacts. *Building and Environment*, *60*, 81-92.

Becerik-Gerber, B., and Kensek, K. (2009). Building information modeling in architecture, engineering, and construction: Emerging research directions and trends. *Journal of professional issues in engineering education and practice*, *136*(3), 139-147.

Becker, F. (2005). *Offices at work: Uncommon workspace strategies that add value and improve performance*: John Wiley & Sons.

Bernardi, E., Carlucci, S., Cornaro, C., and Bohne, R. (2017). An analysis of the most adopted rating systems for assessing the environmental impact of buildings. *Sustainability*, *9*(7), 1226.

Bernstein, P. G., and Pittman, J. H. (2004). Barriers to the adoption of building information modeling in the building industry. *Autodesk building solutions*.

Berwald, S. (2008). From CAD to BIM: The experience of architectural education with building information modeling. In *AEI 2008: Building Integration Solutions* (pp. 1-5).

Bew, M., and Underwood, J. (2010). Delivering BIM to the UK Market. In *Handbook of research on building information modeling and construction informatics: Concepts and technologies* (pp. 30-64): IGI Global.

Bouguerra, K., Lim, Y.-W., Ali, K. N. B., and Aljamal, A. (2019, 2019). *A PILOT STUDY: INVESTIGATION OF THE CURRENT PRACTICES AND THE FEASIBILITY OF BIM IMPLEMENTATION IN ALGERIAN AEC INDUSTRY*. Paper presented at the GBES 2019 conference proceeding – Towards Continuity and Livability Revolution, Malaysia, 147-154.

Bozoglu, J. (2016). Collaboration and coordination learning modules for BIM education. *Journal of Information Technology in Construction (ITcon), 21*(10), 152-163.

Bradley, A., Li, H., Lark, R., and Dunn, S. (2016). BIM for infrastructure: An overall review and constructor perspective. *Automation in Construction, 71*, 139-152.

Brown, R. D., and Hauenstein, N. M. (2005). Interrater agreement reconsidered: An alternative to the rwg indices. *Organizational research methods, 8*(2), 165-184.

Bryde, D., Broquetas, M., and Volm, J. M. (2013). The project benefits of building information modelling (BIM). *International journal of project management, 31*(7), 971-980.

Bui, N., Merschbrock, C., and Munkvold, B. E. (2016). A review of Building Information Modelling for construction in developing countries. *Procedia Engineering, 164*, 487-494.

Bynum II, W. P. (2010). *BUILDING INFORMATION MODELING IN SUPPORT OF SUSTAINABLE DESIGN AND CONSTRUCTION*. UNIVERSITY OF FLORIDA.

Bynum, P., Issa, R. R., and Olbina, S. (2012). Building information modeling in support of sustainable design and construction. *Journal of Construction Engineering and Management, 139*(1), 24-34.

Celento, D. (2007). Innovate or perish: new technologies and architecture's future. *Harvard Design Magazine, 27*, 1-9.

Chan, Darko, A., and Ameyaw, E. E. (2017). Strategies for promoting green building technologies adoption in the construction industry—An international study. *Sustainability, 9*(6), 969.

Chan, C. T. (2014). Barriers of implementing BIM in construction industry from the designers' perspective: A Hong Kong experience. *Journal of System and Management Sciences, 4*(2), 24-40.

Chan, D. W., and Chan, J. H. (2012). Developing a performance measurement index (PMI) for target cost contracts in construction: a Delphi study. *Construction law journal*.

Chapman, S., McNeill, P., and Mcneill, P. (2005). *Research methods*: Routledge.

Cheng, T., and Teizer, J. (2013). Real-time resource location data collection and visualization technology for construction safety and activity monitoring applications. *Automation in Construction, 34*, 3-15.

Chien, K.-F., Wu, Z.-H., and Huang, S.-C. (2014). Identifying and assessing critical risk factors for BIM projects: Empirical study. *Automation in Construction, 45*, 1-15.

Chong, H.-Y., Lee, C.-Y., and Wang, X. (2017). A mixed review of the adoption of Building Information Modelling (BIM) for sustainability. *Journal of Cleaner Production, 142*, 4114-4126.

Chung, Y., and Chin, S. (2015). Factors Affecting the BIM Acceptance of Construction Managers. *Korean Journal of Construction Engineering and Management, 16*(3), 11-23.

Clayton, M. J., Warden, R. B., and Parker, T. W. (2002). Virtual construction of architecture using 3D CAD and simulation. *Automation in Construction, 11*(2), 227-235.

Climatescope. (2017). Jordan/enabling-framework. 2019, from http://2017.global-climatescope.org/en/country/jordan/#/enabling-framework

Coates, P., Arayici, Y., Koskela, K., Kagioglou, M., Usher, C., and O'Reilly, K. (2010). The key performance indicators of the BIM implementation process.

Construction, M.-H. (2010). Green BIM: How building information modeling is contributing to green design and construction. *Bedford, MA*.

Construction, M.-H. (2012). The business value of BIM in North America: multi-year trend analysis and user ratings (2007-2012). *Smart Market Report*.

Construction, M. H. (2014). SmartMarket report: the business value of BIM for construction in major global markets. *Retrieved from McGraw-Hill Construction website: http://analyticsstore. construction. com/smartmarket-reports/GlobalBIMSMR14. html*.

Creswell, J. W., and Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*: Sage publications.

Crotty, R. (2013). *The impact of building information modelling: transforming construction*: Routledge.

Daniel, W. W., and Cross, C. L. (2018). *Biostatistics: a foundation for analysis in the health sciences*: Wiley.

Darko, A., and Chan, A. P. (2017). Review of barriers to green building adoption. *Sustainable Development, 25*(3), 167-179.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly*, 319-340.

Davis, F. D., Bagozzi, R. P., and Warshaw, P. R. (1989). User acceptance of computer technology: a comparison of two theoretical models. *Management science, 35*(8), 982-1003.

Deutsch, R. (2011). *BIM and integrated design: strategies for architectural practice*: John Wiley & Sons.

Diatmika, I., Irianto, G., and Baridwan, Z. (2016). Determinants of behavior intention of accounting information systems based information technology acceptance. *Imperial journal of interdisciplinary research, 2*(8), 125-138.

Ding, L., Zhou, Y., Luo, H., and Wu, X. (2012). Using nD technology to develop an integrated construction management system for city rail transit construction. *Automation in Construction, 21*, 64-73.

Ding, Z., Zuo, J., Wu, J., and Wang, J. (2015). Key factors for the BIM adoption by architects: A China study. *Engineering, Construction and Architectural Management, 22*(6), 732-748.

Doloi, H., Sawhney, A., Iyer, K., and Rentala, S. (2012). Analysing factors affecting delays in Indian construction projects. *International journal of project management, 30*(4), 479-489.

Dowsett, R., and Harty, C. (2013). *Evaluating the benefits of BIM for sustainable design: a review*. Paper presented at the Proceedings of the 29th Annual ARCOM Conference.

Du Plessis, C. (2002). Agenda 21 for sustainable construction in developing countries. *CSIR Report BOU E, 204*.

Dulaimi, M. F., Y. Ling, F. Y., Ofori, G., and Silva, N. D. (2002). Enhancing integration and innovation in construction. *Building research & information, 30*(4), 237-247.

Eadie, R., Odeyinka, H., Browne, M., McKeown, C., and Yohanis, M. (2014). Building information modelling adoption: an analysis of the barriers to implementation. *Journal of Engineering and Architecture, 2*(1), 77-101.

Eastman, C. (1975). The use of computers instead of drawings in building design. *AIA Journal, 63*(3), 46-50.

Eastman, C., Teicholz, P., Sacks, R., and Liston, K. (2011). *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors*: John Wiley & Sons.

Eastman, C., Teicholz, P., Sacks, R., and LISTON, K. (2012). A Guide to Building Information Modeling for Owners, Managers, Architects, Engineers and Contractors. *Australasian Journal of Construction Economics&Building, 12*(3), 101-102.

Eastman, C. T., and Sacks, P. (2008). R. & Liston, K.(2011) BIM Handbook. A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors: New Jersey: John Wiley and Sons, Inc.

Elmualim, A., and Gilder, J. (2014). BIM: innovation in design management, influence and challenges of implementation. *Architectural Engineering and design management, 10*(3-4), 183-199.

Enegbuma, W., Dodo, Y., and Ali, K. (2014). Building information modelling penetration factors in Malaysia. *Int. J. Adv. Appl. Sci, 3*(1), 47-56.

Fadeyi, M. O. (2017). The role of building information modeling (BIM) in delivering the sustainable building value. *International Journal of Sustainable Built Environment, 6*(2), 711-722.

Feng, C.-W., Chen, Y.-J., and Huang, J.-R. (2010). Using the MD CAD model to develop the time–cost integrated schedule for construction projects. *Automation in Construction, 19*(3), 347-356.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics*: sage.

Fischer, M., and Kunz, J. (2004). *The scope and role of information technology in construction.* Paper presented at the Proceedings-Japan society of civil engineers, 1-32.

Fishbein, M., and Ajzen, I. (1977). Belief, attitude, intention, and behavior: An introduction to theory and research.

Fishbein, M., and Ajzen, I. (1980). Understanding attitudes and predicting social behavior.

Flynn, N. (2012). *Public sector management*: SAGE publications.

Gardezi, S. S. S., Shafiq, N., and Khamidi, M. F. B. (2013). Prospects of Building Information Modeling (BIM) in Malaysian construction industry as conflict resolution tool. *Journal of Energy Technologies and Policy, 3*(11), 346-350.

Gerges, M., Austin, S., Mayouf, M., Ahiakwo, O., Jaeger, M., Saad, A., et al. (2017). An investigation into the implementation of Building Information Modeling in the Middle East. *Journal of Information Technology in Construction (ITcon), 22*(1), 1-15.

Gerrish, T. (2017). *Exploring the effectiveness of BIM for energy performance management of non-domestic buildings.* © Tristan Gerrish.

Gerrish, T., Ruikar, K., Cook, M., Johnson, M., Phillip, M., and Lowry, C. (2017). BIM application to building energy performance visualisation and management: Challenges and potential. *Energy and Buildings, 144*, 218-228.

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O., et al. (2017). Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges. *Renewable and Sustainable Energy Reviews, 75*, 1046-1053.

Godoe, P., and Johansen, T. (2012). Understanding adoption of new technologies: Technology readiness and technology acceptance as an integrated concept. *Journal of European Psychology Students, 3*(1).

Goedert, J. D., and Meadati, P. (2008). Integrating construction process documentation into building information modeling. *Journal of construction engineering and management, 134*(7), 509-516.

Gourlis, G., and Kovacic, I. (2017). Building Information Modelling for analysis of energy efficient industrial buildings–A case study. *Renewable and Sustainable Energy Reviews, 68*, 953-963.

Govindan, K., Shankar, K. M., and Kannan, D. (2016). Sustainable material selection for construction industry–A hybrid multi criteria decision making approach. *Renewable and Sustainable Energy Reviews, 55*, 1274-1288.

Green, S. D., Fernie, S., and Weller, S. (2005). Making sense of supply chain management: a comparative study of aerospace and construction. *Construction Management and Economics, 23*(6), 579-593.

Grilo, A., and Jardim-Goncalves, R. (2010). Value proposition on interoperability of BIM and collaborative working environments. *Automation in construction, 19*(5), 522-530.

Gu, N., and London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in construction, 19*(8), 988-999.

Gu, N., Singh, V., Taylor, C., London, K., and Brankovic, L. (2010). BIM adoption: expectations across disciplines. In *Handbook of research on building information modeling and construction informatics: concepts and technologies* (pp. 501-520): IGI Global.

Gupta, A., Cemesova, A., Hopfe, C. J., Rezgui, Y., and Sweet, T. (2014). A conceptual framework to support solar PV simulation using an open-BIM data exchange standard. *Automation in Construction, 37*, 166-181.

Habibi, S. (2017). The promise of BIM for improving building performance. *Energy and Buildings, 153*, 525-548.

Häkkinen, T., and Belloni, K. (2011). Barriers and drivers for sustainable building. *Building Research & Information, 39*(3), 239-255.

Hall, C., and White, S. (2005). Looking inside professional practice: Discourse, narrative and ethnographic approaches to social work and counselling: Sage Publications Sage CA: Thousand Oaks, CA.

Hallberg, D., and Tarandi, V. (2011). On the use of open bim and 4d visualisation in a predictive life cycle management system for construction works. *Journal of Information Technology in Construction (ITcon), 16*, 445-466.

Ham, Y., and Golparvar-Fard, M. (2015). Mapping actual thermal properties to building elements in gbXML-based BIM for reliable building energy performance modeling. *Automation in Construction, 49*, 214-224.

Hamma-adama, M., and Kouider, T. (2019). Comparative Analysis of BIM Adoption Efforts by Developed Countries as Precedent for New Adopter Countries. *Current Journal of Applied Science and Technology*, 1-15.

Hanna, A., Boodai, F., and El Asmar, M. (2013). State of practice of building information modeling in mechanical and electrical construction industries. *Journal of Construction Engineering and Management, 139*(10), 04013009.

Haoues, M., Sellami, A., Ben-Abdallah, H., and Cheikhi, L. (2017). A guideline for software architecture selection based on ISO 25010 quality related

characteristics. *International Journal of System Assurance Engineering and Management, 8*(2), 886-909.

Hartmann, T., and Fischer, M. (2008). Applications of BIM and Hurdles for Widespread Adoption of BIM. *2007 AISC-ACCL eConstruction Roundtable Event Rep*.

Hassouneh, K., Al-Salaymeh, A., and Qoussous, J. (2015). Energy audit, an approach to apply the concept of green building for a building in Jordan. *Sustainable Cities and Society, 14*, 456-462.

Hiyama, K., Kato, S., Kubota, M., and Zhang, J. (2014). A new method for reusing building information models of past projects to optimize the default configuration for performance simulations. *Energy and Buildings, 73*, 83-91.

Hore, A., McAuley, B., West, R., Kassem, M., and Kuang, S. (2017). Ireland's BIM Macro Adoption Study: Establishing Ireland's BIM Maturity.

Hosseini, M. R., Azari, E., Tivendale, L., and Chileshe, N. (2015). *Barriers to adoption of building information modeling (BIM) in Iran: preliminary results.* Paper presented at the The 6th International Conference on Engineering, Project, and Production Management (EPPM2015), Gold Coast, Australia.

Howes, C. J. (2010). Construction management versus construction project management.

Hu, P. J.-H., Clark, T. H., and Ma, W. W. (2003). Examining technology acceptance by school teachers: a longitudinal study. *Information & management, 41*(2), 227-241.

Hussin, J. M., Rahman, I. A., and Memon, A. H. (2013). The way forward in sustainable construction: issues and challenges. *International Journal of Advances in Applied Sciences, 2*(1), 15-24.

Hwang, B.-G., Zhao, X., and Ng, S. Y. (2013). Identifying the critical factors affecting schedule performance of public housing projects. *Habitat International, 38*, 214-221.

Ibem, E., Uwakonye, U., Akpoiroro, G., Somtochukwu, M., and Oke, C. (2018). Building information modeling (BIM) adoption in architectural firms in Lagos, Nigeria. *Int. J. Civ. Eng. Technol, 9*, 902-915.

Ibem, E. O., Aduwo, E. B., and Ayo-Vaughan, E. A. (2017). e-Procurement adoption in the Nigerian building industry: Architects' perspective. *Pollack Periodica, 12*(3), 167-180.

Industry, B. T. (2003). Sustainable building and construction: facts and figures. *Ind Environ, 26*(2-3), 5-8.

Innovation, C. C. (2005). Parametric building development during early design stage.

Jalaei, F., and Jrade, A. (2014). Integrating Building Information Modeling (BIM) and Energy Analysis Tools with Green Building Certification System to Conceptually Design Sustainable Buildings. *Itcon, 19*, 494-519.

Jamal, K. A. A., Mohammad, M. F., and Hashim, N. (2019). BUILDING INFORMATION MODELLING (BIM) FOR SUSTAINABLE INDUSTRY: THE MALAYSIAN ARCHITECT'S PERSPECTIVE. *Energising Green Building, 12*.

Jarrar, O. M. (2013). Cultural Influences in Jordanian Architectural Practices: Post 1990.

Joannides, M. M., Olbina, S., and Issa, R. R. (2012). Implementation of building information modeling into accredited programs in architecture and construction education. *International Journal of Construction Education and Research, 8*(2), 83-100.

Johanson, G. A., and Brooks, G. P. (2010). Initial Scale Development: Sample Size for Pilot Studies. *Educational and Psychological Measurement, 70*(3), 394-400.

Jordan Green Building Council. from https://jordangbc.org/about-jordan-gbc/

Jordanian Engineers Association. (2018). Jordanian Offices & Companies. 2019, from https://www.jea.org.jo/portal/en/jordanian-offices-companies/

Jordanian Engineers Association. (2019, Dec 2019). Jordanian Engineering Offices Index. 2019, from https://www.jea.org.jo/portal/engineering-offices-index/#

Jrade, A., and Jalaei, F. (2013). *Integrating building information modelling with sustainability to design building projects at the conceptual stage.* Paper presented at the Building Simulation, 429-444.

Juan, Y.-K., Lai, W.-Y., and Shih, S.-G. (2017). Building information modeling acceptance and readiness assessment in Taiwanese architectural firms. *Journal of Civil Engineering and Management, 23*(3), 356-367.

Jung, W., and Lee, G. (2015). The status of BIM adoption on six continents. *International journal of civil, environmental, structural, construction and architectural engineering*, *9*(5), 444-448.

Khalid, B. (2017). *Implementation of Building Information Modelling (BIM) in Building Design for Energy Minimisation in Algerian Construction Industry: Architect Perspectives.* Universiti Tun Hussein Onn Malaysia.

Khalid, B. (2020). An Investigation of the Challenges and the Best Practices of BIM Implementation in the Algerian AEC Industry. 287-300.

Khazanchi, D. (2005). Information technology (IT) appropriateness: The contingency theory of "fit" and IT implementation in small and medium enterprises. *Journal of Computer Information Systems*, *45*(3), 88-95.

Khodeir, L. M., and Nessim, A. A. (2017). BIM2BEM integrated approach: Examining status of the adoption of building information modelling and building energy models in Egyptian architectural firms. *Ain Shams Engineering Journal*.

Khosrowshahi, F., and Arayici, Y. (2012). Roadmap for implementation of BIM in the UK construction industry. *Engineering, Construction and Architectural Management*.

Kim, H., and Anderson, K. (2013). Energy modeling system using building information modeling open standards. *Journal of Computing in Civil Engineering*, *27*(3), 203-211.

Kim, H., Shen, Z., Kim, I., Kim, K., Stumpf, A., and Yu, J. (2016). BIM IFC information mapping to building energy analysis (BEA) model with manually extended material information. *Automation in Construction*, *68*, 183-193.

Kim, K., and Teizer, J. (2014). Automatic design and planning of scaffolding systems using building information modeling. *Advanced Engineering Informatics*, *28*(1), 66-80.

Kim, K., and Yu, J. (2014). *Improvement of BIM-Based Building Permit Process.* Paper presented at the Proceedings of the KCICI Academic Conference, 9-10.

Knight, D., and Addis, B. (2011). *Embodied carbon dioxide as a design tool–a case study*. Paper presented at the Proceedings of the Institution of Civil Engineers-Civil Engineering, 171-176.

Kometa, S. T., Olomolaiye, P. O., and Harris, F. C. (1994). Attributes of UK construction clients influencing project consultants' performance. *Construction Management and Economics, 12*(5), 433-443.

Kori, S. I., and Kiviniemi, A. (2015). Toward adoption of BIM in the Nigerian AEC industry; context framing, data collecting and paradigm for interpretation.

Krygiel, E., and Nies, B. (2008). *Green BIM: successful sustainable design with building information modeling*: John Wiley & Sons.

Lai, P. (2017). The literature review of technology adoption models and theories for the novelty technology. *JISTEM-Journal of Information Systems and Technology Management, 14*(1), 21-38.

LeBreton, J. M., and Senter, J. L. (2008). Answers to 20 questions about interrater reliability and interrater agreement. *Organizational research methods, 11*(4), 815-852.

Lee, I., Choi, B., Kim, J., and Hong, S.-J. (2007). Culture-technology fit: effects of cultural characteristics on the post-adoption beliefs of mobile internet users. *International Journal of Electronic Commerce, 11*(4), 11-51.

Lee, S.-K., Kim, K.-R., and Yu, J.-H. (2014). BIM and ontology-based approach for building cost estimation. *Automation in construction, 41*, 96-105.

Lee, S., Yu, J., and Jeong, D. (2013). BIM acceptance model in construction organizations. *Journal of Management in Engineering, 31*(3), 04014048.

Lee, S., Yu, J., and Jeong, D. (2015). BIM Acceptance Model in Construction Organizations. *J. Manage. Eng, 31*(3), 04014048.

Lin, Y.-C. (2014). Construction 3D BIM-based knowledge management system: a case study. *Journal of Civil Engineering and Management, 20*(2), 186-200.

Linderoth, H. C. (2010). Understanding adoption and use of BIM as the creation of actor networks. *Automation in construction, 19*(1), 66-72.

Liu, R., Issa, R., and Olbina, S. (2010). *Factors influencing the adoption of building information modeling in the AEC Industry.* Paper presented at the Proceedings of the International Conference on Computing in Civil and Building Engineering, 139-145.

Loiacono, E. T., Watson, R. T., and Goodhue, D. L. (2002). WebQual: A measure of website quality. *Marketing theory and applications, 13*(3), 432-438.

Love, P. E., Edwards, D. J., Han, S., and Goh, Y. M. (2011). Design error reduction: toward the effective utilization of building information modeling. *Research in Engineering Design, 22*(3), 173-187.

Love, P. E., Simpson, I., Hill, A., and Standing, C. (2013). From justification to evaluation: Building information modeling for asset owners. *Automation in construction, 35*, 208-216.

Lu, Y., Wu, Z., Chang, R., and Li, Y. (2017). Building Information Modeling (BIM) for green buildings: A critical review and future directions. *Automation in Construction, 83*, 134-148.

Lundberg, E. (2017). How to compete effectively with self-service technologies: The impact of technology readiness and the technology acceptance model on self-scanning.

Macpherson, I., Brooker, R., Aspland, T., and Cuskelly, E. (2004). Constructing a territory for professional practice research: Some introductory considerations. *Action Research, 2*(1), 89-106.

Malek, D., al Mumani, M., Abu Awwad, B., Awwad, O., and Omary, A. (2016). Arts and Design Studies Green Architecture with an Example in Amman -Jordan.

Malhotra, N. K. (2011). *Review of marketing research: Special issue–marketing legends*: Emerald Group Publishing Limited.

Malsane, S., Matthews, J., Lockley, S., Love, P. E., and Greenwood, D. (2015). Development of an object model for automated compliance checking. *Automation in Construction, 49*, 51-58.

Matarneh, R. T., and Hamed, S. A. (2017). Exploring the Adoption of Building Information Modeling (BIM) in the Jordanian Construction Industry. *J Archit Eng Tech, 6*(1).

Matthews, J., Love, P. E., Heinemann, S., Chandler, R., Rumsey, C., and Olatunj, O. (2015). Real time progress management: Re-engineering processes for cloud-based BIM in construction. *Automation in Construction, 58*, 38-47.

Mazairac, W., and Beetz, J. (2013). BIMQL–An open query language for building information models. *Advanced Engineering Informatics, 27*(4), 444-456.

McCartney, C. (2010). Factors affecting the uptake of building information modelling (BIM) in the Auckland architecture, engineering & construction (AEC) industry.

McLennan, J. F. (2004). *The philosophy of sustainable design: The future of architecture*: Ecotone publishing.

MEConstructionNews. (2011). Jordanian Government initiates national BuildingSMART forum. 2019, from https://meconstructionnews.com/703/jordanian-government-initiates-national-buildingsmart-forum

Mehran, D. (2016). Exploring the Adoption of BIM in the UAE Construction Industry for AEC Firms. *Procedia Engineering, 145*, 1110-1118.

Merschbrock, C., and Rolfsen, C. N. (2016). BIM technology acceptance among reinforcement workers-the case of Oslo airport's terminal 2.

MGH Construction. (2009). The business value of BIM: Getting building information modeling to the bottom line. *Smart Market Report*, 1-50.

Migilinskas, D., Popov, V., Juocevicius, V., and Ustinovichius, L. (2013). The benefits, obstacles and problems of practical BIM implementation. *Procedia Engineering, 57*, 767-774.

Mohamed, A. E. (2018). The implementation of building information modeling (BIM) towards sustainable construction industry in Egypt "The pre-construction phase".

Mohammad, W. W., Abdullah, M. R., Ismail, S., and Takim, R. (2018). *Overview of Building Information Modelling (BIM) adoption factors for construction organisations.* Paper presented at the IOP Conference Series: Earth and Environmental Science, 012107.

Mohd-Nor, M., and Grant, M. P. (2014). Building information modelling (BIM) in the malaysian architecture industry. *WSEAS Transactions on Environment and Development, 10*, 264-273.

Morton, D. E. (2012). BIM: A transformative technology within the architectural curriculum in Schools of Architecture (Pedagogic Stages of Architectural Education and the Transformative Effect of BIM). *International Journal of 3-D Information Modeling (IJ3DIM), 1*(4), 50-68.

Mugo, D. G., Njagi, K., Chemwei, B., and Motanya, J. O. (2017). The technology acceptance model (TAM) and its application to the utilization of mobile learning technologies. *Journal of Advances in Mathematics and Computer Science*, 1-8.

Muller, M. F., Esmanioto, F., Huber, N., Loures, E. R., and Junior, O. C. (2019). A systematic literature review of interoperability in the green Building Information Modeling lifecycle. *Journal of cleaner production, 223*, 397-412.

Mutai, A. (2009). *Factors influencing the use of building information modeling (BIM) within leading construction firms in the United States of America*: Indiana State University.

Naing, L., Winn, T., and Rusli, B. (2006). Practical issues in calculating the sample size for prevalence studies. *Archives of orofacial Sciences, 1*, 9-14.

Nanajkar, A., and Gao, Z. (2014). BIM implementation practices at India's AEC firms. In *ICCREM 2014: Smart Construction and Management in the Context of New Technology* (pp. 134-139).

Naoum, S. (2012). *Dissertation research and writing for construction students*: Routledge.

Nasir, A. R., Gabriel, H. F., and Choudhry, R. M. (2011). *Cost and time overruns in highway projects of Pakistan.* Paper presented at the Sixth International Conference on Construction in the 21st Century, Kuala Lumpur, Malaysia, 69-76.

Nations, U. (2015). Transforming our world: The 2030 agenda for sustainable development. *General Assembley 70 session*.

Navendren, D., Manu, P., Shelbourn, M., and Mahamadu, A.-M. (2014). Challenges to building information modelling implementation in UK: designers' perspectives.

NBS, N. (2015). National BIM report 2015. *Royal Institute of British Architects*.

Ngowi, A. (2002). Challenges facing construction industries in developing countries: TAYLOR & FRANCIS LTD 4 PARK SQUARE, MILTON PARK,, ABINGDON OX14 4RN, OXON ….

Nikas, A., Poulymenakou, A., and Kriaris, P. (2007). Investigating antecedents and drivers affecting the adoption of collaboration technologies in the construction industry. *Automation in construction, 16*(5), 632-641.

Nisbet, S. L. (2006). Modelling consumer intention to use gambling technologies: an innovative approach. *Behaviour & Information Technology, 25*(03), 221-231.

O'Neill, T. A. (2017). An overview of interrater agreement on Likert scales for researchers and practitioners. *Frontiers in psychology, 8*, 777.

Olatunji, O. A. (2011). Modelling the costs of corporate implementation of building information modelling. *Journal of Financial Management of Property and Construction, 16*(3), 211-231.

Olatunji, S., Olawumi, T., and Awodele, O. (2017). Achieving value for money (VFM) in construction projects. *Journal of Civil and Environmental Research, 9*(2), 54-64.

Olawumi, T. O., and Chan, D. W. (2018). Identifying and prioritizing the benefits of integrating BIM and sustainability practices in construction projects: a Delphi survey of international experts. *Sustainable cities and society, 40*, 16-27.

Olawumi, T. O., Chan, D. W., and Wong, J. K. (2017). Evolution in the intellectual structure of BIM research: A bibliometric analysis. *Journal of Civil Engineering and Management, 23*(8), 1060-1081.

Olawumi, T. O., Chan, D. W., Wong, J. K., and Chan, A. P. (2018). Barriers to the integration of BIM and sustainability practices in construction projects: A Delphi survey of international experts. *Journal of Building Engineering, 20*, 60-71.

Oluwatayo, A., and Amole, D. (2012). Characteristics of global architectural firms. *Engineering, Construction and Architectural Management, 19*(4), 393-405.

Omar, H. S. (2015). *Solutions for the UAE architecture, engineering, and construction (AEC) industry to mandate building information modeling (BIM).* The British University in Dubai (BUiD).

Park, Y., Son, H., and Kim, C. (2012). Investigating the determinants of construction professionals' acceptance of web-based training: An extension of the technology acceptance model. *Automation in construction, 22*, 377-386.

Patermann, C. (1999). The fifth EU framework programme and its consequences for the construction industry. *Building Research & Information, 27*(6), 412-418.

Patterson, K. A., Grimm, C. M., and Corsi, T. M. (2003). Adopting new technologies for supply chain management. *Transportation Research Part E: Logistics and Transportation Review, 39*(2), 95-121.

Petri, I., Kubicki, S., Rezgui, Y., Guerriero, A., and Li, H. (2017). Optimizing energy efficiency in operating built environment assets through building information modeling: a case study. *Energies, 10*(8), 1167.

Pikas, E., Sacks, R., and Hazzan, O. (2013). Building information modeling education for construction engineering and management. II: Procedures and

implementation case study. *Journal of Construction Engineering and Management, 139*(11), 05013002.

Pipada, A., and Xu, S. (2016). The Effect of Data Security Perception on Wearable Device Acceptance: A Technology Acceptance Model.

Porwal, A., and Hewage, K. N. (2013). Building Information Modeling (BIM) partnering framework for public construction projects. *Automation in construction, 31*, 204-214.

Qian, A. Y. (2012). Benefits and ROI of BIM for Multi-disciplinary Project Management. *National University of Singapore, Mar*.

Ramilo, R., and Embi, M. R. B. (2014). Critical analysis of key determinants and barriers to digital innovation adoption among architectural organizations. *Frontiers of Architectural Research, 3*(4), 431-451.

Razkenari, M. A., Nanehkaran, S. M., and Barati, K. (2016). Comprehensive Evaluation of Different Aspects of BIM Applications in Sustainable Design.

Redmond, A., Hore, A., Alshawi, M., and West, R. (2012). Exploring how information exchanges can be enhanced through Cloud BIM. *Automation in construction, 24*, 175-183.

Ren, Y., Skibniewski, M. J., and Jiang, S. (2012). Building information modeling integrated with electronic commerce material procurement and supplier performance management system. *Journal of Civil Engineering and Management, 18*(5), 642-654.

Rezgui, Y., Hopfe, C. J., and Vorakulpipat, C. (2010). Generations of knowledge management in the architecture, engineering and construction industry: An evolutionary perspective. *Advanced Engineering Informatics, 24*(2), 219-228.

Rogers Everett, M. (1995). Diffusion of innovations. *New York, 12*.

Roodman, D. M., Lenssen, N. K., and Peterson, J. A. (1995). *A building revolution: how ecology and health concerns are transforming construction*: Worldwatch Institute Washington, DC.

Rostami, R., and Thomson, C. (2017). *Sustainable Development of the UK Construction Industry for Future Development.* Paper presented at the 2nd International conference: Civil Engineering, Architecture, and Crisis Management.

Sacks, R., Koskela, L., Dave, B. A., and Owen, R. (2010). Interaction of lean and building information modeling in construction. *Journal of construction engineering and management, 136*(9), 968-980.

Saidan, M. (2012). Sustainable energy mix and policy framework for Jordan. *Friedrich Ebert Stiftung: Amman, Jordan*.

Salgueiro, I. B., and Ferries, B. (2015). An "environmental BIM" approach for the architectural schematic design stage. *International Journal of Architectural Computing, 13*(3-4), 299-312.

Saunders, M. N. (2011). *Research methods for business students, 5/e*: Pearson Education India.

Schlueter, A., and Thesseling, F. (2009). Building information model based energy/exergy performance assessment in early design stages. *Automation in construction, 18*(2), 153-163.

Sebastian, R. (2011). Changing roles of the clients, architects and contractors through BIM. *Engineering, construction and architectural management, 18*(2), 176-187.

Sev, A. (2009). How can the construction industry contribute to sustainable development? A conceptual framework. *Sustainable Development, 17*(3), 161-173.

Sharif, T. (2011). BIM in the Middle East. *Middle-East buildingSMART, 64*.

Shavelson, R. (1996). Statistical Reasoning for the Behavioral Science (Custom Edition for Oklahoma State University): Boston, MA: Pearson Education Company.

Shen, L., Edirisinghe, R., and Yang, M. (2016). *An investigation of BIM readiness of owners and facility managers in Singapore: institutional case study*. Paper presented at the CIB World Building Congress.

Shirowzhan, S., Sepasgozar, S. M., Edwards, D. J., Li, H., and Wang, C. (2020). BIM compatibility and its differentiation with interoperability challenges as an innovation factor. *Automation in Construction, 112*, 103086.

Shrivastava, S., and Chini, A. (2012). Using building information modeling to assess the initial embodied energy of a building. *International Journal of Construction Management, 12*(1), 51-63.

Singh, V., Gu, N., and Wang, X. (2011). A theoretical framework of a BIM-based multi-disciplinary collaboration platform. *Automation in construction, 20*(2), 134-144.

Skibniewski, M. J., and Zavadskas, E. K. (2013). Technology development in construction: a continuum from distant past into the future. *Journal of Civil Engineering and Management, 19*(1), 136-147.

Smith, P. (2014). BIM implementation–global strategies. *Procedia Engineering, 85*, 482-492.

Solla, M., Ismail, L. H., and Yunus, R. (2016). Investigation on the potential of integrating BIM into green building assessment tools. *ARPN Journal of Engineering and Applied Sciences, 11*(4), 2412-2418.

Son, H., Kim, C., Chong, W. K., and Chou, J. S. (2011). Implementing sustainable development in the construction industry: constructors' perspectives in the US and Korea. *Sustainable Development, 19*(5), 337-347.

Son, H., Lee, S., Hwang, N., and Kim, C. (2014). *The adoption of building information modeling in the design organization: An empirical study of architects in Korean design firms.* Paper presented at the ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction, 1.

Son, H., Lee, S., and Kim, C. (2015). What drives the adoption of building information modeling in design organizations? An empirical investigation of the antecedents affecting architects' behavioral intentions. *Automation in construction, 49*, 92-99.

Son, H., Park, Y., Kim, C., and Chou, J.-S. (2012). Toward an understanding of construction professionals' acceptance of mobile computing devices in South Korea: An extension of the technology acceptance model. *Automation in construction, 28*, 82-90.

Soust-Verdaguer, B., Llatas, C., and García-Martínez, A. (2017). Critical review of bim-based LCA method to buildings. *Energy and Buildings, 136*, 110-120.

Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. *Automation in construction, 18*(3), 357-375.

Succar, B., and Kassem, M. (2015). Macro-BIM adoption: Conceptual structures. *Automation in construction, 57*, 64-79.

Succar, B., Sher, W., and Williams, A. (2012). Measuring BIM performance: Five metrics. *Architectural Engineering and Design Management, 8*(2), 120-142.

Sultan, F., and Chan, L. (2000). The adoption of new technology: the case of object-oriented computing in software companies. *IEEE transactions on Engineering Management, 47*(1), 106-126.

Sun, C., Jiang, S., Skibniewski, M. J., Man, Q., and Shen, L. (2017). A literature review of the factors limiting the application of BIM in the construction industry. *Technological and Economic Development of Economy, 23*(5), 764-779.

Surahman, U., Kubota, T., and Higashi, O. (2015). Life cycle assessment of energy and CO2 emissions for residential buildings in Jakarta and Bandung, Indonesia. *Buildings, 5*(4), 1131-1155.

Sweis, R., Sweis, G., Attar, G., and Hammad, A. A. (2011). The relationship between information technology adoption and job satisfaction in the Jordanian construction industry. *International Journal of Information Technology Project Management (IJITPM), 2*(2), 32-52.

Tabachnick, B. G., Fidell, L. S., and Ullman, J. B. (2007). *Using multivariate statistics* (Vol. 5): Pearson Boston, MA.

Tang, P., Huber, D., Akinci, B., Lipman, R., and Lytle, A. (2010). Automatic reconstruction of as-built building information models from laser-scanned point clouds: A review of related techniques. *Automation in construction, 19*(7), 829-843.

Taylor, J. E. (2007). Antecedents of successful three-dimensional computer-aided design implementation in design and construction networks. *Journal of Construction Engineering and Management, 133*(12), 993-1002.

Tewfik, M., and Ali, M. M. (2014). Public green buildings in Jordan. *Eur. Int. J. Sci. Technol, 3*, 284-300.

Tsikriktsis, N. (2004). A technology readiness-based taxonomy of customers: A replication and extension. *Journal of Service Research, 7*(1), 42-52.

Tulubas Gokuc, Y., and Arditi, D. (2017). Adoption of BIM in architectural design firms. *Architectural Science Review, 60*(6), 483-492.

Tuohy, P. G., and Murphy, G. B. (2015). Closing the gap in building performance: learning from BIM benchmark industries. *Architectural Science Review, 58*(1), 47-56.

Veiga, J. F., Floyd, S., and Dechant, K. (2001). Towards modelling the effects of national culture on IT implementation and acceptance. *Journal of Information technology, 16*(3), 145-158.

Venkatesh, V., and Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management science, 46*(2), 186-204.

Weiner, B. J. (2009). A theory of organizational readiness for change. *Implementation science, 4*(1), 67.

Welle, B., Rogers, Z., and Fischer, M. (2012). BIM-Centric Daylight Profiler for Simulation (BDP4SIM): A methodology for automated product model decomposition and recomposition for climate-based daylighting simulation. *Building and Environment, 58*, 114-134.

Won, J., Lee, G., Dossick, C., and Messner, J. (2013). Where to focus for successful adoption of building information modeling within organization. *Journal of Construction Engineering and Management, 139*(11), 04013014.

Wong, A. K., Wong, F. K., and Nadeem, A. (2011). Government roles in implementing building information modelling systems: Comparison between Hong Kong and the United States. *Construction innovation, 11*(1), 61-76.

Wong, J. K. W., and Zhou, J. (2015). Enhancing environmental sustainability over building life cycles through green BIM: A review. *Automation in Construction, 57*, 156-165.

Wong, K.-d., and Fan, Q. (2013). Building information modelling (BIM) for sustainable building design. *Facilities, 31*(3/4), 138-157.

World Bank. (2019). Country and Lending Groups. Retrieved 15 March, 2019, from https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups.

Wu, J.-H., and Wang, S.-C. (2005). What drives mobile commerce?: An empirical evaluation of the revised technology acceptance model. *Information & management, 42*(5), 719-729.

Wu, W., and Handziuk, E. (2013). Use of building information modeling in aging-in-place projects: a proof of concept. In *Computing in Civil Engineering (2013)* (pp. 443-450).

Xu, H., Feng, J., and Li, S. (2014). Users-orientated evaluation of building information model in the Chinese construction industry. *Automation in Construction, 39*, 32-46.

Yalcinkaya, M., and Singh, V. (2015). Patterns and trends in building information modeling (BIM) research: A latent semantic analysis. *Automation in Construction, 59*, 68-80.

Yan, W., Culp, C., and Graf, R. (2011). Integrating BIM and gaming for real-time interactive architectural visualization. *Automation in Construction, 20*(4), 446-458.

Yin, R. K. (2003). Case study research: design and methods (ed.). *Thousand Oaks*.

Zanni, M.-A., Soetanto, R., and Ruikar, K. (2014). Defining the sustainable building design process: methods for BIM execution planning in the UK. *International Journal of Energy Sector Management, 8*(4), 562-587.

Zanni, M. A., Soetanto, R., and Ruikar, K. (2017). Towards a BIM-enabled sustainable building design process: roles, responsibilities, and requirements. *Architectural Engineering and Design Management, 13*(2), 101-129.

Zhang, L., and Issa, R. R. (2012). Ontology-based partial building information model extraction. *Journal of Computing in Civil Engineering, 27*(6), 576-584.

Zhao, X., Feng, Y., Pienaar, J., and O'Brien, D. (2017). Modelling paths of risks associated with BIM implementation in architectural, engineering and construction projects. *Architectural Science Review, 60*(6), 472-482.