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Amman - Jordan

The Impact of Building Information Modeling on Competitive Advantage in Architectural Firms in Jordan

أثر نمذجة معلومات المباني على الميزة التنافسية في الشركات المعمارية في الأردن

Prepared by

Othman Mohammad Attallah

Supervised by

Prof. Dr. Abdel-Aziz Ahmad Sharabati

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Management Department

Business Faculty

Middle East University

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Authorization

I, **Othman Attallah,** authorize the Middle East University to provide copies of my thesis on paper and electronically to libraries, organizations, and institutions concerned with scientific study and studies upon request.

Name: Othman Attallah.

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Signature:

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This Thesis titled "**The Impact of Building Information Modeling on Competitive Advantage in Architectural Firms in Jordan**" was successfully defended and approved on Data: 3rd June 2024.

Examination Committee Members:

No.	Name	Title	University	Signature
1	Prof. Dr. Abdel-Aziz Ahmad Sharabati	Supervisor	Middle East University	
2	Prof. Dr. Ali Mohammad Al-Adaileh	Internal Member and Head of Committee	Middle East University	
3	Dr. Fayez Ahmad Al Badri	Internal Member	Middle East University	
4	Prof. Dr. Shafiq Ibrahim Haddad	External Member	Princess Sumaya University for Technology	

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Othman Attallah

Dedication

To my cherished parents, whose steadfast love, enduring support, and boundless encouragement have been my pillars of strength and inspiration throughout this journey.

And to my dear friends, whose unwavering support and camaraderie have enriched this experience immeasurably.

I am profoundly grateful for your belief in me and your unwavering presence by my side.

Othman Attallah

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The Impact of Building Information Modeling on Competitive Advantage in Architectural Firms in Jordan

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Supervised by
Prof. Dr. Abdel-Aziz Ahmad Sharabati

Abstract

Purpose: Building information modeling has been implemented as a tool to manage the work in the engineering industry, which attempts to define the relationship of BIM with Competitive Advantages (Cost, Quality, Responsiveness, Reliability, and Innovation). Therefore, this study aims to investigate the impact of building information modeling on the Competitive Advantages of the Jordanian architectural industry.

Design/Methodology/Approach: This study is a qualitative descriptive study. To actualize this study a questionnaire then it was checked by BIM coordinators, managers, and academics. The data was collected from 186 managers (suitable sample), BIM Coordinators, and BIM users who are working at Jordanian architectural organizations by questionnaire. After confirming the normality, validity, and reliability of the tool, descriptive analysis was carried out, and the correlation between variables was checked. Finally, the impact was tested by multiple regressions.

Findings: The findings show the high impact of implementing building information modeling (BIM) in architectural firms. It also shows that there is a strong correlation between Building information modeling sub-variables and Competitive Advantages dimensions. Also, it shows how BIM Affects the competitive advantage sub-variables as below: the highest impact was for cost, followed by Time followed by Reliability, followed by quality. Finally, it shows that there is a significant and positive impact of building information modeling (BIM) on the Competitive Advantages of the Jordanian architectural Industry.

Practical and Managerial Implications: Implementing building information modeling in the architectural industry is mandatory not an option. Therefore, including Building information modeling within the vision, mission, and strategies will direct plans and daily activities toward Competitive Advantages.

Social Implications: This study recommends companies consider corporate social responsibility with their Building information modeling activities, starting from selecting the common data environment (CDE).

Limitations/Recommendations: The current study was conducted on architectural organizations. Therefore, it is recommended that future researchers collect more data over a longer time to check the current model validity and measuring instrument. It also recommends carrying out similar studies on other industries in Jordan and the same industry outside Jordan to test its results' generalizability.

Originality/Value: This study may be considered as one of few studies that tackle the issue of building information modeling (BIM) and investigates its impact on the Competitive Advantages of the Jordanian architectural Industry.

Keywords: Building information modeling, level of development, Competitive Advantages, Jordanian architectural Industry.

أثر نمجذة معلومات البناء على الميزة التنافسية في شركات الهندسة المعمارية في الأردن

إعداد: **عثمان محمد عطاالله**

إشراف: **الأستاذ الدكتور عبد العزيز أحمد الشرباتي**

الملخص

الغرض: ظهرت نمذجة معلومات البناء كأداة لإدارة العمل في صناعة الهندسة، والتي تعرف العلاقة بين نمذجة معلومات البناء (BIM) والميزات التنافسية (التكلفة، الجودة، الاستجابة، الموثوقية، والابتكار). لذلك، تهدف هذه الدراسة إلى التحقيق في أثر نمذجة معلومات البناء على الميزة التنافسية في قطاع الهندسة المعمارية الأردنية.

التصميم/المنهجية/الطريقة العلمية:هذه الرسالة نوعية وصفية. لتحقيق الدراسة تم تطوير استبيان و تم تحكيمه من قبل ممارسين ومدراء و عدد من المدرسين وقد تم جمع عينة ملائمة بلغت البيانات من 186 مديراً ومنسقاً ومستخدماً لنمذجة معلومات البناء (BIM) يعملون في المنظمات الهندسية الأردنية من خلال استبيان. بعد تأكيد الحالة الطبيعية، الصلاحية والموثوقية للأداة، تم إجراء التحليل الوصفي والتحقق من الارتباط بين المتغيرات. وأخيراً، تم اختبار الأثر بواسطة الانحدار المتعدد.

النتائج: تُظهر النتائج الأثر الكبير لتطبيق نمذجة معلومات البناء (BIM) في الشركات المعمارية و تُظهر النتائج أن هناك ارتباطًا قويًا بين متغيرات نمذجة معلومات البناء وأبعاد الميزة التنافسية يؤثر على متغيرات الميزة التنافسية الفرعية كما يلي: كان التأثير الأكبر على التكلفة، يليه الوقت، يليه الموثوقية، ثم الجودة. أخيرًا، تُظهر النتائج أن هناك تأثيرًا كبيرًا وإيجابيًا لنمذجة معلومات البناء (BIM) على الميزات التنافسية في قطاع العمارة الأردنية.

التطبيقات العملية والإدارية: يعتبر تطبيق نمذجة معلومات البناء في صناعة الهندسة المعمارية إلزامياً وليس خياراً. لذلك، يتوجب تضمين نمذجة معلومات البناء في الرؤية والرسالة والاستراتيجيات التي ستوجه الخطط والأنشطة اليومية نحو المزايا التنافسية.

التطبيقات الاجتماعية: توصي هذه الدراسة الشركات بأخذ المسؤولية الاجتماعية للشركات في الاعتبار في أنشطتها الخاصة بنمذجة معلومات البناء، بدءاً من اختيار بيئة البيانات المشتركة.(CDE)

القيود/التوصيات: تم إجراء الدراسة الحالية على المنظمات الهندسية. لذلك، توصي الباحثين المستقبليين بجمع المزيد من البيانات على مدى فترة أطول للتحقق من صلاحية النموذج الحالي وأداة القياس. كما توصي بإجراء دراسات مشابهة على قطاعات أخرى في الأردن ونفس القطاع خارج الأردن لاختبار تعميم النتائج.

الأصالة/القيمة: يمكن اعتبار هذه الدراسة واحدة من الدراسات القليلة التي تتناول مسألة نمذجة معلومات البناء (BIM) وتحقق في تأثيرها على الميزة التنافسية لقطاع الهندسة المعمارية الأردنية.

الكلمات الرئيسية: نمذجة معلومات البناء، مستوى التطوير، الميزة التنافسية، قطاع الهندسة المعمارية الأردنية

CHAPTER ONE
Introduction

1.1 Background

Over the past few years, the construction industry has encountered difficulties in aligning activities among the architectural, mechanical, electrical, and construction sectors. To address this coordination issue, a technology known as the common data environment (CDE) has been implemented. This thesis delves into the specifics of one such technology, namely Building Information Modeling (BIM), exploring its role in overcoming coordination challenges. The focus is on examining how BIM has effectively addressed these issues and understanding the advantages it brings to architectural fields. Additionally, this thesis explores the potential influence of the evolving BIM on enhancing competitive advantages within the industry.

In recent decades, there has been a growing interest in the construction sector regarding the adoption of Building Information Models (BIM). This interest stems from the various advantages and resource efficiencies that BIM offers during the design, planning, and construction phases of new buildings. According to Volk, at. al. (2014), The origins of 3D modeling can be traced back to the 1970s, evolving from early computer-aided design (CAD) initiatives across multiple industries. While many sectors developed integrated analysis tools and embraced object-based parametric modeling (the fundamental concept of BIM), the construction industry adhered to traditional 2D design for an extended period (Eastman, at. al. 2018).

The introduction of BIM modeling in pilot projects in the early 2000s aimed to support the building design efforts of architects and engineers. Subsequently, major research efforts concentrated on enhancing preplanning and design processes, clash detection, visualization, quantification, costing, and data management. More recently, specialized tools in design, architecture, and engineering professions have integrated with the core functionalities of BIM, encompassing aspects like energy analysis, structural analysis, scheduling, progress tracking, and job site safety (Volk, at. al. 2014).

The utilization of BIM has been primarily focused on preplanning, design, construction, and integrated project delivery for buildings and infrastructure. However, in recent times, there has been a shift in research focus from earlier life cycle stages to considerations involving maintenance, refurbishment, deconstruction, and end-of-life, especially for complex structures (Volk, at. al. 2014).

The BIM implementation frameworks employed in developed nations are not universally comprehensive and have led to certain drawbacks. These include the failure to realize the full benefits of BIM, a shortage of extensive BIM projects, challenges in adoption, and economic burdens on small and medium-sized organizations (Hewage & Porwal 2013; Succar & Kassem 2015).

In countries such as the United States, Canada, United Kingdom, Singapore, Spain, Portugal, and Sweden; BIM implementation models have manifested in the form of the establishment of a national BIM program, mandatory use of BIM for spatial program validation of projects in 2007, development of a national BIM standard, development of BIM protocol and Integrated Project Delivery documents, and development of BIM guidelines (Lu & Cheng 2015) BIM institute has been established, BIM guidelines and standards have been developed, and BIM has become a mandatory requirement in the contractor selection process (Hewage & Porwal 2013) BIM implementation initiatives in the United States and Canada relied heavily on BIM awareness, BIM adoption by government agencies, a mandatory requirement of BIM, BIM guidelines, and BIM standards to drive BIM adoption. The development of the BIM library, the establishment of a BIM center and steering committee, mandatory BIM e-submissions for new projects, and BIM fund, with Industry Foundation Classes development and BIM classification standard initiatives. In addition, the BIM Task Group, BIM academic forum, and Construction Industry Council have been established to drive BIM implementation in many countries such as the United Kingdom, Finland, and Norway. These groups and committees have developed a specification framework for BIM commissioning, BS 1192 for collaborative working, BS 1192-4 for interoperability for classification systems, PAS 1192-5 for security, and BIM use specifications (Lu & Cheng 2015, Johansson, at. al. 2015) The application of these BIM implementation approaches has played a crucial role in fostering BIM adoption in these nations, as evidenced by the numerous reports detailing the utilization of BIM across various project types in these regions (Gledson & Greenwood, 2017; Kiviniemi & Codinhoto, 2014).

Following the discussion on the background of BIM, this study centers on examining the impact of BIM on the competitive advantage of architectural firms. To achieve this, it is essential to comprehend the concepts of the main two keywords in this study which are **competitive advantage** and the specific impacts that **BIM** can have to understand the relationship between BIM and competitive advantage, it is required to:

Study the effect of emerging BIM with its main functions (architecture, mechanical electrical, and civil) on the competitive advantage (Quality, Time, Reliability, Cost, and Innovation) of architectural firms and how the variation in development occurred in a noticeable way which affected the competitive advantage of the local firms, in comparison to the local and international firms that implemented it, and how emerging such technology like BIM affected the whole industry.

1.2 Study Purpose and Objectives

The purpose of the study is to investigate how emerging BIM in architectural firms will affect their competitive advantage directly cost, innovation, quality, and reliability.

To be clearer, these are the main objectives of this study:

1. To measure the level of implementation of Building information modeling (BIM) in Jordanian Architectural Organizations.
2. To define the level of competitive advantage in Jordanian Architectural Organizations.
3. To evaluate the relationship between Building information modeling (BIM) and the competitive advantage in Jordanian Architectural Organizations.
4. To evaluate the effect of Building information modeling (BIM) on the competitive advantage in Jordanian Architectural Organizations.

1.3 Study Significance and Importance:

This study might be considered one of the leading studies that examine the impact of implementing BIM on competitive advantage in architectural firms in Jordan's architectural industries. Moreover, this study aims to draw a valuable understanding of guidelines about the impact of building information modeling on the Competitive Advantages of the Jordanian architectural Industry, other engineering industries, institutions, and decision-makers. The content also maybe an interest to academic studies related to the reporting and decision making concerning building information modeling.

Therefore, the value of this study arises from the following scientific and practical considerations:

1- Drive attention to building information modeling and its influence on enhancing the Competitive Advantages of the Jordanian architectural Industry.
2- Highlight the importance of controlling building information modeling sub-variables and the quick influence on competitive advantage dimensions in the Jordanian architectural Industry.
3- Support other research in the study of building information modeling, and its importance either in the architectural industry or in other engineering industries.
4- Support the decision-makers in the architectural industry or even other industries, and recommend applying building information modeling.

The importance of the current study is to emphasize the role of building information modeling in enhancing the Competitive Advantages for Jordanian architectural industries; moreover, it helps other industries to achieve Competitive Advantages. In addition, it lays out a practical road map for decision-makers to adopt building information modeling systems based on their significant impact. Finally, the current study may add value for libraries to be used as a secondary source of data, as well as it may help scholars and practitioners to open the debate about the practicality of deploying building information modeling.

1.4 Study Problem Statement

The construction industry faces significant challenges due to its fragmented nature, requiring coordination among diverse professionals and organizations Arayici (2021). The intricate life cycle of construction projects involves extensive documentation and information sharing, leading to issues like misunderstandings, frequent verifications, clarifications, disappointment, lack of trust, and conflicts among stakeholders. These problems negatively affect the traditional project goals of time, cost, quality, competitiveness, and productivity (Al-Ashmori, at. al. 2020). Additionally, insufficient knowledge about the benefits of incorporating Building Information Modeling (BIM) within local architectural firms hinders the growth of the local market, especially compared to the advancements in the global architectural industry (Olanrewaju, at. al. 2020).

1.5 Study Questions

The current study is devoted to answering the following questions:

1. What is the level of implementation of Building information modeling (BIM) in Jordanian Architectural Organizations?
2. What is the level of competitive advantage in Jordanian Architectural Organizations?
3. Is there a relationship between Building information modeling (BIM) and the competitive advantage in Jordanian Architectural Organizations?
4. What is the effect of Building information modeling (BIM) on the competitive advantage in Jordanian Architectural Organizations?

Questions one and two will be answered by descriptive analysis, question three will be answered by correlation test, and question fourth will be answered by the following hypothesis.

1.6 Study Hypothesis

The fourth question will be answered by evaluating the following hypothesis:

H01: The building information modeling (BIM) does not affect the competitive advantage (Cost, Innovation, Reliability, Time, and Quality) of Jordanian Architectural Organizations, at $\alpha \leq 0.05$.

H01.1: The building information modeling (BIM) does not affect the competitive advantage (Cost) of Jordanian Architectural Organizations, at $\alpha \leq 0.05$.

H01.2: The building information modeling (BIM) does not affect the competitive advantage (Innovation) of Jordanian Architectural Organizations, at α≤0.05.

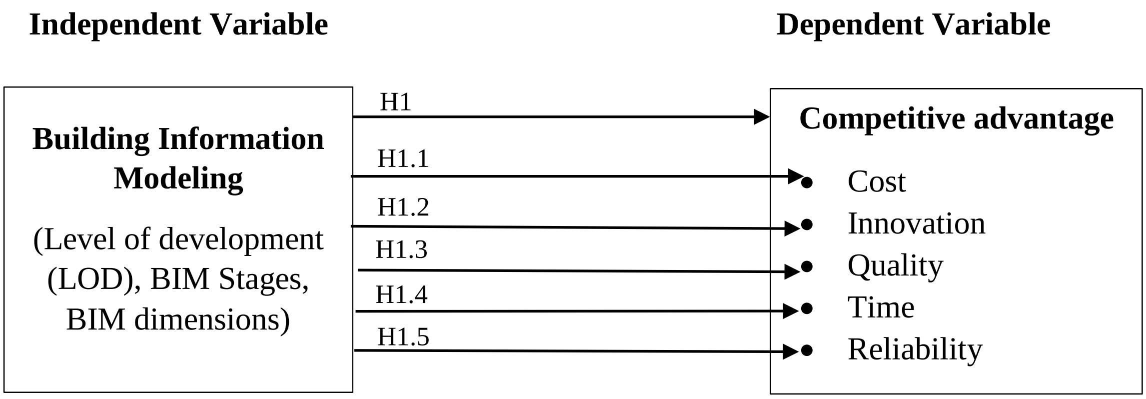
H01.3: The building information modeling (BIM) does not affect the competitive advantage (Reliability) of Jordanian Architectural Organizations, at α≤0.05.

H01.4: The building information modeling (BIM) does not affect the competitive advantage (Time) of Jordanian Architectural Organizations, at α≤0.05.

H01.5: The building information modeling (BIM) does not affect the competitive advantage (Quality) of Jordanian Architectural Organizations, at α≤0.05.

1.7 Study Model

Based on the problem statement and its questions the following model has been developed to study the effect of building information modeling on competitive strategies, as shown in the model



Model 1. 1: Study model

Resources: this model was developed based on the following previous studies: **Independent**: (Abbas, at. al. 2016; Adillah, at. al. 2015; lu & Cheng 2015; Volk, at. al. 2014; Sholeh, at. al. 2020; Succar, at. al. 2020; Behún & Behúnová, 2023). **Dependent:** (Porter & Van der Linde 1996; Ambe, 2010; Hewage & Porwal 2013).

1.8 Operational Definitions

Building information modeling is a collaborative, digital process that manages information about a structure throughout its lifecycle, from planning and design to construction, operation, and demolition. Central to BIM is a three-dimensional model that coordinates the efforts of stakeholders like investors, planners, contractors, and operators. BIM, also known as n-D Modeling or Virtual Prototyping Technology, enhances the Architecture, Engineering, and Construction (AEC) industry by enabling project visualization, early issue detection, and improved collaboration. It combines technology and procedures to streamline project management and data handling, providing significant benefits while also presenting implementation challenges, and it will be measured through the three dimensions below.

Level of development is a protocol in Building Information Modeling (BIM) that sets guidelines for content requirements, model use, and information availability at different project stages. It aims to minimize issues caused by insufficient project information. A study on LOD application in Malaysian construction found that its implementation varies and serves different purposes. LOD helps construction professionals access necessary project information. The LOD concept, originally from computer graphics, was adapted by BIM Forum to specify expected information at each level, updated yearly. The levels range from LOD 100 (conceptual model) with minimal detail to LOD 500 (as-built model) with detailed, verified information. Each intermediate level (LOD 200, 300, 350, and 400) progressively adds more detailed geometric, semantic, and coordination information to the model. Questions 1-6 were developed to measure it.

Stages The Pre-BIM stage involves traditional building practices that rely on manual and computer-based documents, such as CAD drawings and spreadsheets. Even advanced 3D CAD is not considered part of BIM maturity unless it includes object-based modeling, as defined by Succar's model, which sets strict criteria for BIM maturity. Pre-BIM practices are characterized by 2D drafting, linear workflows, asynchronous communication, and a lack of interoperability. In some industries, such as in Sri Lanka, many organizations do not meet any BIM maturity levels, making BIM adoption challenging. A simple statement of 'no maturity' is inadequate for decision-making. Instead, a comprehensive assessment framework is needed to compare current practices with ultimate BIM maturity levels. Questions 7-9 were developed to measure it.

Dimensions range from 3D to 7D and denote various layers of information integrated into BIM models to enhance comprehension of construction projects. Each dimension signifies distinct data types facilitating project management and decision-making across the project lifecycle. Questions 10-12 were developed to measure it.

Competitive Advantage is the ability of a company to achieve high customer satisfaction with its products and services. It involves implementing strategies to sustain this advantage over competitors. Porter (2008) Generic Competitive Strategies play a crucial role in positioning a company within its industry or across industries. Competitive advantages enable companies to offer high-quality products at competitive prices and adapt to meet customer demands, thereby maintaining a strong competitive position, It will be measured through the five dimensions below.

The cost concept as a competitive advantage is widely recognized. It allows organizations to compete by offering lower prices or providing the same services at a lower cost than competitors. This involves developing internal efficiencies to reduce costs and managing operational expenses across the supply chain, including labor, materials, management, and transportation. Additionally, focusing on specific customer groups or regional markets can help leverage cost advantages. Questions 13-20 were developed to measure it.

Innovation as a competitive strategy encompasses the development and introduction of new products and features to the market, along with the exploration of new markets through the implementation of novel organizational methods, practices, procedures, or external relationships. It also involves the cultivation of capabilities that enable organizations to differentiate their offerings from competitors. Questions 21-27 were developed to measure it.

Quality is the importance of delivering high-quality products and services that provide value to customers. It is seen as a competitive advantage when organizations can consistently offer superior quality and performance, leading to customer satisfaction and a positive perception of product quality. Quality is not only about meeting customer expectations but also about creating value and achieving a high perceived level of quality in the eyes of the customer. Questions 28-33 were developed to measure it.

Time is the Competitive Advantage that capable organizations to handle changes in customers' demands or requirements. Responsiveness is based on two pillars, the first one is the organization's flexibility to adopt any changes in demand quantities or requirements, and the second pillar is the organization's speed to fulfill the demand. Questions 34-39 were developed to measure it.

Reliability is defined as the ability to consistently meet mission requirements and deliver products or services. It involves ensuring that tasks are completed as expected, with high predictability of process outputs to achieve the right timing, quantity, and quality. Reliability also entails minimizing uncertainty to ensure on-time delivery and maintain product quality. Questions 40-44 were developed to measure it.

1.9 Study Limitations and Delimitations:

Human Limitation: This study has been conducted on managers, BIM coordinators, and BIM modelers in architectural firms.

Place Limitation: The study will be conducted in Amman, Jordan.

Time Limitation: This study will be conducted during March 2023.

Study Delimitation: this study examines the relationship between building information modeling and competitive advantage. However, many architectural firms did not implement BIM in their firms, although, this study covered the significant relationships between them.

CHAPTER TWO

Theoretical and Conceptual Framework and Literature Review

2.1 Introduction:

This chapter includes variable Definitions simplifications, the relationship between variables, previous studies including previous models, and the way this study differentiates from previous studies.

2.2 Definitions and Components of Independent Variable (Building Information Modeling (BIM):

Building Information Modeling (BIM): BIM entails the collaborative generation and utilization of information related to a structure, serving as a foundation for decision-making throughout the entire lifespan of the facility—from initial planning and design to the issuance of design documents, construction, operation, and eventual demolition. The core of BIM lies in a three-dimensional information model, which serves as the focal point around which the activities of an investor, customer, general planner, general contractor, and operator are organized (Aridova, 2016). Building Information Modeling (BIM), also known as n-D Modeling or Virtual Prototyping Technology, is revolutionizing the Architecture, Engineering, and Construction (AEC) industry. BIM encompasses both a technological aspect and a procedural approach. The technological component allows stakeholders to visualize projects in a simulated environment, helping to identify potential design, construction, or operational issues before they arise. The procedural component fosters close collaboration and integrates the roles of all project stakeholders. This paper provides an overview of BIM, highlighting its core concepts, its application throughout the project lifecycle, and the benefits it offers to stakeholders through various case studies. Additionally, the paper discusses the risks and barriers to implementing BIM and explores future trends in the industry. BIM consists of a combination of policies, processes, and technologies that together create a methodology for managing crucial building design and project data in a digital format throughout the entire lifecycle of a building (Johansson at. al. 2015).

In summary: Building Information Modeling (BIM) is a collaborative, digital process that manages information about a structure throughout its lifecycle, from planning and design to construction, operation, and demolition. Central to BIM is a three-dimensional model that coordinates the efforts of stakeholders like investors, planners, contractors, and operators. BIM, also known as n-D Modeling or Virtual Prototyping Technology, enhances the Architecture, Engineering, and Construction (AEC) industry by enabling project visualization, early issue detection, and improved collaboration. It combines technology and procedures to streamline project management and data handling, providing significant benefits while also presenting implementation challenges. It is divided into 3 variables: Level of development, Stages, And Dimensions.

Level of development (LOD): is a protocol that outlines the basic guidelines for Building Information Modeling (BIM). These guidelines are designed to specify content requirements, authorize the use and purpose of the model, and indicate the amount of information available at any given stage of the project. LOD aims to minimize issues arising from insufficient project information. To achieve the application of LOD in BIM projects, A literature review was conducted to identify the fundamental guidelines of the LOD specification. Additionally, semi-structured interviews were held with BIM consultants from both the public and private sectors. The findings show that the implementation of LOD. By utilizing LOD, construction professionals can access the necessary information for their projects (Latiffi, at. al. 2015). The Level of Detail (LOD) concept is an old topic that existed in computer graphics for bridging the graphical complexity and performance by regulating the amount of detail used to visualize the virtual world (Luebke, 2019). The BIM forum subsequently has published updated versions of the Level of Development Specification in a yearly cycle with the aim of providing a common understanding of the expected information at every LOD. The first level, LOD 100 (conceptual model), is limited to a generic representation of the building, meaning no shape information or geometric representation. The second level, LOD 200 (approximate geometry), consists of generic elements as placeholders with approximate geometric and semantic information. At LOD 300 (precise geometry), all the elements are modeled with their quantity, size, shape location, and orientation. Next, to enable detailed coordination between the different disciplines, such as clash detection and avoidance, LOD 350 (construction documentation) is introduced, including the interfaces between all the building systems. Reaching LOD 400, the model incorporates additional information about detailing, fabrication, assembly, and installation. Lastly, at LOD 500 (as built), the model elements are a field-verified representation in terms of size, shape, location, quantity, and orientation (Bredberg & Bergqvist 2020).

In summary: The Level of Development (LOD) is a protocol in Building Information Modeling (BIM) that sets guidelines for content requirements, model use, and information availability at different project stages. It aims to minimize issues caused by insufficient project information. A study on LOD application in Malaysian construction found that its implementation varies and serves different purposes. LOD helps construction professionals access necessary project information. The LOD concept, originally from computer graphics, was adapted by BIM Forum to specify expected information at each level, updated yearly. The levels range from LOD 100 (conceptual model) with minimal detail to LOD 500 (as-built model) with detailed, verified information. Each intermediate level (LOD 200, 300, 350, and 400) progressively adds more detailed geometric, semantic, and coordination information to the model.

BIM Stages: The Pre-BIM stage represents the conventional building practices, or the industry before the implementation of BIM. This stage includes both manual and computer-based documents such as CAD drawings and spreadsheet schedules. Even 3D CAD is not considered a stage of maturity of BIM. Only object-based modeling and better is considered as BIM. Thus, Succar's model is comparatively stringent on the maturity level at the lower end. The pre-BIM stage would be characterized by 2D droughting, document-based linear workflows, asynchronous communication, and a lack of interoperability. This stage may also include advanced use of CAD such as 3D CAD. However, until and unless the modeling is object-based, it will not be considered as a BIM maturity phase. The challenge a BIM infant industry like that of Sri Lanka would face is that the majority of organizations will not fall into any of the BIM maturity levels in either the Bew-Richard or Succar's models. Apparently, with their experience in the industry, authors are unaware of any organization falling into any BIM maturity level. In this context, the simple notion that 'there is no maturity' will not yield much help in terms of decision-making on BIM adoption. On the other hand, it is questionable if such an industry should target the first maturity level (phase 1 or stage 1 in the above models) as the next step because there can be alternative roadmaps when well informed structural approach becomes possible. Therefore, an expanded framework for assessment is preferred. It should also be ensured that the assessment framework enables comparison and contrast of the current status with the ultimate BIM maturity level so that it will help design the BIM roadmap at the industry or organization level (Khosrowshahi & Arayici, 2012). Building Information Modelling Maturity (BIMM) represents a ranking system including all the important areas of an effective modeling process to deliver the expected BIM product/service (Succar, at. al. 2020).

In summary: The Pre-BIM stage involves traditional building practices that rely on manual and computer-based documents, such as CAD drawings and spreadsheets. Even advanced 3D CAD is not considered part of BIM maturity unless it includes object-based modeling, as defined by Succar's model, which sets strict criteria for BIM maturity. Pre-BIM practices are characterized by 2D drafting, linear workflows, asynchronous communication, and a lack of interoperability. In some industries, such as in Sri Lanka, many organizations do not meet any BIM maturity levels, making BIM adoption challenging. A simple statement of 'no maturity' is inadequate for decision-making. Instead, a comprehensive assessment framework is needed to compare current practices with ultimate BIM maturity levels.

BIM Dimensions: 3D, 4D, 5D, 6D, and even 7D, enhance the data associated with the model to share a greater level of understanding of the construction project. Adding extra information to data, in fact, enables you to find out how the project will be delivered, what it will cost, and how it should be maintained. (Acca, 2020). BIM dimensions refer to different aspects or levels of information that can be incorporated into the BIM models. Each dimension represents a specific type of data that enhances project management and decision-making throughout the project lifecycle (Succar, at. al. 2020).

In summary: BIM dimensions, ranging from 3D to 7D, denote various layers of information integrated into BIM models to enhance comprehension of construction projects. Each dimension signifies distinct data types facilitating project management and decision-making across the project lifecycle.

2.3 Definitions and Components of Dependent Variable (Competitive Advantage):

Competitive advantage: The high satisfaction levels achieved by the targeted market through its products and services are significant (Ambe, 2010). Strategies can be adapted to develop a sustainable competitive advantage (Goetsch and Davis, 2014). Porter (2008) Generic Competitive Strategies are crucial for any business globally, as they describe a company's efforts to establish its position among competitors within the same industry or across different industries (Kumlua, 2014).

In summary: Competitive advantage is the ability of a company to achieve high customer satisfaction with its products and services. It involves implementing strategies to sustain this advantage over competitors. Porter's Generic Competitive Strategies play a crucial role in positioning a company within its industry or across industries. Competitive advantages enable companies to offer high-quality products at competitive prices and adapt to meet customer demands, thereby maintaining a strong competitive position.

Cost: The concept of cost as a competitive advantage has been widely agreed upon by researchers and scholars. Li et al. (2006) described cost as a competitive advantage that allows organizations to compete by offering lower prices in the market. Similarly, Ambe (2010) defined it as a competitive advantage when an organization provides the same services as its competitors but at a lower cost. According to Sirmon at. al. (2011) cost advantage involves developing internal capabilities that enable efficiencies and reduce costs compared to competitors. The Council (2012) explained cost strategy as competing with other organizations by effectively managing operational costs across the supply chain, including labor, materials, management, and transportation. Wheelen &

Hunger (2017) characterized the cost-competitive strategy as focusing on specific customer groups or regional markets and leveraging that niche for competitive advantage.

In summary: The concept of cost as a competitive advantage is widely recognized. It allows organizations to compete by offering lower prices or providing the same services at a lower cost than competitors. This involves developing internal efficiencies to reduce costs and managing operational expenses across the supply chain, including labor, materials, management, and transportation. Additionally, focusing on specific customer groups or regional markets can help leverage cost advantages.

Innovation: There is a consensus among researchers regarding the definition of innovation as a competitive strategy. According to Koufteros (1995), innovation is characterized by organizations developing and introducing new products and features to the market. Bloch (2007) describes innovative organizations as those that introduce new or enhanced products, services, or processes, and explore new markets by implementing novel organizational methods, practices, procedures, or external relationships. Sirmon et al., (2011) define innovation as a systemic strategy aimed at developing capabilities that allow organizations to distinguish their offerings from competitors. Innovation is a comprehensive process that is tied to a business strategy for enterprise use. This includes company policies, market interactions, research, technology, and resource capabilities (Zhang & Zhang, 2022).

In summary: The definition of innovation as a competitive strategy encompasses the development and introduction of new products and features to the market, along with the exploration of new markets through the implementation of novel organizational methods, practices, procedures, or external relationships. It also involves the cultivation of capabilities that enable organizations to differentiate their offerings from competitors.

Quality: There is no universally accepted definition of quality as a competitive advantage among researchers. Koufteros (1995) defined quality as an organization's ability to produce high-quality, high-performance products that are valuable to customers. Li et al., (2006) described quality as a competitive advantage when organizations can offer products and services that provide high value to customers through superior quality and performance. Slack et al., (2010) stated that a quality competitive advantage involves an organization focusing on quality as a means of creating value, thereby achieving customer satisfaction and a high perceived level of product quality.

In summary: Quality is the importance of delivering high-quality products and services that provide value to customers. It is seen as a competitive advantage when organizations can consistently offer superior quality and performance, leading to customer satisfaction and a positive perception of product quality. Quality is not only about meeting customer expectations but also about creating value and achieving a high perceived level of quality in the eyes of the customer.

Time: There is a different definition for time Competitive Advantages, some researchers and scholars refer to speed and flexibility concepts as an alternative for responsiveness but some researchers enrolled them as sub-variables of responsiveness. Holweg, (2005) & Duclos, et. al. (2003) defined supply chain responsiveness as the punctual capability and strength of the supply chain to adopt any change in market behavior and demand. Stadtler & Kilger (2008) describe responsiveness as a Competitive Advantage that can be achieved by the supply chain's capabilities to response fast against changes in the target market in the desired time. Slack, et. al. (2010), and Chopra & Meindl (2013) Attempt to identify responsiveness as a supply chain Competitive Advantage through two main scopes; the first one is indicating the flexibility of an organization to cover the changes and disturbances in the marketplace and customer demand, the second scope is the speed of supply chain to deliver the customer’s orders. Georgise, et. al. (2012) and Council (2012) focused on speed as responsiveness achieved by organizations' capability to deliver the products to the customer in the shortest time. Thatte, et. al. (2013) indicate that responsiveness is the integration and responsiveness of the functions of Operations, logistics, and suppliers.

In summary, time is the Competitive Advantage that capable organizations to handle changes in customers’ demands or requirements. Responsiveness is based on two pillars, the first one is the organization's flexibility to adopt any changes in demand quantities or requirements, and the second pillar is the organization's speed to fulfill the demand.

Reliability: Upon reviewing various studies and research, it is evident that there is a consensus among researchers on the definition of reliability. as the capability to meet tasks based on expectations, requiring high predictability of process outputs to ensure the right timing, quantity, and quality. Thomas (2002) defined reliability as the ability of the supply chain to accomplish mission requirements and supply along the value chain. Slack et al. (2010) emphasized that reliability involves minimizing uncertainty to ensure on-time delivery and product quality. Georgise, et. al. (2012) stated that reliability is the capability to achieve tasks based on expectations and that requires high predictability of process outputs to achieve the metrics of the right time, quantity, and quality.

In summary: Reliability is defined as the ability to consistently meet mission requirements and deliver products or services. It involves ensuring that tasks are completed as expected, with high predictability of process outputs to achieve the right timing, quantity, and quality. Reliability also entails minimizing uncertainty to ensure on-time delivery and maintain product quality.

Relationships Between Independent and Dependent Variables:

The relationship between an independent variable (Building information modeling) and a dependent variable (competitive advantage) was defined and demonstrated in previous studies and models as below:

The Ministry of Construction of the Russian Federation underscores the importance and potential of BIM technologies. According to the Ministry's calculations, construction and operational costs can be reduced by 30%, and the design period can be shortened by 50%. As per the Ministry's plans, from 2019 onward, all public expense construction projects must use BIM for their design. In 2016, as part of developing the regulatory framework, the R&D Center Stroitelstvo created four codes of practice for BIM, which outline the general principles for applying this technology (Abakumov & Naumov, 2018).

After conducting surveys among executives from prominent construction and design firms, the authors emphasized the immediate and long-term benefits of transitioning from CAD (Computer-Assisted Design) to BIM (Building Information Modeling) technologies, as illustrated in Figure 2.2 BIM technology presents various advantages. It enables the integration of existing organizational data with new insights arising from adopting BIM. Additionally, it facilitates data interchange between an enterprise's current systems and a BIM model. Furthermore, the information model serves as a data repository for procurement, scheduling, project management, internal ERP, and other enterprise systems.

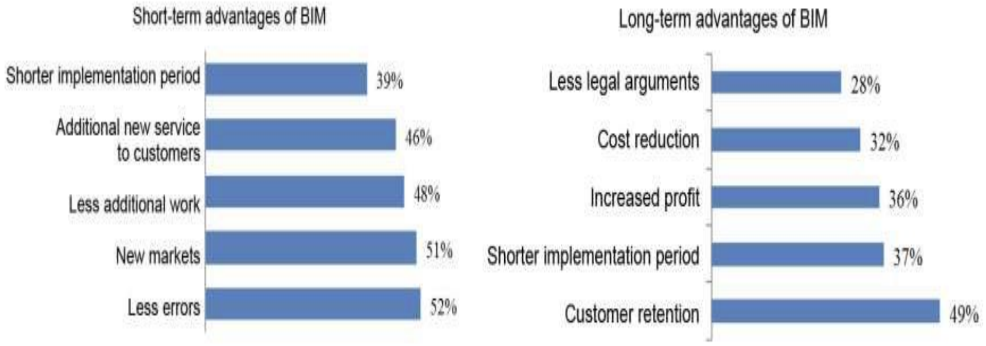


Figure 2. 1: Effect of BIM adoption, data from the Ministry of Construction of Russia. ("Industry The Importance of City Information - IOPscience")

In today's competitive business landscape, firms must embrace modern technologies and cultivate their innovative capacities to remain viable and prosper (Gokuc & Arditi, 2017). Within the construction sector, the advent of Building Information Modelling (BIM) presents an opportunity for companies to gain a competitive edge. Eastman et. al. (2018) asserts that achieving a competitive advantage is a primary motivation for BIM adoption among both design and construction firms. BIM generates business value, encompassing cost and time savings, enhanced information, and product quality, expanded market opportunities and services, customer retention, and a positive return on investment, All of which contribute to competitive advantages. This value stems from increased project efficiencies and the provision of novel services like project visualization, clash detection, and structural and energy simulations, among others, which streamline project management tasks. Small and medium-sized consultancy firms possess inherent advantages over larger counterparts, particularly in the realm of digital transformation, owing to their leaner organizational structures that facilitate quicker adaptation. Consequently, these firms are poised to realize BIM-related benefits sooner, with potentially more pronounced impacts than larger enterprises. The literature underscores the strategic importance of developing digital BIM objects for material suppliers to engage digital-savvy designers and contractors more effectively (Bredberg & Bergqvist 2020). Conversely, research suggests that SMEs lacking explicit BIM adoption strategies may face competitive disadvantages in both public and private markets (Awwad at. al. 2019). However, there is a gap in existing research concerning how construction consultancy SMEs can effectively pursue BIM-related competitive strategies to attain and sustain their competitive advantages. Adopting a life cycle perspective, integrating tools and data, setting BIM-specific goals, and conducting continuous reviews. The research underscores the significance of prioritizing complementarity in BIM management across all organizational levels to formulate effective implementation strategies. Centralized workflows, backed by senior management support, facilitate efficient information management and mitigate potential disputes among stakeholders. Upskilling the BIM workforce is essential for maximizing the benefits of BIM adoption and enhancing client satisfaction. Furthermore, adherence to industry standards ensures credibility and transparency throughout the asset life cycle, leading to more productive and profitable BIM-enabled projects. Overall, the study emphasizes the importance of strategic BIM positioning in a saturated market, providing actionable recommendations for organizations to navigate uncertainties and maintain competitiveness. These insights serve as valuable guidance for companies seeking to leverage BIM as a strategic asset in an increasingly competitive industry landscape (Arayici, 2021). the need for further exploration as BIM becomes integrated into architectural design studios, with a focus on preserving and enhancing design integrity. Collaboration should encourage innovation in problem-formation rather than simply solution-finding, fostering a mindset of valuing each discipline's expertise while respecting contributions from all stakeholders. Recommendations include embracing a perspective where all participants prioritize quality over quantity, considering innovation and risk alongside cost-effectiveness. By appreciating each other's contributions to design thinking, biases that hinder the quality of the built environment can be overcome, leading to better outcomes for all involved (Pihlak, et al., 2020).

In summary, the previous studies (Abakumov & Naumov, 2018; Eastman et. al. (2018); Arayici, 2021; Pihlak, et al., 2020) Proved that there is a strong positive relationship between building information and competitive advantage.

2.4 Previous Studies

Cesarotti & Di Silvio (2014) titled: “BIM-based approach to Building Operating Management: A Strategic Lever to achieve Efficiency, Risk-shifting, Innovation, and Sustainability”. The paper highlights the effectiveness of Building Information Modeling (BIM) in reducing expenditures in Building Operating Management by enhancing data availability and interoperability. It introduces a BIM layer for Site and Vendor Compliance Management, illustrated through a case study of energized SPA, indicating its suitability for the public sector due to its cost reduction and outsourcing potential. The study anticipates future government regulations promoting BIM adoption in both construction and building management. Furthermore, the research aims to transfer BIM best practices from the private to the public sector, emphasizing the integration of design and operating phases to enhance building management sustainability. Case studies, such as the one from Eltek Hospital in Türkiye, demonstrate the benefits of BIM in optimizing service design, resource allocation, coordination, and cost reduction. Standardized data storage in BIM layers facilitates compliance model implementation. The paper advocates for further study and replication of such case studies to generalize and consolidate the proposed methodology. It underscores the importance of embracing BIM technology to address economic, environmental, and social challenges in building operations and maintenance, promoting efficiency, innovation, and sustainability.

Chen & Luo (2014) A study titled: “A BIM-based construction quality management model and its applications”. A case in China. The study addresses the underexplored integration of Building Information Modeling (BIM) into construction quality management, proposing a BIM-based quality model to enhance current practices. This model combines BIM technology with the existing quality Product, Organization, and Process (POP) model, streamlining the quality management process and improving collaboration among project participants through visualized data. The proposed construction quality model offers several advantages: ensuring information consistency using design data, integrating standardized construction codes for clear task requirements, and leveraging 4D technology for timely inspection and visualization of the construction process. Although quantitative results are not provided, comparisons with non-BIM-based projects suggest the efficacy of the BIM-based approach. Recommendations for future improvement include addressing limitations such as manually adding temporary structures to BIM models and enhancing the convenience of using computers onsite. This could be achieved through advancements in mobile device usage for data recording and transfer. Overall, the BIM-based construction quality application proves beneficial for quality compliance management, leveraging data consistency and design information virtualization to improve quality management processes.

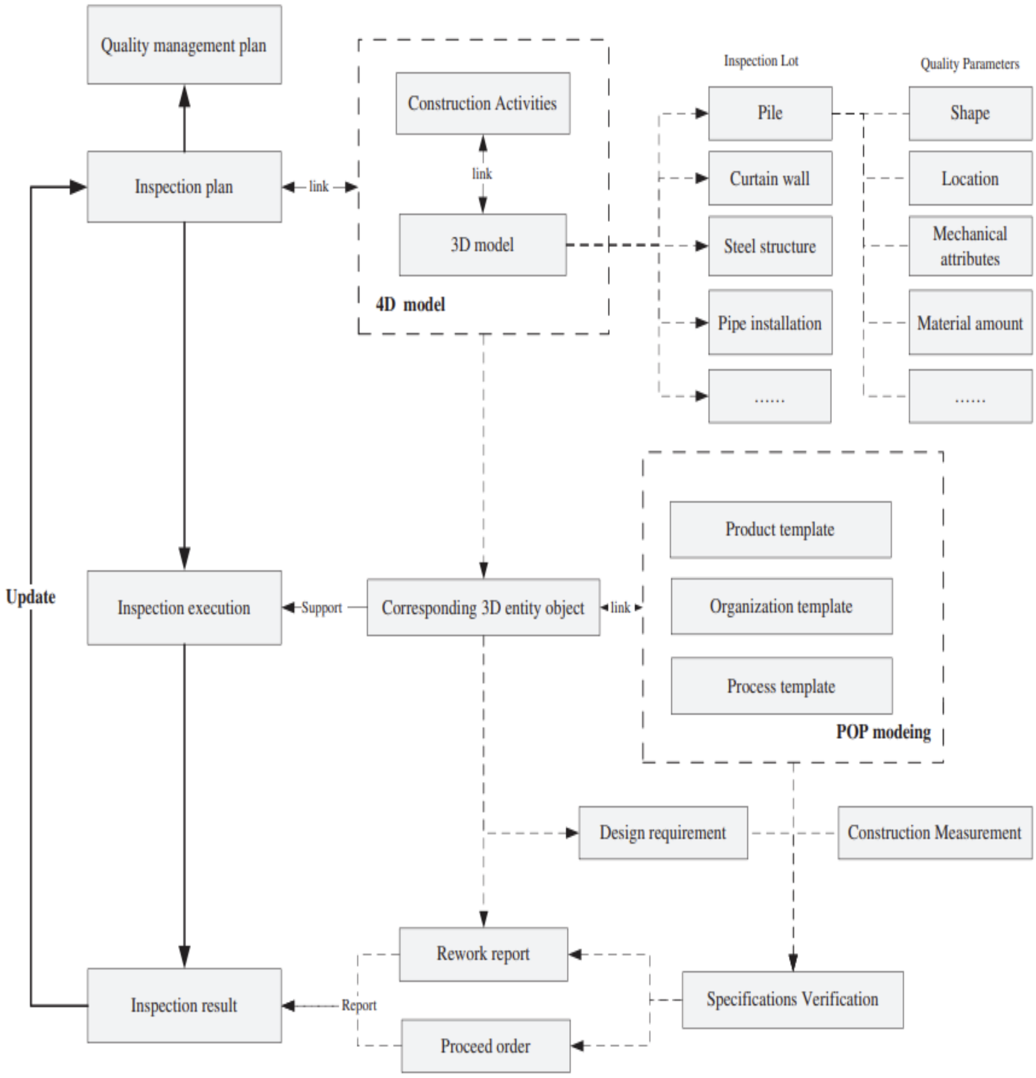


Figure 2. 2: The execution of the construction quality management inspection plan using the BIM quality model.

Zhao & Wang (2014) a study titled: "A Comparison of Using Traditional Cost Estimating Software and BIM for Construction Cost Control". A case in Kunming, China. The paper highlights the limitations hindering the widespread adoption of Building Information Modeling (BIM) in construction cost control, despite its recognized potential benefits. The case study comparing traditional cost control methods with a BIM-based approach reveals the need for improvements in leveraging BIM to fulfill cost control requirements effectively.

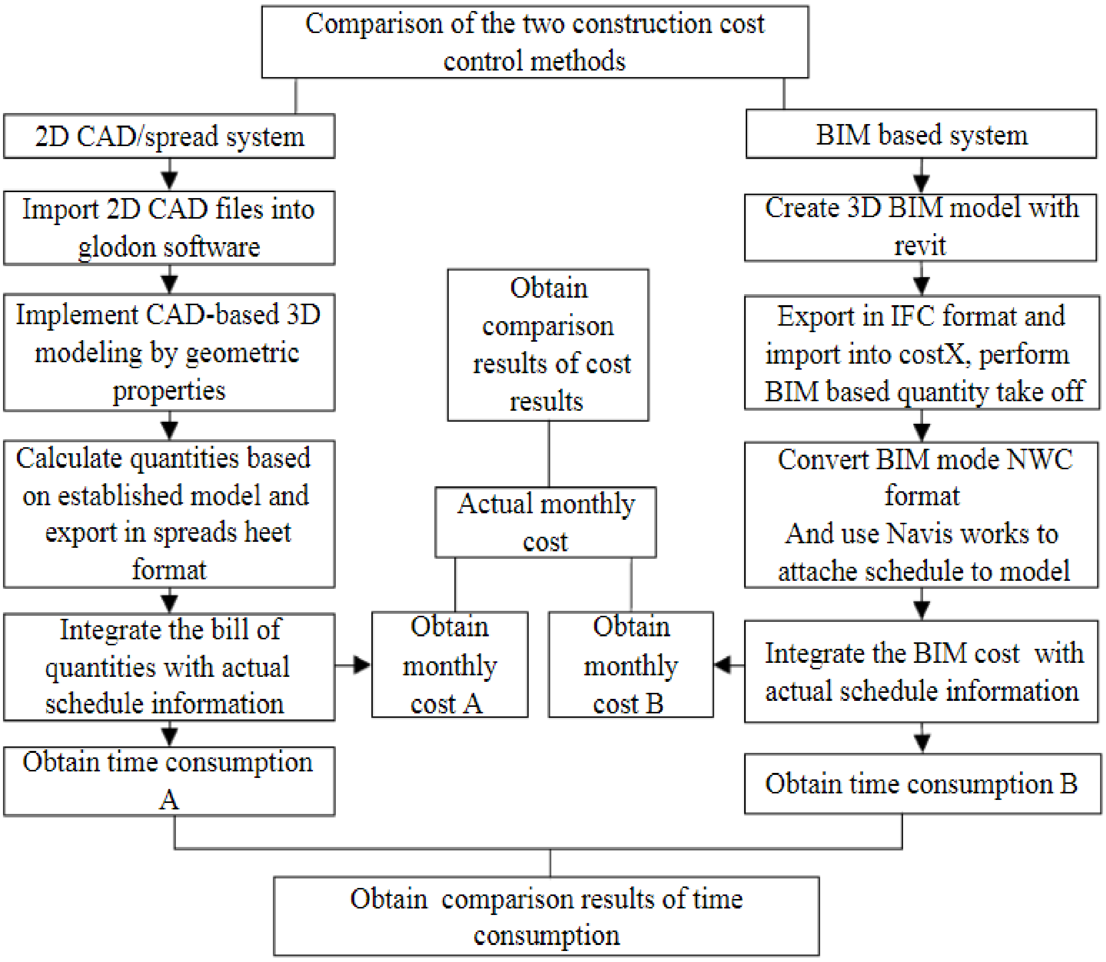


Figure 2. 3: Process map of research tasks and workflow.

The conclusion emphasizes the importance of practitioners undergoing thorough training and gaining sufficient practice to utilize BIM effectively. It also stresses the significance of time-based cost information in demonstrating its value, with BIM features such as visualization, accurate information sharing, and automation offering viable solutions to meet this requirement. Recommendations include enhancing the technical capabilities of BIM in cost control tasks and focusing future research on utilizing the Information Delivery Manual (IDM) method. This involves establishing a detailed construction cost control process through the IDM method, which encompasses creating a Process Map, specifying Exchange Requirements, and setting up related Exchange Requirement Models. The aim is to achieve a more recognizable, interoperable, dependable, and efficient cost-control process in the construction industry. Future studies were recommended to explore compatibility as a key construct in the BIM adoption model, with scholars urged to develop specific measures to predict BIM compatibility levels in diverse contexts. Additionally, the paper addressed challenges related to interoperability as significant barriers to BIM implementation, emphasizing the need for construction companies to understand compatibility concepts to assess their infrastructures effectively before adopting BIM fully. Overall, the findings aim to enhance BIM applications and accelerate adoption rates by facilitating seamless data and model exchange among stakeholders with varying needs and file formats.

Johansson at. al. (2015) A study titled: “Real-Time Visualization of Building Information Models BIM”. A case in Sweden. The paper highlights the challenges associated with real-time visualization of large and intricate Building Information Models (BIMs) and presents two main contributions: an evaluation of existing BIM viewers and the development of a prototype viewer tailored for managing such models. The evaluation of current BIM viewers reveals disparities in rendering performance, with hardware utilization playing a significant role alongside traditional factors like model complexity. Despite variations, none of the tested viewers consistently achieved satisfactory frame rates for all models, indicating shared limitations in rendering large and complex BIMs in real-time. The prototype BIM viewer developed in the study overcomes these limitations by employing an efficient occlusion culling algorithm, resulting in improved rendering performance across various models. However, challenges remain in optimizing draw calls and addressing scalability issues for extremely detailed models. The paper emphasizes the importance of addressing the limitations of existing BIM viewers and suggests future research directions. These include leveraging modern graphics APIs and implementing level-of-detail techniques to enhance scalability and rendering efficiency. By exploring these avenues, advancements can be made to facilitate the real-time visualization of large and detailed BIMs, improving the overall efficiency and effectiveness of BIM utilization in the construction industry.

Allen & Shakantu (2016) study titled: "The BIM Revolution: A Literature Review on Rethinking the Business of Construction". A case in South Africa. The conclusion emphasizes the imperative for process improvement in the construction industry, driven by the need for cost reduction and innovation. The adoption of technologies like Building Information Modelling (BIM) is highlighted as a crucial step towards achieving these goals. BIM enables more efficient collaboration among industry professionals, streamlining processes and enhancing project outcomes. Furthermore, BIM facilitates automation in various construction aspects, contributing to cost reduction and fostering innovation in project delivery methods. The paper recommends re-engineering major business processes in the construction sector to leverage technologies like BIM effectively. Embracing a more integrated and performance-oriented approach is essential to meet owner objectives and address communication challenges within project teams. By embracing innovation and enhancing collaboration through BIM adoption, construction companies can remain competitive in a rapidly evolving global market.

Adekunle at. al. (2016) study titled: "Principal Component Analysis of Organizational BIM Implementation". A case study in Nigeria. This research takes an objective stance to uncover the advantages of implementing Building Information Modelling (BIM) in the Nigerian construction industry. Employing a quantitative approach through questionnaire surveys with purposive sampling, the study identifies significant benefits associated with BIM adoption, including enhanced job productivity, access to international projects, increased job satisfaction, improved outputs, and more efficient processes. These benefits are categorized into three clusters: gaining a competitive advantage, optimizing organizational processes, and enhancing project outcomes, using principal component analysis. The study underscores the importance of recognizing these organizational benefits to guide and support BIM implementation efforts in construction organizations. It suggests that stakeholders must understand and leverage these advantages to drive successful BIM adoption. Furthermore, the paper recommends future research to explore the impact of BIM on organizational workflows and cultures within the Nigerian construction sector. It proposes adopting qualitative methods or mixed methods approaches for deeper insights into this area. Overall, the findings offer valuable insights for practitioners and policymakers alike, facilitating informed decision-making and strategic planning regarding BIM implementation in Nigeria's construction industry.

Taher et. al. (2018) A study titled: “Improving Cost and Time Control in Construction Using Building Information Model (BIM): A Review Ain Shams Engineering Journal”. The paper concludes by emphasizing the significant impact of delays and cost overruns on construction projects, often leading to disputes and project abandonment. These issues, stemming from several factors such as contractor-related, consultant-related, owner-related, and external factors, continue to challenge the industry despite technological advancements. However, the application of Building Information Model (BIM) technology holds promise in addressing these challenges by enhancing efficiency and output quality. BIM applications, including estimation, clash detection, and integration, are anticipated to mitigate delays and cost overruns, improving project management in the construction industry. Recommendations include further exploration and implementation of BIM technology to maximize its potential benefits and minimize project risks. Overall, the paper highlights the importance of leveraging technology like BIM to enhance collaboration and control costs and time effectively in construction projects.

Khudhair, at. al. (2018) A study titled: “Towards Future BIM Technology Innovations: A Bibliometric Analysis of Literature”. A study in UK. The article concludes that while Building Information Modelling (BIM) has revolutionized collaboration and data-sharing processes in the construction industry, its full potential can only be realized with the support of additional emerging technologies driving digital transformation. Through a literature review and bibliometric analysis, the study identifies technologies such as ontology, artificial intelligence (AI), machine learning (ML), and blockchain (BC) as promising complements to BIM. However, it emphasizes that individual technologies cannot fully address all issues, and a comprehensive approach is necessary for optimal results. The study advocates for the fusion of multiple technologies to better support BIM development, highlighting the importance of ongoing research and the inclusion of innovative ideas. While the integration of advanced technologies with BIM shows promise, the study acknowledges that realizing its full potential may take time. Recommendations include a collective integration of multiple technologies with BIM to create a dynamic environment and address current limitations. Despite limitations such as the focus on English-language literature and the inability to cover all research, the study provides valuable insights into the current state and future directions of BIM research and development.

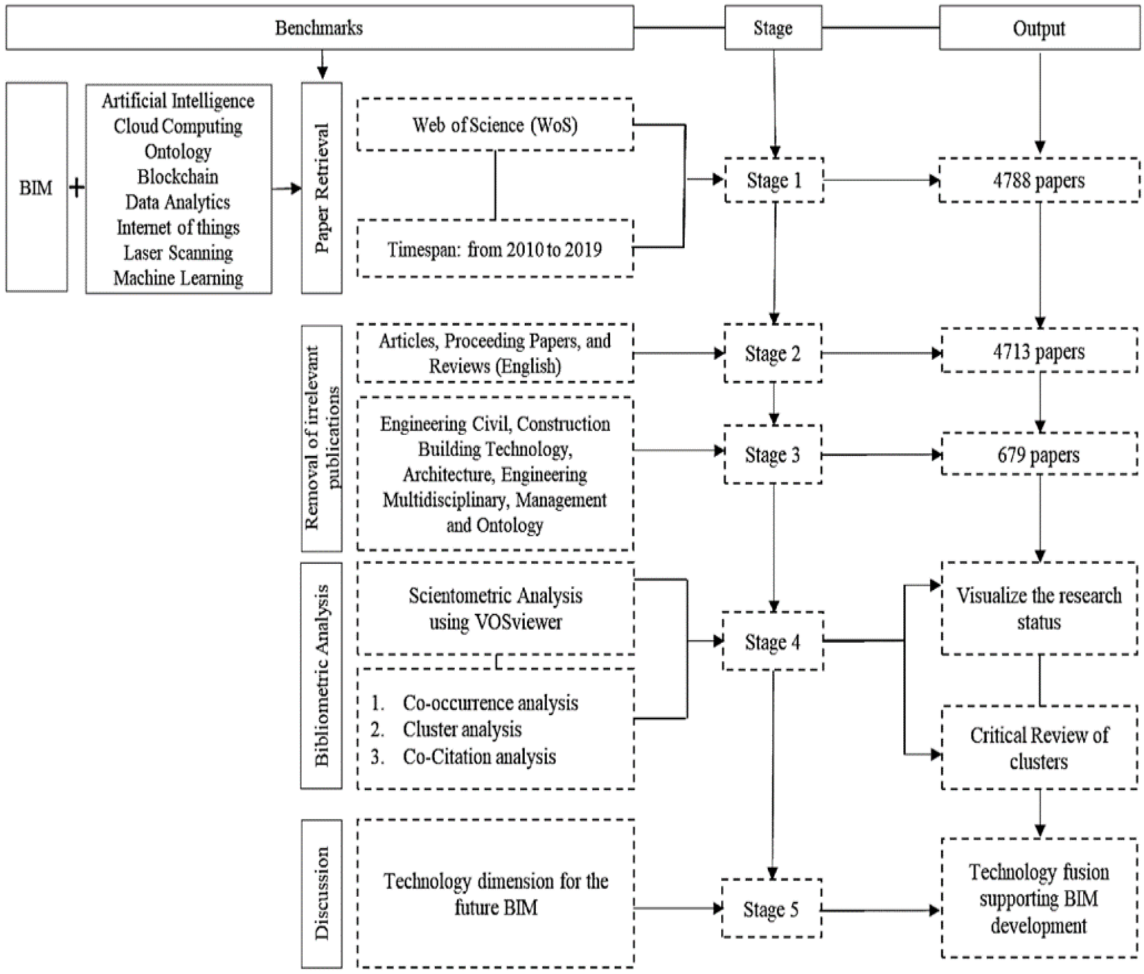


Figure 2. 4: Research methodology.

Ma, at. al. (2018) A study titled: "Construction quality management based on a collaborative system using BIM and indoor positioning". A study in China. The study proposes a collaborative system for construction quality management that integrates Building Information Modeling (BIM) and indoor positioning technologies. By leveraging BIM, the system generates inspection tasks aligned with standards, while indoor positioning facilitates efficient data collection by correlating on-site objects with BIM elements. Testing in an actual building project validates the system's efficiency, mitigating risks associated with missing check items and streamlining inspection processes for inspectors. Additionally, it fosters effective collaboration among stakeholders. Future enhancements may include automatic association with construction schedules, customization of check items, and integration of additional data collection technologies such as voice input and augmented reality. These improvements can further optimize construction quality management processes and enhance collaboration among stakeholders.

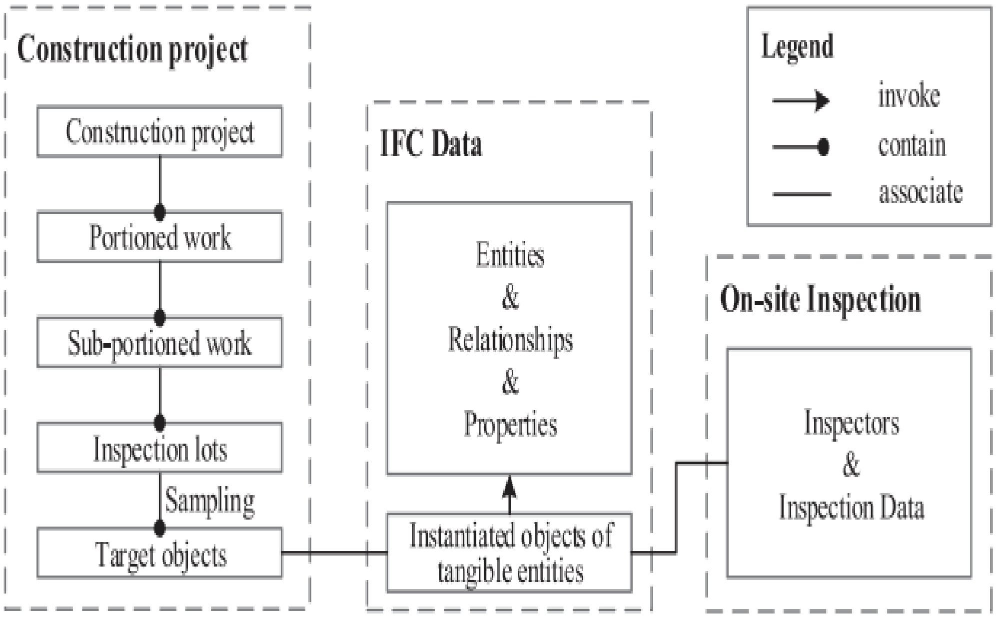


Figure 2. 5: Construction quality inspection model based on BIM.

Sadek, at. al. (2019) A study titled: "Impact of BIM on building design quality. The research underscores the significant benefits of adopting Building Information Modeling (BIM) to enhance design quality, impacting practitioners, decision-makers, and academics alike". BIM facilitates improved information sharing and collaborative decision-making within design and construction teams, enhancing building quality. Decision makers are urged to update building codes to mandate BIM model submission for permits and offer incentives for its adoption through tax incentives. Meanwhile, academics can enrich educational models by integrating BIM into architectural design and engineering courses, fostering student engagement in training programs. By presenting a conceptual model linking BIM-enabled capabilities to design quality, the research contributes to BIM literature and highlights its potential benefits for construction stakeholders.

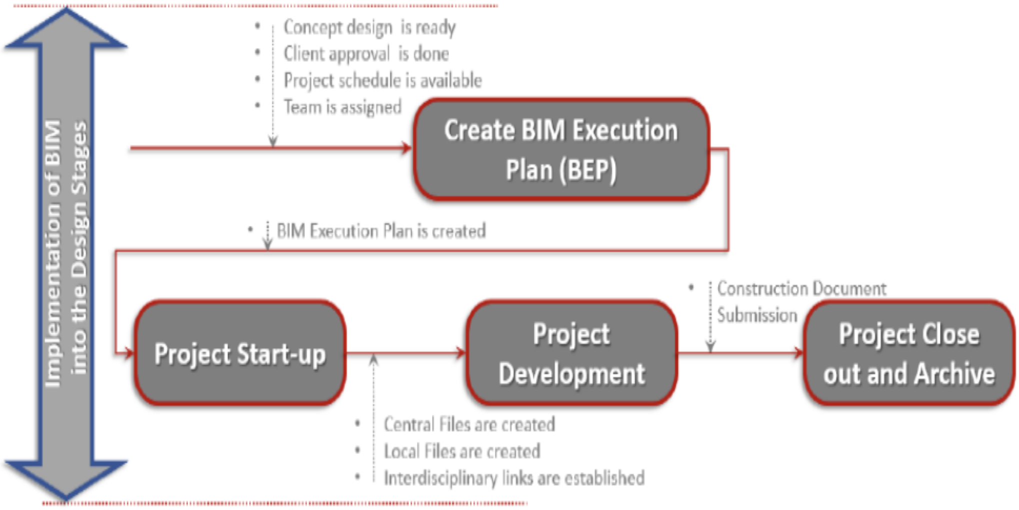


Figure 2. 6: Implementation of BIM into the design stages.

Milivojević (2020) A study titled: "Critical Factors to BIM team development applying innovation, knowledge, and change management perspectives. The study successfully achieved its objectives by identifying challenges and development strategies for BIM implementation in the Architecture, Engineering, and Construction (AEC) industry". Through literature reviews, expert interviews, and case studies, critical factors for BIM team development were identified, emphasizing the importance of a combined approach to Innovation Management (IM), Change Management (CM), and Knowledge Management (KM) principles. The study's findings include a validated model of critical factors for BIM team development and practical recommendations for industry practitioners based on expert insights and analysis. Recommendations highlight the need for management support, improved communication, social and experiential learning, collaborative planning, and sharp vision to optimize technology usage and reap its benefits. Additionally, sustainable mechanisms for implementation are proposed, with an emphasis on engaging individuals and managing perceptions about BIM tools. The study provides detailed insights and comparisons with established theories, offering valuable guidance for AEC project teams seeking to enhance BIM adoption and team development.

Pihlak at. al. (2020) A study titled: “Building Information Modeling (BIM) and the Impact on Design Quality”. A case in Penn State, USA. The discussion highlights the importance of recognizing and respecting the distinct values, methods, and standards of different disciplines within integrated design studios using Building Information Modeling (BIM). While collaboration is essential, it is crucial to ensure that design, traditionally led by architects, receives sufficient attention, and is not overshadowed by other considerations such as numbers, time, and finances. The conclusion emphasizes the need for further exploration as BIM becomes integrated into architectural design studios, with a focus on preserving and enhancing design integrity. Collaboration should encourage innovation in problem-formation rather than simply solution-finding, fostering a mindset of valuing each discipline's expertise while respecting contributions from all stakeholders. Recommendations include embracing a perspective where all participants prioritize quality over quantity, considering innovation and risk alongside cost-effectiveness. By appreciating each other's contributions to design thinking, biases that hinder the quality of the built environment can be overcome, leading to better outcomes for all involved.

Shirowzhan at. al. (2020) A study titled: “BIM Compatibility and its Differentiation with Interoperability Challenges as an Innovation Factor”. A case in Sydney, Australia. The paper systematically reviewed BIM compatibility literature within the framework of the Diffusion of Innovation (DOI) theory, aiming to address the significant gap in understanding compatibility in BIM adoption. Through the creation of a BIM compatibility (BIM-COM) database and analysis of 131 relevant articles, the study identified the lack of attention to compatibility, particularly at the organizational level, and highlighted interoperability as a primary practical barrier to BIM implementation. The paper proposed a conceptual framework extending DOI theory, emphasizing the intertwined nature of interoperability and compatibility in the BIM-COM literature. It underscored the importance of considering interoperability as a crucial measure for successful BIM implementation, especially with the rapid advancement of software programs. However, the study noted the oversight of compatibility as a contextual factor for BIM adoption at the organizational level.

Succar at. al. (2020) A study titled: “Measuring BIM performance: Five metrics”. A study in Australia. The article discusses five key components of a Building Information Modeling (BIM) framework designed to help stakeholders in Design, Construction, and Operations (DCO) evaluate and enhance their BIM performance. These components—BIM capability stages, maturity levels, competencies, organizational scales, and granularity levels—work together to facilitate targeted and adaptable performance analyses, ranging from informal self-assessments to comprehensive organizational audits. The framework aims to standardize BIM implementation and assessment processes, with ongoing efforts to expand and refine assessment metrics and develop online tools tailored to different disciplines and levels of detail. The goal is to establish an independent BIM certification body to accredit individuals, organizations, and collaborative project teams based on their BIM proficiency. With further testing and refinement, these five components have the potential to consistently evaluate and improve BIM performance across the industry.

Haider at. al. (2020) study titled: “Cost Comparison of a Building Project by Manual and BIM”. A study in Czech Republic. The research concludes that using Revit Software for cost estimation significantly outperforms traditional manual methods in terms of efficiency, accuracy, and ease of adjustment. Manual estimation is laborious, time-consuming, and prone to errors due to the complexity of formulas and the separate considerations required for various tasks like quantity calculation and cost abstraction. In contrast, Revit Software automates these processes, eliminating the need for manual calculations and allowing direct insertion of measurements into the model to obtain material quantities. Errors are easier to rectify in Revit, and the software provides more precise estimations by accounting for finishing items such as plastering, flooring, and skirting, which are often overlooked in manual estimates. The study highlights that BIM-assisted estimations show lower percentage differences and a total cost difference of just 4.8% compared to manual estimations, indicating superior performance with BIM software. The research recommends adopting BIM software like Revit for more accurate, efficient, and error-free cost estimation in construction projects.

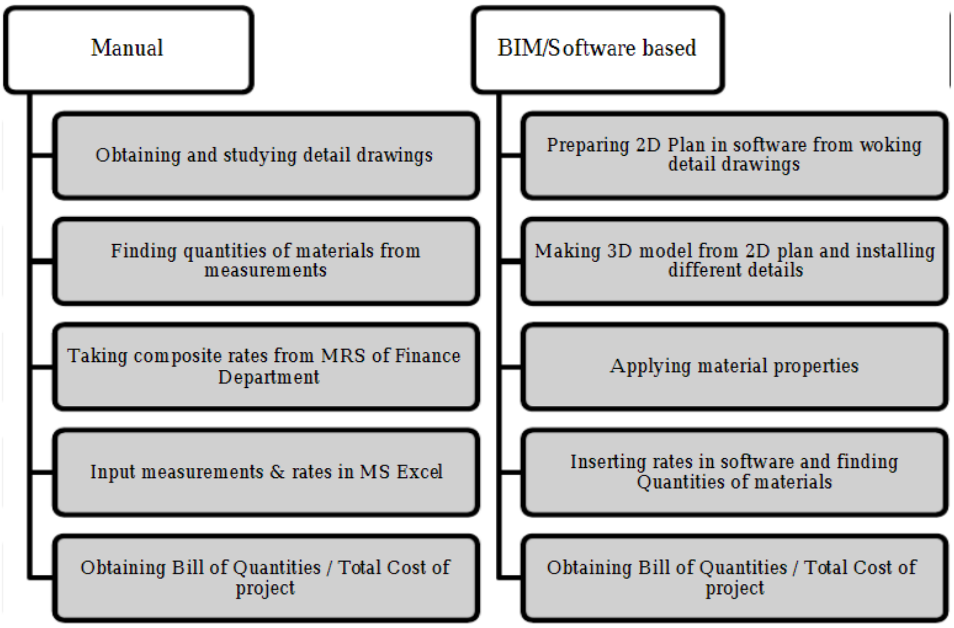


Figure 2. 7: Comparison of Manual and BIM Software-Based Estimation.

Choi at. al. (2020) A Study titled: “Development of Quality Control Requirements for Improving the Quality of Architectural Design Based on BIM”. A study in China. The study concludes that adopting systematic quality control standards based on Building Information Modeling (BIM) can significantly enhance the quality of architectural designs. Through case studies, the research developed a rule-based quality-checking system, categorizing BIM data quality targets into physical/logical and data quality aspects. By aligning these targets with specific requirements, quality control criteria and checklists were formulated. The study highlights the importance of integrating regulatory checks into design criteria and proposes detailed quality control targets for space, design, and construction criteria. To improve architectural design quality, the study recommends using checklists for self-checking progress and adopting rule-based quality-checking software to enhance efficiency and minimize errors. Additionally, while the focus is on design processes, extending quality control measures to other project phases, such as construction and maintenance, is suggested for comprehensive project lifecycle management. This structured approach ensures rigorous assessment and continuous improvement in architectural design quality using BIM technology.

Sholeh at. al. (2020) A study titled: “Effect of Building Information Modeling (BIM) on Reduced Construction time-costs”. A Case Study in Indonesia. Building Information Modeling (BIM) presents an intriguing avenue for exploration The study concludes that Building Information Modeling (BIM) offers a promising solution to the challenges of reducing time and cost in construction projects, particularly amidst the backdrop of the COVID-19 pandemic. By conducting a case study on a construction project, the research demonstrated significant improvements in time and cost efficiency, with a 50% reduction in project duration and a 52.36% decrease in costs attributed to BIM utilization. These enhancements are primarily due to accelerated design processes, structure calculations, and optimized workforce utilization with BIM software. The study emphasizes the importance of integrated management in addressing construction challenges and highlights BIM as a solutive answer. It suggests that further research could delve into detailed design work or structural calculations and recommends conducting additional case studies to explore the characteristics of several types of construction projects, particularly in the context of Indonesia. This research provides valuable insights into the advantages and disadvantages of BIM, serving as literature for construction projects seeking to enhance efficiency and productivity.

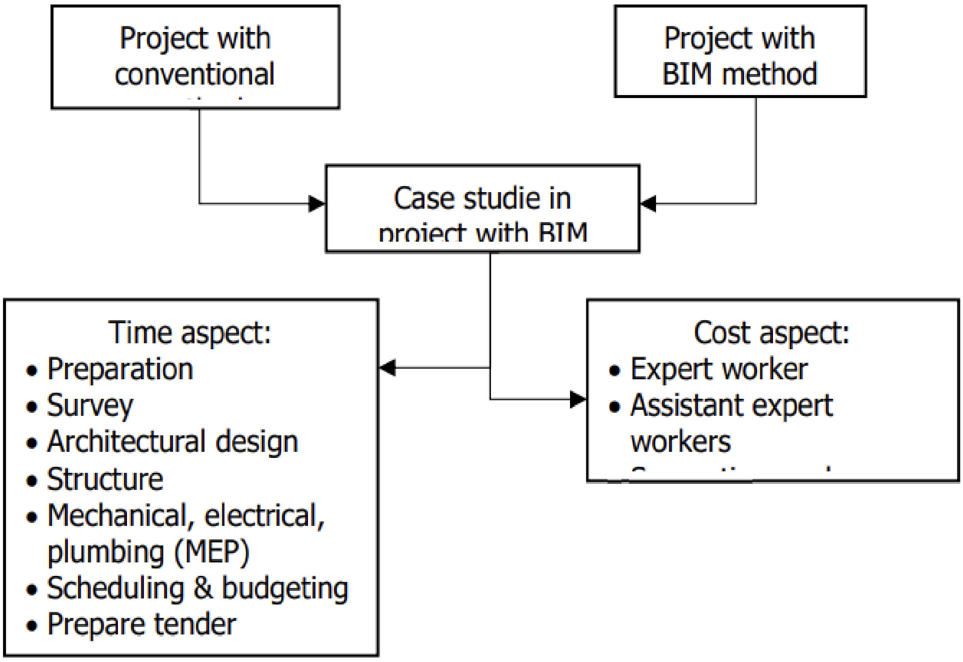


Figure 2. 8: The research framework analyzes the effect of BIM on time costs.

Nguyen et. al. (2021) study titled: "BIM-based Competitive Advantages and Competitive Strategies for Construction Consultancy SMEs". A Case Study in Vietnam. The conclusion drawn from the case study of a small and medium-sized construction consultancy firm utilizing Building Information Modelling (BIM) emphasizes the significance of leveraging core competencies to achieve competitive advantages in the market. By focusing on BIM strategic services, BIM services, and BIM-enabled services, the firm strategically capitalized on its expertise, reputation, and network developed through a funded BIM research project. These competencies enabled the firm to reduce costs, enhance its reputation, and offer unique products/services, positioning itself favorably in contract competitions for BIM consultancy services. Moreover, the study suggests that while cost leadership strategies faced challenges in achieving economies of scale, coupling cost leadership with BIM-enabled services could be a viable approach. Providing BIM-enabled consultancy and/or construction services has the potential to further reduce costs compared to offering BIM services alone, thus enhancing competitiveness in the market. Therefore, the recommendation for construction consultants is to continue leveraging their core competencies in BIM-related skills while exploring opportunities to expand into BIM-enabled services to maximize competitive advantages and performance outcomes.

Ismail at. al. (2021) A study titled: “Assessing BIM Adoption Towards Reliability in QS Cost Estimates”. A study in Selangor, Malaysia. The study explores the impact of Building Information Modeling (BIM) on cost estimation practices among Malaysian Quantity Surveyors within the framework of the Construction Industry Transformation Program (CITP) 2016-2020. It highlights BIM's potential to improve the accuracy and reliability of cost estimates by providing detailed and coordinated project data, facilitating better visualization and interdisciplinary collaboration, thus enhancing productivity and sustainability in construction practices. However, it also identifies limitations such as data overload and insufficient data in BIM models, leading to increased assumptions in cost estimation. These challenges underscore the necessity for designers to provide comprehensive data and for estimators to combine technological proficiency with traditional measurement skills. The study recommends enhancing estimator training to improve technological proficiency while maintaining traditional skills, ensuring designers provide sufficient data in BIM models, and balancing digital software knowledge with external pricing factors and professional judgment for accurate pricing. It also emphasizes promoting interdisciplinary collaboration, encouraging continuous learning and adaptation to modern technologies among quantity surveyors, and integrating sustainability elements into cost estimation practices using BIM to enhance the overall sustainability of construction projects. By following these recommendations, the construction industry in Malaysia can optimize BIM utilization, leading to more accurate and sustainable cost-estimating practices among Quantity Surveyors.

Arayici (2021) study titled: “Gaining Competitive Advantage through BIM: Strategic Positioning of BIM”. This research delves into the dynamics of managing Building Information Modelling (BIM) adoption in a saturated market to maintain a competitive edge. Through semi-structured interviews with industry professionals, the study identifies strategies for strategically positioning BIM within organizations. Key findings reveal that tailored BIM implementation processes can yield competitive advantages. These strategies include ensuring complementarity in BIM management, enhancing BIM skills, synchronizing off-site and on-site workflows, standardizing BIM processes, adopting a life cycle perspective, integrating tools and data, setting BIM-specific goals, and conducting continuous reviews. The research underscores the significance of prioritizing complementarity in BIM management across all organizational levels to formulate effective implementation strategies. Centralized workflows, backed by senior management support, facilitate efficient information management and mitigate potential disputes among stakeholders. Upskilling the BIM workforce is essential for maximizing the benefits of BIM adoption and enhancing client satisfaction. Furthermore, adherence to industry standards ensures credibility and transparency throughout the asset life cycle, leading to more productive and profitable BIM-enabled projects. Overall, the study emphasizes the importance of strategic BIM positioning in a saturated market, providing actionable recommendations for organizations to navigate uncertainties and maintain competitiveness. These insights serve as valuable guidance for companies seeking to leverage BIM as a strategic asset in an increasingly competitive industry landscape.

Manzoor, at. al. (2021) A study titled: “Influence of Building Information Modeling (BIM) Implementation in High-Rise Buildings towards Sustainability”. A study in Korea. The study sheds light on the impact of Building Information Modeling (BIM) implementation on sustainability in high-rise buildings, particularly in the context of Malaysia. Through exploratory factor analysis (EFA) and structural equation modeling (SEM), it reveals significant connections between BIM adoption and sustainability factors. Despite uncovering limited awareness and utilization of BIM technology in Malaysian high-rise construction, the study identifies critical factors such as productivity, visualization, coordination, sustainability, and safety improvement that influence BIM progress in this domain. Addressing a knowledge gap in developing countries, the research offers valuable insights for policymakers and practitioners. It advocates for future research to conduct detailed analyses across diverse cultural backgrounds to effectively advance sustainability goals. As BIM adoption continues to grow globally, fueled by ongoing research, its advantages become increasingly recognized, signaling promising prospects for the construction industry's sustainable development.

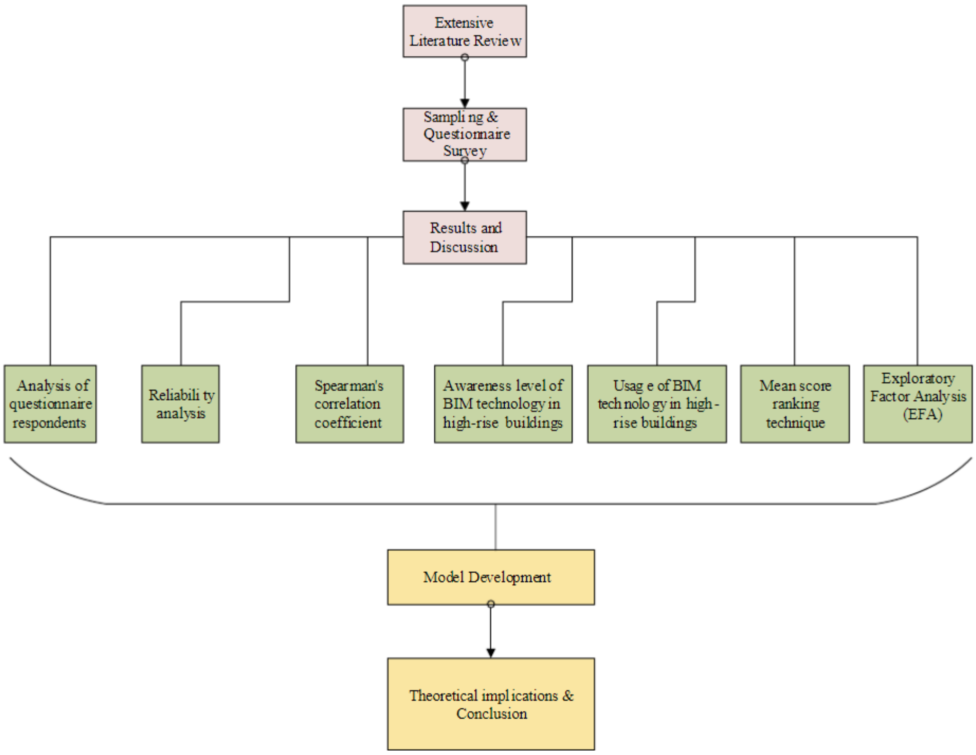


Figure 2. 9: Research flowchart design.

Parsamehr at. al. (2022) A study titled: "A Review of Construction Management Challenges and BIM- based Solutions": perspectives from the schedule, cost, quality, and safety management. ("A review of construction management challenges and BIM-based (Springer). The review concludes that Building Information Modeling (BIM) significantly enhances predictive decision-making in construction management by addressing challenges related to schedule, cost, safety, and quality management. It underscores the industry's growing emphasis on safety management and the increasing interest in BIM-related literature, indicating its vital role in construction management. The review identifies promising technologies such as digital twins, augmented reality (AR), virtual reality (VR), and artificial intelligence (AI) for advancing BIM-based decision-making, although further development is needed. It highlights the importance of data storage and sharing for big data analysis and identifies knowledge gaps, suggesting future research areas such as mobile applications for schedule management, machine learning models for cost prediction, BIM-integrated safety management systems, and automated quality management systems. Despite existing tools and software, their utilization in construction lags other industries, pointing to the need for further research on BIM implementation challenges and strategies. Ultimately, adopting advanced BIM-based methods is crucial for optimizing construction management and enabling predictive decision-making to address project challenges proactively.

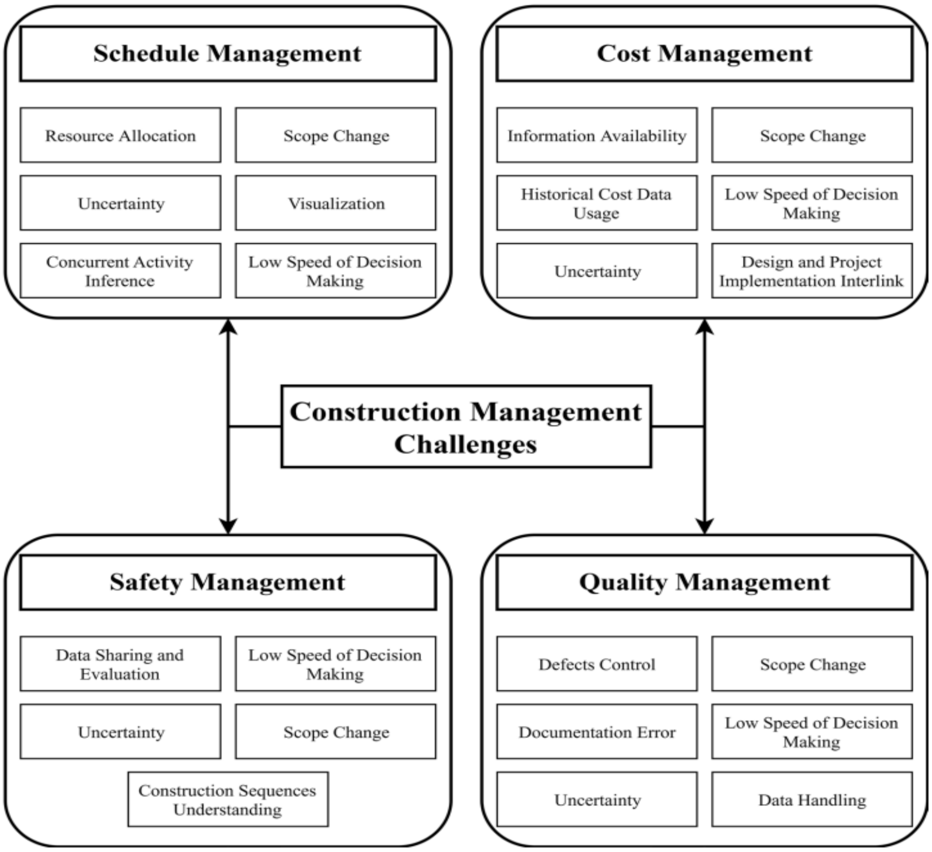


Figure 2. 10: Construction management challenges.

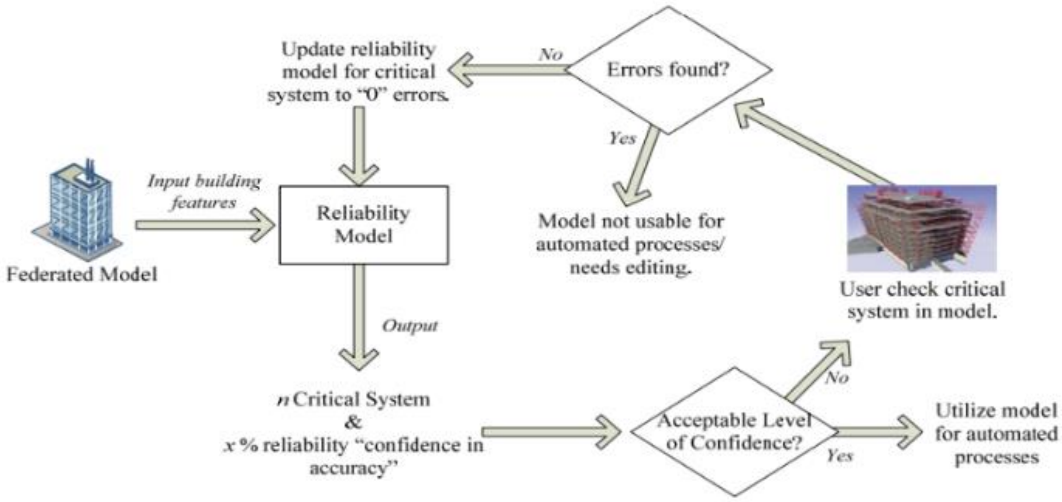
Leygonie & Motamedi (2022) A study titled: "Development of quality improvement procedures and tools for facility management BIM". The study enhances the knowledge base of Building Information Modeling (BIM) for Operation and Maintenance (O&M) by introducing a comprehensive quality management framework. This framework includes a detailed checklist for evaluating the quality of delivered BIM models, defining quality assurance and control processes to ensure the usability of these models, and developing semi-automated tools for quality control. It focuses on aligning as-built models with O&M requirements and employing procedures and tools to facilitate quality management activities. Validated through two case studies, the framework proved effective in assessing QC tools during handover and adaptable to specific project delivery methods during construction. The study emphasizes the importance of defining owner requirements, establishing QC guidelines, and automating QC processes, although challenges such as manual QC efforts and tool limitations persist. Recommendations for future improvements include leveraging AI and Machine Learning for enhanced automation, refining contractual documentation for digital delivery, expanding the checklist with additional requirements, and further investigating issues related to transferring native models to IFC format and data import in FM platforms.

Shaqour (2022) A study titled: “The role of implementing BIM applications in enhancing project management knowledge areas in Egypt”. The study concludes that integrating Building Information Modeling (BIM) technology into project management processes significantly enhances various management areas in Egypt's construction industry. Quality, time, cost, and scope management are key focus areas, although there's room for improvement in all aspects. Challenges in project integration and communication management underscore the need for enhanced communication tools and strategies. BIM applications show promise in enhancing risk management and communication management, offering benefits such as improved data flow, cost control, scheduling, stakeholder management, resource utilization, decision-making, and risk reduction. The study advocates for the widespread adoption of technology applications, including BIM, across all phases of construction projects (design, construction, and operation), to enhance the industry's performance. Recommendations include prioritizing the use of BIM applications for their numerous benefits and addressing challenges through enhanced communication strategies and tools. Overall, the study emphasizes the transformative potential of BIM technology in optimizing project management efficiency and meeting stakeholder expectations in Egypt's construction industry.

Lucas at. al. (2022) A study titled: “A Reliability Model for BIM-Related Automated Processes”. A case in Clemson University. The study highlights the challenges and opportunities brought about by the widespread adoption of Building Information Modeling (BIM) in the Architecture, Engineering, and Construction (AEC) industry. While acknowledging the advantages of BIM, the paper specifically addresses the challenge of accurately calculating material quantities through automated processes. It also raises broader questions about integrating computer algorithms into traditional professional tasks within the AEC sector and the necessary skill sets for evaluating and responsibly applying automated outcomes. Through the development of a reliability model, the study provides AEC professionals with a systematic tool to assess the accuracy of automated BIM processes, particularly in estimating material quantities. By enhancing confidence in automated models, professionals can mitigate risks associated with using models developed by others and optimize their utilization. This can lead to cost and time savings while improving stakeholder satisfaction. The recommendations stemming from this research emphasize the importance of embracing automated processes in the AEC industry while ensuring thorough evaluation and validation of outcomes. Professionals should continue to develop their skillsets and methodologies for effectively harnessing algorithms and evaluating automated results. Additionally, ongoing research and development efforts are needed to further refine reliability models and enhance confidence in the reliability of automated BIM processes.

Figure 2. 11: A Reliability Model for BIM-Related Automated Processes

Criminale & Langar (2022) A study titled: "Challenges with BIM Implementation: A Review of Literature". A study in Mississippi Hattiesburg, Mississippi. The study conducted by Criminale & Langar (2022) systematically identified 36 barriers to the implementation of Building Information Modeling (BIM) within the Architecture,



Engineering, and Construction (AEC) industry. Most of these barriers are rooted in organizational structures and adoption processes rather than project-level issues. Key challenges include employee training, the lack of national BIM standards in the US, software interoperability, and data management issues. These barriers can significantly hinder BIM adoption if not addressed promptly, especially for small and medium-sized design and construction firms. To address these issues, the study recommends that firms prioritize the identified challenges in their implementation plans and invest in comprehensive training programs to equip employees with the necessary BIM skills. Additionally, there is a critical need for the establishment of national BIM standards in the US to ensure consistency and ease of implementation across the industry. Efforts should be made to enhance software interoperability to facilitate smoother transitions and integrations. The economic factors related to the time and cost of hiring or training personnel for BIM, especially for smaller firms, should also be addressed. Further research should explore the severity of these challenges from different stakeholders' perspectives and categorize them into broader groups such as interoperability, education, hiring, technology, and legal issues. Monitoring and incorporating technological advancements can also help alleviate some of the current challenges associated with BIM implementation. By following these recommendations, firms can better navigate the complexities of BIM adoption, leading to more effective and widespread use of this transformative technology in the AEC industry.

2.5 Expected Contributions of the Current Study as Compared with Previous Studies:

1- Building information modeling concept: It seems that the current study is one of the few studies, which considers Building information modeling elements. Therefore, it aims to increase awareness about the role of Building information modeling in improving organizations' performance.

2- Purpose: Most of the previous study works were conducted to test the impact of Building information modeling from a traditional viewpoint on Competitive Advantages; the current study is carried out to study the impact of the building information modeling components on the Competitive Advantages and BIM impact on competitive advantage components.

3- Environment: Most previous studies have been carried out in different countries outside the Arab region. The current study is carried out in Jordan.

4- Industry: It seems that this study is the first study, that implements Building information modeling in the architectural industry. Therefore, the current study is dedicated to the architectural industry.

5- Methodology: Most previous studies were based on annual reports of different organizations and industries. The current study is based on managers, BIM coordinators, and BIM users' perceptions related to actual implementation.

6- Population: Most previous research considered public shareholder organizations that are listed in the stock markets, while the current study covered both public and private shareholder organizations.

7- Comparison: The current study results are compared with previous studies results to highlight similarities and differences that might be there and why.

CHAPTER THREE
Methodology

3.1 Introduction

This chapter includes study design, population and sampling, data collection methods, data collection analysis, study tool, and validity and reliability test. In addition to the respondent demographic description.

3.2 Study Design

This qualitative descriptive and cause/effect study aims to examine the impact of emerging building information modeling (BIM) technology on competitive advantages (cost, innovation, quality, time, and reliability) in the Jordanian architecture industry. The study begins with a literature review and expert interviews with BIM coordinators to develop a questionnaire for data collection, then it has been checked by referees. The gathered data will be verified and coded using SPSS. Subsequently, tests for normality, validity, and reliability will be conducted, and the correlations between variables will be analyzed. Finally, multiple regressions will be employed to test the hypotheses.

3.3 Study Population, Sample, and Unit of Analysis

Population and Sample: The study population (2000) from architectural firms in Jordan, and the sample have been selected from the population using the convenience sample method.

Unit of Analysis: The survey unit of analysis are managers, BIM Coordinators, and BIM users of Jordanian architectural firms. The sample consest of 186 managers, BIM coordinators and BIM users and have been sent to them.

Data Sources:

Data has been collected from two sources: primary and secondary. Secondary data will be sourced from books, research studies, articles, dissertations, theses, working papers, journals, and the Internet. Primary data will be obtained through a questionnaire, developed based on previous literature and expert input.

3.4 Instrument (Tool) The Questionnaire

The questionnaire is built based on the previous studies (Eastman, at. al. 2018; Volk, at. al. 2014; Hewage & Porwal 2013; Succar & Kassem 2015), Interviews with managers and BIM coordinators. in this thesis and then has been referred by a Panel of judges including academicians and professionals as shown in Appendix (1).

Questionnaire Variables:

The questionnaire includes three sections as follows:

- Demographic dimensions include (Age, and experience)
- Independent Variable (building information modeling): This includes the following sub-variables: Level of development, Stages, and Dimensions.
- Dependent Variable (Competitive Advantages): This includes the following variables: Cost, Innovation, Quality, Time, and Reliability

All sub-variables will be measured by suitable questions rated by five Likert scales to measure architectural managers’ perception, ranging from value 1 (strongly disagree) to value 5 (strongly agree) used all over the questionnaire.

Data Collection:

The questionnaire has been distributed purposely online to managers, BIM coordinators, and BIM users, who are working in architectural firms. 186 questionnaires sent and 6 were returned, Only 180 questionnaires were suitable for further analysis. Then data were coded against SPSS. The other 6 surveys were rejected because they were not completed so they are not suitable for further analysis.

3.4.1 Validity Test

The tool's validity was established using three methods: content, face, and construct validity.

Content Validity: This was confirmed by gathering data from various sources, including books, working papers, research studies, theses, journals, articles, and dissertations.

Face Validity: A Judges Committee (Appendix 1), comprising 10 referees, academicians, and professionals, was used to confirm face validity. After collecting their feedback, suggestions, and opinions on the questionnaire, the survey items were rephrased linguistically, some were adjusted or combined, and certain questions were removed. Items that received an approval rate of 90% or higher were retained.

Construct Validity (Factor Analysis):

Construct validity was verified using exploratory factor analysis (EFA). This involved principal components analysis with Kaiser-Meyer-Olkin (KMO) testing, Varimax rotation, and a predetermined number of factors to be extracted.

Construct validity was confirmed using Principal Component Factor Analysis with the Kaiser-Meyer-Olkin (KMO) test. The data's explanatory power and suitability were assessed through Principal Factor Analysis. Factor loadings above 0.50 are considered strong, though values over 0.40 are acceptable (Hair et al., 2014). The KMO measure evaluates sampling adequacy, consistency, and inter-correlations, with values between

0.8 and 1 indicating high adequacy and values over 0.6 being acceptable. Bartlett's Test of Sphericity is another key indicator, used to assess data suitability and correlation. A significance value below 0.05 at a 95% confidence level suggests the factor analysis is appropriate. The percentage of variance indicates the explanatory power of the factors (Cerny & Kaiser, 1977).

Level of Development:

Table (3.1) shows that the loading factor of Level of Development data scored between 0.588 and 0.810. Therefore, the construct validity is assumed. KMO has rated 68.0%, which indicates good adequacy, and the Chi^2 is 182.708, which indicates the fitness of the model. Moreover, the variance percentage is 55.99, so it can explain 55.99% of the variation. Finally, the significance of Bartlett's Sphericity is lower than 0.05, which indicates the factor analysis is useful.

Table 3. 1: Principal Component Analysis Level of Development

No.	Item	F1	KMO	Chi^2	BTS	Var%	Sig.
1	The BIM level of development enhances facility management.	0.704	0.680	182.708	15	55.99	0.00
2	The BIM level of development alters long-term maintenance.	0.766					
3	The BIM level of development defines the project requirement.	0.588					
4	The BIM level of development determines the cost of the project depending on the scale of the project.	0.715					
5	The BIM level of development clarifies project stages.	0.810					
6	The BIM level of development enhances collaboration between disciplines.	0.660					

Principal Component Analysis.

Stages:

Table (3.2) shows that the loading factor of Stages data scored between 0.646 and 0.571. Therefore, the construct validity is assumed. KMO has rated 59.5%, which indicates good adequacy, and the Chi2 is 30.564, which indicates the fitness of the model. Moreover, the variance percentage is 49.79, so it can explain 49.79% of the variation. Finally, the significance of Bartlett's Sphericity is lower than 0.05, which indicates the factor analysis is useful.

Table 3. 2: Principal Component Analysis Stages

No.	Item	F1	KMO	Chi^2	BTS	Var%	Sig.
1	The BIM by stages clarifies the collaboration between disciplines.	0.646	0.595	30.564	3	49.79	0.00
2	The BIM stages raise the maturity level.	0.751					
3	The BIM stages encourage the model lifecycle integration.	0.717					

Principal Component Analysis.

BIM Dimensions:

Table (3.3) shows that the loading factor of Dimensions data scored between 0.542 and 0.821. Therefore, the construct validity is assumed. KMO has rated 46.5%, which indicates good adequacy, and the Chi2 is 18.576, which indicates the fitness of the model. Moreover, the variance percentage is 77.43, so it can explain 77.43% of the variation. Finally, the significance of Bartlett's Sphericity is lower than 0.05, which indicates the factor analysis is useful.

Table 3. 3: Principal Component Analysis Dimensions

No.	Item	F1	KMO	Chi^2	BTS	Var%	Sig.
1	The BIM dimensions reduce the model complexity.	0.542	0. 465	18.576	3	77.43	0.00
2	The BIM dimensions show the level of services given.	0.821					

3	The company shares The BIM dimensions and raises the forecast with partners.	0.576						

Principal Component Analysis.

Cost:

Table (3.4) shows that the loading factor of cost data scored between 0.528 and 0.820, Therefore, the construct validity is assumed. KMO is rated 78.8%, which indicates good adequacy, and the Chi2 is 299.516, which indicates the fitness of the model. Moreover, the variance percentage is 52.082, so it can explain 52.082% of the variation. Finally, the significance of Bartlett's Sphericity is lower than 0.05, which indicates the factor analysis is useful.

Table 3. 4: Principal Component Analysis Cost

No.	Item	F1	KMO	Chi^2	BTS	Var%	Sig.
1	The company reduces procurement costs.	0.655	0.788	299.561	28	52.082	0.00
2	The company eliminates waste project lifecycle maintenance.	0.679					
3	The company determines a suitable salary structure for employees	0.630					
4	The company decreases variation orders (VO's) costs.	0.733					
5	The company increases project profitability	0.629					
6	The company determines the bill of quantity (BOQ).	0.820					
7	The company defines minimum tenders' cost.	0.701					
8	The company enhances collaboration between disciplines.	0.528					

Principal Component Analysis.

Innovation:

Table (3.5) shows that the loading factor of cost data scored between 0.533 and 0.881, Therefore, the construct validity is assumed. KMO has rated 79.2%, which indicates good adequacy, and the Chi2 is 289.201, which indicates the fitness of the model. Moreover, the variance percentage is 57.866, so it can explain 57.866% of the variation. Finally, the significance of Bartlett's Sphericity is lower than 0.05, which indicates the factor analysis is useful.

Table 3. 5: Principal Component Analysis Innovation

No.	Item	F1	KMO	Chi^2	BTS	Var%	Sig.
1	The company gets new ideas to increase productivity	0.743	0.792	289.201	21	57.866	0.00
2	The company creates new solutions.	0.747					
3	The company raises responsiveness.	0.533					
4	The company raises interoperability.	0.881					
5	The company utilizes databases for the diffusion of innovation (DOI).	0.720					
6	The company enables innovation in construction design.	0.628					
7	The company encourages teamwork to get new ideas.	0.754					

Principal Component Analysis.

Quality:

Table (3.6) shows that the loading factor of cost data scored between 0.550 and 0.801, therefore, the construct validity is assumed. KMO is rated 76.7%, which indicates good adequacy, and the Chi2 is 292.119, which indicates the fitness of the model. Moreover, the variance percentage is 48.378, so it can explain 48.378% of the variation. Finally, the significance of Bartlett's Sphericity is lower than 0.05, which indicates the factor analysis is useful.

Table 3. 6: Principal Component Analysis Quality

No.	Item	F1	KMO	Chi^2	BTS	Var%	Sig.
1	The company follows international standards (ISO).	0.747	0.767	292.119	15	48.378	0.00
2	The company reduces errors.	0.645					

3	The company develops a documentation system.	0.801					
4	The company uses it for work-sharing.	0.786					
5	The company reduces the environmental impact.	0.550					
6	The company ensures construction safety.	0.664					

Principal Component Analysis.

Time:

Table (3.7) shows that the loading factor of Time items scored between 0.550 and 0.770, Therefore, the construct validity is assumed. KMO is rated 72.7%, which indicates good adequacy, and the Chi2 is 306.787, which indicates the fitness of the model. Moreover, the variance percentage is 66.118, so it can explain 66.118% of the variation. Finally, the significance of Bartlett's Sphericity is less than 0.05, which indicates the factor analysis is useful.

Table 3. 7: Principal Component Analysis Time

No.	Item	F1	KMO	Chi^2	BTS	Var%	Sig.
1	The company defines stages as time.	0.690	0.727	306.787	15	66.118	0.00
2	The company sets milestones.	0.770					
3	The company raises conflict detection.	0.712					
4	The company increases collaboration between multidisciplinary teams.	0.745					
5	The company speeds the communication among stakeholders.	0.727					
6	The company controls the progress of work.	0.500					

Principal Component Analysis.

Reliability and Flexibility:

Table (3.8) shows that the loading factor of Reliability and Flexibility data scored between 0.605 and 0.929 Therefore, the construct validity is assumed. KMO is rated

63.5%, which indicates accepted adequacy, and the Chi2 is 158.291, which indicates the fitness of the model. Moreover, the variance percentage is 65.191, so it can explain 65.191% of the variation. Finally, the significance of Bartlett's Sphericity is less than 0.05, which indicates the factor analysis is useful.

Table 3. 8: Principal Component Analysis Reliability and Flexibility

No.	Item	F1	KMO	Chi^2	BTS	Var%	Sig.
1	The company ensures communication between works management and suppliers.	0.746	0.635	158.291	10	65.191	0.00
2	The company adheres to project standard requirements.	0.812					
3	The company ensures accurate visualization of the entire project.	0.605					
4	The company reduces the variation in operations.	0.743					
5	The company responds to clients' changes.	0.929					

Principal Component Analysis.

3.4.2 Reliability Test:

The data reliability is assessed through Cronbach's alpha, the reliable tools have a Cronbach's alpha above 0.70 and are accepted if it exceeds 0.60 (Hair, et. al. 2014). Table (3.9) shows that the reliability of the building information modeling variables ranges between 0.779 and 0.812, and for Competitive Advantages dimensions is between 0.760 and 0.779.

Table 3. 9: Reliability Test for all Variables

`	Items/Sub-Variables	Cronbach's Alpha
Level of Development	6	0.812
Stages	3	0.786
Dimensions	3	0.779
Building Information Modeling	**3 Sub-Variable**	**0.801**
Cost	8	0.761
Innovation	7	0.778
Quality	6	0.779
Time	6	0.781
Reliability & Flexibility	5	0.760
Competitive Advantages	**5 Dimensions**	**0.917**

3.4.3 Demographic Analysis:

The demographic analysis shown in the below sections is based on the characteristics of the valid respondent i.e., frequency and percentage of participants such as age and Experience.

Age: Table (3.10) shows that most respondents aged (20-24) 59 (32.8 %) out of the total sample and then those ages between (25-29 years) 89 (49.4%), after the respondents (30-35 years) 23 (12.8%), and finally those above 35 years 9 (5.0%).

Table 3. 10: Respondents Age

		Frequency	**Percent**
Age	20-24	59	32.8
	25-29	89	49.4
	30-35	23	12.8
	Above 35	9	5.0
	Total	**180**	**100.0**

Experience:

Table (3.11) shows that most respondents have experience (1-4 years) 139 (77.2%), then respondents experience between (5-9 years) 27 (15.0%), followed by those with experience (10-14 years) 9 (5.0%). Finally, respondents who have (15 and above) years of experience were very few at 5 (2.8%).

Table 3. 11: Respondents' Experience

		Frequency	**Percent**
Experience	1-4	139	77.2
	5-9	27	15.0
	10-14	9	5.0
	15 and above	5	2.8
	Total	**180**	**100.0**

CHAPTER FOUR

The Results

4.1 Introduction

The following chapter includes the data descriptive statistical analysis of respondent perception, and Pearson Bivariate Correlation matrix to evaluate the relationships among Building information modeling sub-variables with each other, Competitive Advantages dimensions with each other; and between building information modeling variable and sub-variables with Competitive Advantages dimensions.

4.2 Descriptive Statistical Analysis

1. What is the level of implementation of Building information modeling (BIM) in Jordanian Architectural Organizations?

2. What is the level of competitive advantage in Jordanian Architectural Organizations?

These two questions will be answered through descriptive analysis.

The data was entered into the SPSS program (V.26), and the following statistical analyses were performed: The mean, standard deviation, t-value, ranking, and implementation level are used to describe the respondents' perception and the degree of implementation of each variable, dimension, and item.

The implementation level is divided into three categories based on the following formula: $\frac{5-1}{3} = 1.33$

Therefore, the implementation is considered high if it is within the range of (3.67-5.00), medium if it is between (2.34 – 3.66), and low implementation is between (1.00 – 2.33).

Independent Variable (Building Information Modeling):

Table (4.1) shows that the means of Building Information Modeling sub-variables range from 4.14 to 4.22 with a standard deviation between 0.44 and 0.49. This indicates that respondents agree with the high implementation of Building Information Modeling sub-variables that are supported and rated by a high t-value compared to the T-tabulated. The average mean is 4.17 with a standard deviation of 0.41, which indicates that the respondents are highly aware and concerned about the Building Information Modeling where the t-value is 38.61>T-tabulated = 1.960. Dimensions sub-variable has rated highest implementation followed by the level of development and then stages.

Table 4. 1: Mean, Standard Deviation, t-value, Ranking, and Implementation Level of Building Information Modeling

No.	Dimensions	M.	S.D.	t	Sig.	Rank	Impl.
1	Level of Development	4.16	0.44	34.93	0.00	2	High
2	Stages	4.14	0.49	31.20	0.00	3	High
3	Dimensions	4.22	0.46	35.31	0.00	1	High
	Building Information Modeling	**4.17**	**0.41**	**38.61**	**0.00**		**High**

T-tabulated=1.960

Level of Development:

Table (4.2) shows that the means Level of Development items range from 3.98 to 4.33 with a standard deviation between 0.67 and 0.79, This indicates that respondents agree on high implementation of Level of Development data, this is supported by a high t-value compared to T-tabulated. The average mean is 4.16 with a standard deviation of 0.44, which indicates that the respondents are highly aware and concerned about the Level of Development, where the t-value is 34.933>T-tabulated = 1.960.

Table 4. 2: Mean, Standard Deviation, t-value, Ranking, and Implementation Level of Level of Development

No.	Items	M.	S.D.	t	Sig.	Rank	Impl.
1	The BIM level of development enhances facility management.	4.28	0.70	24.480	0.00	2	High
2	The BIM level of development alters long-term maintenance.	4.18	0.67	23.591	0.00	3	High
3	The BIM level of development defines the project requirement.	4.07	0.77	18.688	0.00	5	High
4	The BIM level of development determines the cost of the project depending on the scale of the project.	3.98	0.76	17.386	0.00	6	High
5	The BIM level of development clarifies project stages.	4.09	0.79	18.613	0.00	4	High
6	The BIM level of development enhances collaboration between disciplines.	4.33	0.79	22.759	0.00	1	High
	Level of Development	**4.16**	**0.44**	**34.933**	0.00	**High**	

T-tabulated=1.960

Stages:

Table (4.3) shows that the means of Stages data range from 4.10 to 4.20 with a standard deviation between 0.68 and 0.75. This indicates that respondents agree on the high implementation of Stages items, this is supported by a high t-the value compared to T-tabulated. The average mean is 4.14 with a standard deviation of 0.49, which indicates that the respondents are highly aware and concerned about Stages, where the t-value is 31.199>T-tabulated = 1.960.

Table 4. 3: Mean, Standard Deviation, t-value, Ranking, and Implementation Level of Stages

No.	Items	M.	S.D.	t	Sig.	Rank	Impl.
1	The BIM by stages clarifies the collaboration between disciplines.	4.20	0.66	24.265	0.00	1	High
2	The BIM stages raise the maturity level.	4.13	0.68	22.357	0.00	2	High
3	The BIM stages encourage the model lifecycle integration.	4.10	0.75	19.725	0.00	3	High
	Stages	**4.14**	**0.49**	**31.199**	**0.00**		**High**

T-tabulated=1.960

Dimensions:

Table (4.4) shows that the means Dimensions items range from 4.08 and 4.41 with a standard deviation between 0.71 and 0.72. This indicates that respondents agree on the high implementation of Dimensions items, this is supported by a high t-value compared to T-tabulated. The average mean is 4.22 with a standard deviation of 0.46, indicating that the respondents are highly aware and concerned about Dimensions, where the t-value is 35.313>T-tabulated = 1.960.

Table 4. 4: Mean, Standard Deviation, t-value, Ranking, and Implementation Level of Dimensions

No.	Items	M.	S.D.	t	Sig.	Rank	Impl.
1	The BIM dimensions raise the model complexity.	4.08	0.71	20.526	0.00	3	High
2	The BIM dimensions show the level of services given.	4.17	0.72	21.978	0.00	2	High
3	The company shares The BIM dimensions to raise the end forecast with partners.	4.41	0.71	26.684	0.00	1	High
	Dimensions	**4.22**	**0.46**	**35.313**	**0.00**		**High**

T-tabulated=1.960

Dependent Variable (Competitive Advantages):

Table (4.5) shows that the means of Competitive Advantages sub-variables range from 3.81 to 4.13 with a standard deviation between 0.46 and 0.50. This indicates that respondents agree on the high implementation of Competitive Advantages sub-variables that are supported by high t-value compared to T-tabulated. The average mean is 4.00 with a standard deviation of 0.39, indicating that the respondents are highly aware and concerned about Competitive Advantages, where the t-value is 34.735>T-tabulated = 1.960. The time sub-variable has rated the highest implementation, then quality, followed by reliability and flexibility, innovation, and cost, respectively.

Table 4. 5: Mean, Standard Deviation, t-value, Ranking, and Implementation Level of Competitive Advantages

No.	Dimensions	M.	S.D.	t	Sig.	Rank	Impl.
1	Cost	3.81	0.49	22.130	0.00	5	High
2	Innovation	3.95	0.46	28.004	0.00	4	High
3	Quality	4.12	0.50	30.108	0.00	2	High
4	Time	4.13	0.47	31.800	0.00	1	High
5	Reliability and Flexibility	4.08	0.47	30.985	0.00	3	High
	Competitive Advantages	**4.00**	**0.39**	**34.735**	**0.00**		**High**

T-tabulated=1.960

Cost:

Table (4.6) shows that the means Cost items range from 3.32 and 4.28 with a standard deviation between 0.64 and 0.90. This indicates that respondents agree on high implementation of Cost items, this is supported by a high t-value compared to the T-tabulated. The average mean is 3.81 with a standard deviation of 0.49, which indicates that the respondents are highly aware and concerned about Cost, where the t-value is 22.130>T-tabulated = 1.960.

Table 4. 6: Mean, Standard Deviation, t-value, Ranking, and Implementation Level of Cost

No.	Items	M.	S.D.	t	Sig.	Rank	Impl.
1	The company reduces procurement costs.	3.73	0.87	11.216	0.00	6	High
2	The company eliminates waste project lifecycle maintenance.	3.75	0.78	12.851	0.00	5	High
3	The company determines a suitable salary structure for employees	3.32	0.86	4.930	0.00	8	Medium
4	The company decreases variation orders (VO’s) costs.	3.58	0.90	8.586	0.00	7	Medium
5	The company increases project profitability	3.91	0.80	15.264	0.00	3	High
6	The company determines the bill of quantity (BOQ).	4.11	0.74	20.150	0.00	2	High
7	The company defines minimum tenders’ cost.	**3.83**	**0.82**	**13.712**	**0.00**	**4**	**High**
8	The company enhances collaboration between disciplines.	4.28	0.64	26.643	0.00	1	High
	Cost	**3.81**	**0.49**	**22.130**	0.00		**High**

T-tabulated=1.960

Innovation:

Table (4.7) shows that the means Innovation items range from 3.76 and 4.08 with a standard deviation between 0.62 and 0.78. This indicates that respondents agree on high implementation of Innovation items, this is supported by a high t-value compared to T-tabulated. The average mean is 3.95 with a standard deviation of 0.46, indicating that the respondents are highly aware and concerned about Innovation, where the t-value is 28.004>T-tabulated = 1.960.

Table 4. 7: Mean, Standard Deviation, t-value, Ranking, and Implementation Level of Innovation

No.	Items	M.	S.D.	t	Sig.	Rank	Impl.
1	The company gets new ideas to increase productivity	3.97	0.78	16.559	0.00	4	High
2	The company creates new solutions.	4.03	0.68	20.267	0.00	3	High
3	The company raises responsiveness.	4.08	0.68	21.249	0.00	1	High
4	The company raises interoperability.	3.83	0.71	15.681	0.00	6	High
5	The company utilizes databases for the diffusion of innovation (DOI).	3.76	0.66	15.397	0.00	7	High
6	The company enables innovation in construction design.	3.94	0.62	20.388	0.00	5	High
7	The company encourages teamwork to get new ideas.	4.06	0.72	19.600	0.00	2	High
	Innovation	**3.95**	**0.46**	**28.004**	**0.00**		**High**

T-tabulated=1.960

Quality:

Table (4.8) shows that the means Quality items range from 3.88 and 4.28 with a standard deviation between 0.69 and 0.76. This indicates that respondents agree on the high implementation of Quality items, this is supported by a high t-value compared to the T-tabulated. The average mean is 4.12 with a standard deviation of 0.50, which indicates that the respondents are highly aware and concerned about Quality, where the t-value is 30.108>T-tabulated = 1.960.

Table 4. 8: Mean, Standard Deviation, t-value, Ranking, and Implementation Level of Quality

No.	Items	M.	S.D.	t	Sig.	Rank	Impl.
1	The company follows international standards (ISO).	4.19	0.74	21.604	0.00	3	High
2	The company reduces errors.	4.13	0.73	20.894	0.00	4	High
3	The company develops a documentation system.	4.26	0.69	24.268	0.00	2	High
4	The company uses it for work-sharing.	4.28	0.76	22.698	0.00	1	High
5	The company reduces the environmental impact.	3.88	0.74	15.972	0.00	6	High
6	The company ensures construction safety.	3.99	0.69	19.143	0.00	5	High
	Quality	**4.12**	**0.50**	**30.108**	**0.00**		**High**

T-tabulated=1.960

Time:

Table (4.9) shows that the means Time items range from 3.98 and 4.27 with a standard deviation between 0.62 and 0.74. This indicates that respondents agree on the high implementation of Time items, this is supported by a high t-value compared to the T-tabulated. The average mean is 4.13 with a standard deviation of 0.47, which indicates that the respondents are highly aware and concerned about Time, where the t-value is 31.800>T-tabulated = 1.960.

Table 4. 9: Mean, Standard Deviation, t-value, Ranking, and Implementation Level of Time

No.	Items	M.	S.D.	t	Sig.	Rank	Impl.
1	The company defines stages as time.	4.10	0.73	20.344	0.00	5	High
2	The company sets milestones.	4.13	0.73	20.873	0.00	3	High
3	The company raises conflict detection.	3.98	0.74	17.926	0.00	6	High
4	The company increases collaboration between multidisciplinary teams.	4.27	0.62	27.361	0.00	1	High
5	The company speeds the communication among stakeholders.	4.15	0.64	24.168	0.00	2	High
6	The company controls the progress of work.	4.12	0.66	22.616	0.00	4	High
	Time	**4.13**	**0.47**	**31.800**	**0.00**		**High**

T-tabulated=1.960

Reliability and Flexibility:

Table (4.10) shows that the means Reliability and Flexibility items range from 3.96 and 4.24 with a standard deviation between 0.63 and 0.79.

Table 4. 10: Mean, Standard Deviation, t-value, Ranking, and Implementation Level of Reliability & Flexibility

No.	Items	M.	S.D.	t	Sig.	Rank	Impl.
1	The company ensures communication between works management and suppliers.	3.96	0.79	16.395	0.00	5	High
2	The company adheres to project standard requirements.	4.10	0.66	22.328	0.00	2	High
3	The company ensures accurate visualization of the entire project.	4.08	0.74	19.668	0.00	3	High
4	The company reduces the variation in operations.	3.99	0.75	17.762	0.00	4	High
5	The company responds to clients' changes.	4.24	0.63	26.464	0.00	1	High
	Reliability and Flexibility	**4.08**	**0.47**	**30.985**	**0.00**		**High**

T-tabulated=1.960

This indicates that respondents agree on high implementation of Reliability and Flexibility items, this is supported by a high t-value compared to the T-tabulated. The average mean is 4.08 with a standard deviation of 0.47, which indicates that the respondents are highly aware and concerned about Reliability and Flexibility, where the t-value is 30.985>T-tabulated = 1.960.

Relationship between Independent and Dependent Variables:

The study used the Bivariate Pearson Correlation Test to check the relationship between variables. Table (4.11) shows that the relationships among Building Information Modeling sub-variables are strong, where r ranges from 0.56 to 0.74. Moreover, the relationships among Competitive Advantage dimensions are also strong, where r ranges between 0.32 and 0.70. Finally, the relationship between independent and dependent variables is strong, where r equals 0.62.

Table 4. 11: Relationship between Independent and Dependent Variables

No.	Dimensions	1	2	3	4	5	6	7	8	9	10
1	Level of Development	-									
2	Stages	*0.63	-								
3	Dimensions	*0.74	*0.56	-							
4	**Building Information Modeling**	*0.94	*0.81	*0.85	-						
5	Cost	*0.53	*0.47	*0.40	*0.55	-					
6	Innovation	*0.41	*0.40	*0.35	*0.44	*0.50	-				
7	Quality	*0.53	*0.43	*0.43	*0.54	*0.55	*0.58	-			
8	Time	*0.43	*0.32	*0.35	*0.43	*0.56	*0.60	*0.63	-		
9	Reliability & Flexibility	*0.47	*0.46	*0.39	*0.51	*0.54	*0.44	*0.57	*0.70	-	
10	**Competitive Advantage**	*0.59	*0.52	*0.48	*0.62	*0.81	*0.80	*0.78	*0.82	*0.78	-

****. Correlation is significant at the 0.01 level (2-tailed).*. Correlation is significant at the 0.05 level (2-tailed). ("Correlation of variables in SPSS - Project Guru")**

4.3 Hypothesis Testing:

Main Hypothesis:

H01: The building information modeling (BIM) does not affect the competitive advantage (Cost, Innovation, Reliability, Time, and Quality) of Jordanian Architectural Organizations, at α≤0.05.

H01.1: The building information modeling (BIM) does not affect the competitive advantage (Cost) of Jordanian Architectural Organizations, at α≤0.05.

H01.2: The building information modeling (BIM) does not affect Building the competitive advantage (Innovation) of Jordanian Architectural Organizations, at α≤0.05.

H01.3: The building information modeling (BIM) does not affect the competitive advantage (Reliability) of Jordanian Architectural Organizations, at α≤0.05.

H01.4: The building information modeling (BIM) does not affect the competitive advantage (Time) of Jordanian Architectural Organizations, at α≤0.05.

H01.5: The building information modeling (BIM) does not affect Building the competitive advantage (Quality) of Jordanian Architectural Organizations, at α≤0.05.

Multiple Regressions:

H01: The building information modeling (BIM) does not affect the competitive advantage (Cost, Innovation, Reliability, Time, and Quality) of Jordanian Architectural Organizations, at $\alpha \leq 0.05$.

After checking the validity, reliability, and correlation between independent and dependent variables, the following tests should be conducted to be able to use regression analysis (Sekaran, 2003):

Normality: Figure (4.1) shows that the shape follows the normal distribution, in such case the model does not violate this assumption.

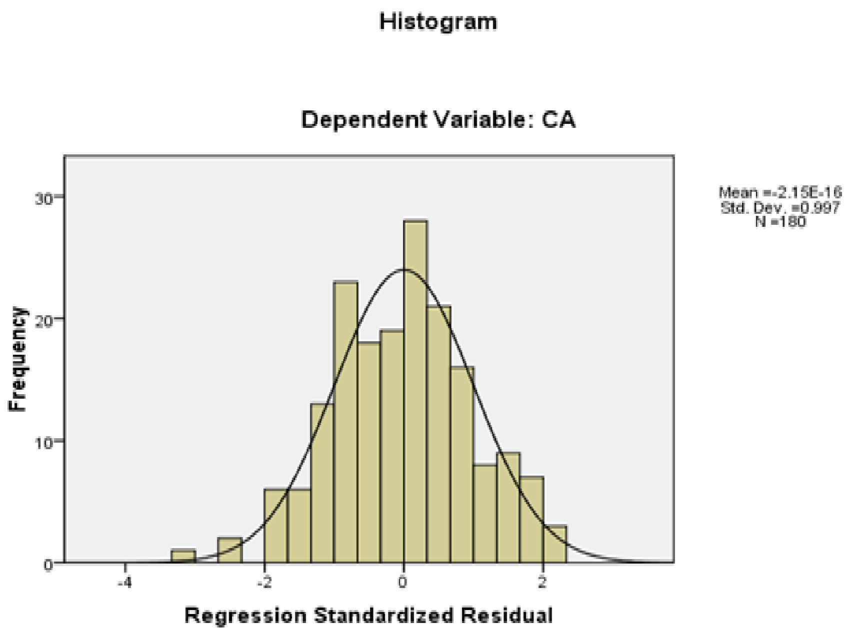


Figure 4.1: Normality Test

Linearity test: figure (4.2) shows that there is a linear relationship between independent and dependent variables. In such a case, the model does not violate this assumption.

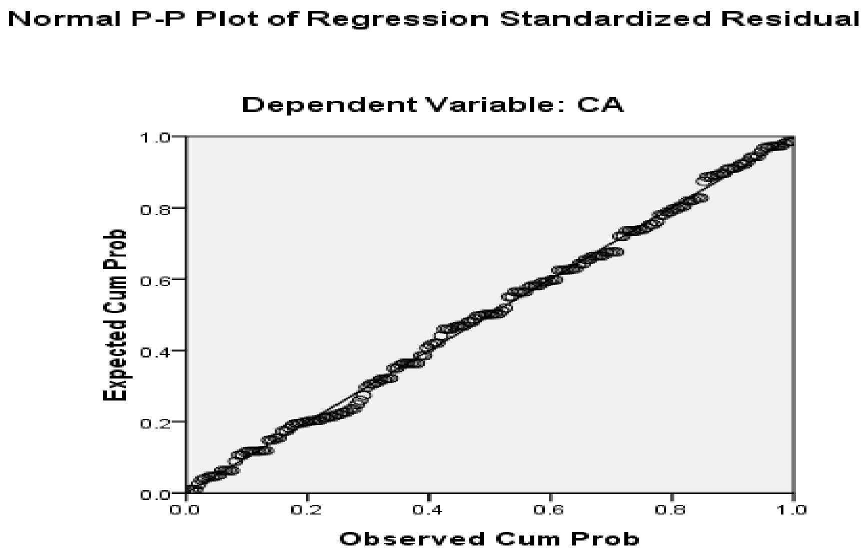


Figure 4.2: Linearity Test

Equal variance (homoscedasticity): figure (4.3) shows that the errors are scattered around the mean, therefore there is no relation between errors and predicted values, in such case, the model does not violate this assumption.

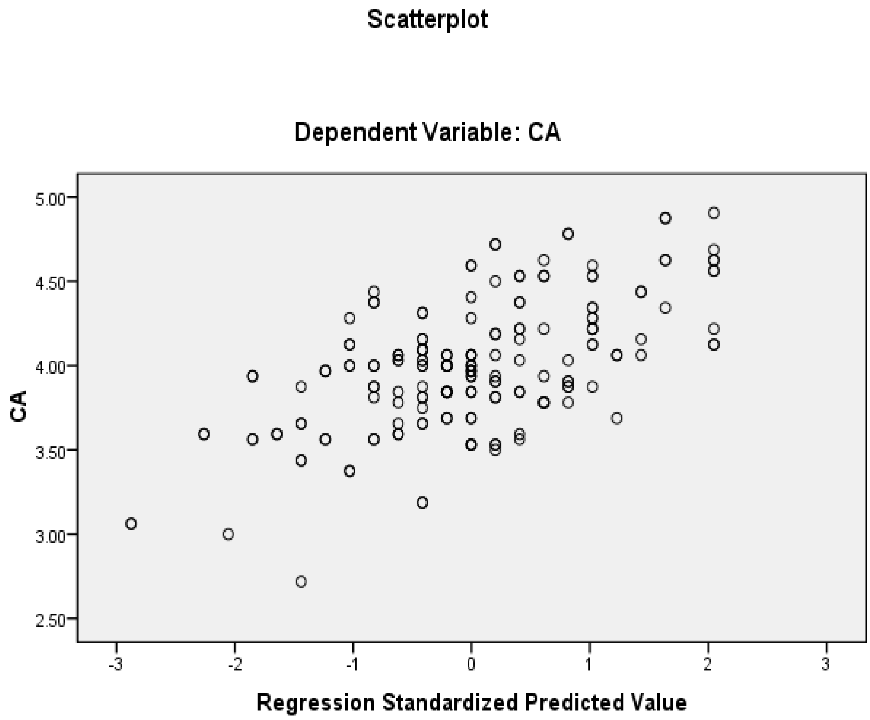


Figure 4. 3: Qual variance (homoscedasticity)

Multi-Collinearity: the VIF (Variance Inflation Factor) value is less than 10, and tolerance is more than 10%, in such case the Collinearity model does not violate this assumption.

Table 4. 12: Tolerance and Variance Inflation Factor

Model		Collinearity Statistics	
		Tolerance	VIF
	Cost	.720	1.388
	innovation	.186	5.366
	Quality	.359	2.783
	Time	.344	2.906
	Reliability	.409	2.447

a. Dependent Variable: competitive advantage

Table (4.13) shows that when regressing building information modeling (BIM) against the five sub-variables of the competitive advantage, the model shows that building information modeling (BIM) can explain 34.6% of the variation of competitive advantage, where (R2=0.346, F=18.396, Sig.=0.000). Therefore, the null hypothesis is rejected, and the alternative hypothesis is accepted, which states that building information modeling (BIM) does affect Building the competitive advantage (Cost, Innovation, Reliability, Time, and Quality) of Jordanian Architectural Organizations, at α≤0.05

Table 4. 13: Multiple Regressions of Dynamic Capabilities of Building Information Modeling (BIM) on Competitive Advantage Sub-variables.

Model	R	R^2	Adjusted R^2	f	Sig.
1	.588[a]	.346	.327	18.396	.000[a]

a. Predictors: (Constant), Reliability, Cost, Quality, Time, innovation. b. Dependent Variable: competitive advantage.

Table 4. 14: Multiple Regressions of Dynamic Capabilities of Building Information Modeling (BIM) Sub-variables on Competitive Advantage Dimensions.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	.378	.555		.681	.497
H01.1	Cost	.774	.109	.512	7.092	.000
H01.2	Innovation	.730	.305	.340	2.395	.018
H01.3	Quality	.232	.162	.147	1.438	.152
H01.4	Time	.494	.174	.297	2.841	.005
H01.5	Reliability	.288	.162	.170	1.773	.078

a. Dependent Variable: Building Information Modeling, T-Tabulated=1.960

H01.1: The building information modeling (BIM) does not affect the competitive advantage (Cost) of Jordanian Architectural Organizations, at $\alpha \leq 0.05$.

Table (4.14) shows that cost affects the competitive advantage, where (β=0.512, t=7.092, Sig.=0.000), therefore the null hypothesis is rejected and the alternative is accepted which indicates that The building information modeling (BIM) affects Building the competitive advantage (Cost) of Jordanian Architectural Organizations, at $\alpha \leq 0.05$.

H01.2: The building information modeling (BIM) does not affect the competitive advantage (Innovation) of Jordanian Architectural Organizations, at $\alpha \leq 0.05$.

Table (4.14) shows that innovation affects the competitive advantage, where (β=0.340, t=2.395, Sig.=0.018), therefore the null hypothesis is rejected and the alternative is accepted which indicates that the building information modeling (BIM) affects the competitive advantage (Innovation) of Jordanian Architectural Organizations, at α=0.05.

H01.3: The building information modeling (BIM) does not affect the competitive advantage (Reliability) of Jordanian Architectural Organizations, at $\alpha \leq 0.05$.

Table (4.14) shows that reliability affects the competitive advantage, where (β=0.170, t=1.773, Sig.=0.078), therefore the null hypothesis is accepted which indicates that The building information modeling (BIM) does not affect the competitive advantage (Reliability) of Jordanian Architectural Organizations, at $\alpha \leq 0.05$.

H01.4: The building information modeling (BIM) does not affect the competitive advantage (Time) of Jordanian Architectural Organizations, at $\alpha \leq 0.05$.

Table (4.14) shows that time affects the competitive advantage, where (β=0.297, t=2.841, Sig.=0.005), therefore the null hypothesis is rejected and the alternative is accepted which indicates that the building information modeling (BIM) affects the competitive advantage (Time) of Jordanian Architectural Organizations, at $\alpha \leq 0.05$.

H01.5: The building information modeling (BIM) does not affect the competitive advantage (quality) of Jordanian Architectural Organizations, at $\alpha \leq 0.05$.

Table (4.14) shows that quality affects the competitive advantage, where (β=0.147, t=1.438, Sig.=0.152), therefore the null hypothesis is accepted which indicates that the building information modeling (BIM) does not affect Building the competitive advantage (Quality) of Jordanian Architectural Organizations, at $\alpha \leq 0.05$.

In summary:

Descriptive Analysis: The dimensions sub-variable has rated the highest implementation followed by the level of development and then stages. The time sub-variable has rated the highest implementation, then quality, followed by reliability and flexibility, innovation, and cost, respectively.

Correlation: The study used the Bivariate Pearson Correlation Test to check the relationship between variables. the relationships among Building Information Modeling sub-variables are strong. Moreover, the relationships among Competitive Advantage dimensions are also strong. Finally, the relationship between independent and dependent variables is strong.

Effect: Furthermore, the Building information modeling (BIM) sub-variables impacted the competitive advantage as below: the highest impact was for the Level of Development, followed by Stages, followed by Dimensions rated.

based on the components of competitive advantage, table (4.14) shows the impact of building information modeling (BIM) on the competitive advantage sub-variable, where impacted by building information modeling (BIM), The highest impact was for cost, Followed by Innovation, Followed by Time, Followed by Reliability, Followed by quality.

Summary: The findings show the high implementation of building information modeling (BIM) and its sub-variables on competitive advantage in the Jordanian architectural industry. The building information modeling (BIM) impacted the competitive advantage sub-variables as below: the highest impact was for cost, followed by Innovation, followed by Time, followed by Reliability, followed by quality.

CHAPTER FIVE

Results' Discussion, Conclusion, and Recommendations

5.1 Introduction

This study examines the impact of Building Information Modeling (BIM) on competitive advantages in the Jordanian architectural industry. Analyzing data from 184 managers, BIM coordinators, and users, The study employed descriptive analysis, correlation tests, and multiple regressions. The findings show that high BIM implementation significantly enhances competitive advantages. The study emphasizes the importance of integrating BIM into organizational strategies to achieve competitive advantages, with managerial and corporate social responsibility implications, especially in selecting common data environments.

5.2 Results' Discussion

The result of this study shows that the high impact of implementing building information modeling (BIM) in architectural firms will affect the competitive advantage sub-variables as below: the highest impact was for cost, followed by Innovation followed by Time, followed by Reliability, followed by quality

The medium implementation rate for reliability and quality resulted from the ability to do the engineering work in an ordinary way using the ordinary ways of communication between disciplines. Which is dependable for them and, they can produce high-quality documents, although implementing building information modeling systems will affect the other competitive advantage sub-variables as the study proceeds.

The following summarizes the impact of building information modeling (BIM) on Competitive Advantages (Cost, Quality, Responsiveness, Reliability, and Innovation), the results are as follows:

1. The significant impact of total building information modeling on the total Competitive Advantages, which supported by previous studies: (Nguyen, at. al. 2021; Allen & Shakantu, 2016; Chen & Luo 2014).
2. The significant impact of total building information modeling on Cost, which supported by previous studies: (Ismail at. al. 2021; Haider, at. al. 2020).
3. The significant impact of total building information modeling on innovation, which supported by previous studies: (Khudhair, at. al. 2018; Behún & Behúnová, 2023; Milivojević, 2020).
4. The significant impact of total building information modeling on Time, which supported by previous studies: (Taher, et al., 2018; Sholeh at. al. 2020; Johansson, 2015).
5. There wasn't a significant impact of total building information modeling on Reliability, which disagreed with previous studies: (Ismail, at. al. 2021; Manzoor, at. al. 2021). The reason for the disagreement was because there are many other ways to make their work reliable and there is no need for them to update their typical ways of working according to them.
6. There wasn't a significant impact of total building information modeling on Quality, which was disagreed by previous studies: (Sadek, at. al. 2019; Ma, et. al. 2018; Leygonie & Motamedi 2022). The reason for the disagreement was because some firms are working on the ordinary type of work and they can complete their work in an optimal way according to their standards.

5.3 Conclusion

This study tool place in the Jordanian architectural industry, and employed descriptive analysis, correlation tests, and multiple regressions. The main purpose of this study is to answer the main questions, which are:

1. What is the level of implementation of Building information modeling (BIM) in Jordanian Architectural Organizations?
2. What is the level of competitive advantage in Jordanian Architectural Organizations?
3. Is there a relationship between Building information modeling (BIM) and the competitive advantage in Jordanian Architectural Organizations?
4. What is the effect of Building information modeling (BIM) on the competitive advantage in Jordanian Architectural Organizations?

Questions one and two were answered by descriptive analysis, question three was answered by correlation test, and question fourth was answered by testing the hypothesis.

Data was collated via a questionnaire, which was tested for its validity and reliability. Then correlation and multiple regressions were used to test the hypothesis.

The results of this study show the high implementation of building information modeling (BIM) and its sub-variables on competitive advantage in the Jordanian architectural industry. The building information modeling (BIM) impacted the competitive advantage sub-variables as below: the highest impact was for cost, followed by Innovation, followed by Time, followed by Reliability, followed by quality.

5.4 Recommendations

5.4.1 Recommendations for Jordanian Architectural and Other Industries. (Services and products), decision maker.

This study recommends that Jordanian architectural organizations should:

- Implement Building information modeling within their work strategy.

- Implement Building information modeling components together to benefit from its emerging optimally.
- Have methods, tools, and KPIs to check building information modeling developments and benefits through evaluating benchmarking and comparing its components with other organizations within the architectural and engineering industry.
- Always improve and update their work strategy to align with the international changes and updates in the methods of building, modeling, drafting, documenting, and planning.
- Implement building information modeling to improve communication between disciplines.
- Establish a transitional plan to implement (BIM) and recruit professional employees with considerable experience to improve and evolve their work strategies.

5.4.2 Recommendations for Future Research:

Given that this study focuses on managers, BIM coordinators, and BIM users in the Jordanian architectural industry, it is recommended to also include employees who do not use BIM in their work.

Since the study is conducted within the Jordanian architectural industry, to generalize the findings, it is advisable to replicate the study in similar industries in other countries, particularly in Arab countries due to their comparable social and cultural contexts.

As this research pertains specifically to the architectural industry, applying the same variables to other engineering sectors is suggested.

The study was conducted over a limited time frame; therefore, it is recommended to conduct a follow-up study after an appropriate interval to assess industry developments.

Extending the analysis to different industries and countries presents future research opportunities. Further testing with larger samples within the same industry and including other industries will help address the challenge of generalizing conclusions across different organizations and sectors.

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Appendix 1: Referee Committee

No.	**Name**	**Qualification**	**Organization**
1	Prof. Dr. Ahmed Ali Saleh	Professor of Management	Middle East University
2	Prof. Dr. Ali Al Adaileh	Professor of Management	Middle East University
3	Prof. Dr. Azzam Abu Moghli	Professor of Management	Middle East University
4	Hanan Awad	BIM Coordinators	Arabtech Jerdana - HDP
5	Maysoon Al Desi	Director	Arabtech Jerdana
6	Radi Al Shamaileh	BIM Coordinators	Praxis
7	Qais Al Zebin	BIM Coordinators	Arabtech Jerdana
8	Baker Mehyar	Senior Architect	Arabtech Jerdana - HDP
9	Jawad Hamaideh	BIM Coordinators	KEO
10	Mohammad Haddad	BIM Coordinators	Praxis
11	Tamara Jadallah	BIM Coordinators	Arabtech Jerdana - HDP

Appendix 2: Survey

You are invited to take part in a survey aimed at exploring the relationship between competitive advantage and Building Information Modeling (BIM) within the architectural and construction industries. Your valuable insights will contribute to a better understanding of how organizations leverage BIM to gain a competitive edge in the market.

Purpose:

This survey aims to examine the extent to which organizations perceive BIM as a driver of competitive advantage. By gathering data on the adoption, utilization, and perceived benefits of BIM, this research seeks to uncover insights into the strategic implications of BIM implementation for organizations seeking to maintain or enhance their competitive position.

Your Participation:

Your participation in this survey is vital in capturing diverse perspectives and experiences related to BIM adoption and its impact on competitive advantage. Your responses will remain confidential and will only be used for research purposes.

Survey Details:

* The survey consists of 46 questions and should take approximately 10 Minutes to complete.
* Your responses will be anonymized and aggregated for analysis.
* Participation in this survey is voluntary, and you may withdraw at any time without penalty.

Acknowledgment:

Your contribution to this research is greatly appreciated and will help advance our understanding of the strategic implications of BIM adoption in the architectural and construction industries.

Thank you for your time and valuable insights.

Sincerely,

Othman Atallah

Part one: Demographic information

Company (optional):

Gender: □Male □Female

Age (years): □Bet.20-24 □ Bet. 25-29 □Bet. 30-34 □Above 35

Experience (years): □Less 4 □Bet.5-9 □Bet.10-14 □More than 15.

Part two: The following forty-four questions evaluate the relationship between Building information modeling in Jordan Mid and large-sized companies and Competitive Advantages.

Please, rate each question according to actual implementation and not based on your belief, as follows:

1 = Strongly disagree, 2 = disagree, 3 =Neutral, 4 = Agree, 5 = Strongly agree.

Level of development is a measure that defines the degree of detail and accuracy of 3D geometry and associated information within a Building Information Model. It helps stakeholders understand what can be expected from the model at different stages of a project's lifecycle.						
		1	**2**	3	4	5
1.	The BIM level of development enhances facility management.					
2.	The BIM level of development alters long-term maintenance.					
3.	The BIM level of development defines the project requirement.					
4.	The BIM level of development determines the cost of the project depending on the scale of the project					
5.	The BIM level of development clarifies project stages					
6.	The BIM level of development enhances collaboration between disciplines					
Stages: BIM stages refer to the different levels of maturity in Building Information Modeling (BIM) implementation. These stages typically range from 0 to 4 or 6, with each stage representing a higher level of BIM integration and sophistication.						
7.	The BIM by stages clarifies the collaboration between disciplines.					
8.	The BIM stages raise the maturity level.					
9.	The BIM stages encourage the model lifecycle integration.					
Dimensions: Refer to the various aspects or properties of a building model beyond just its geometric representation.						
10.	The BIM dimensions raise the model complexity.					
11.	The BIM dimensions show the level of services given.					
12.	The BIM dimensions raise the environmental integration.					
Cost: can be defined as the financial outlay associated with various aspects of business operations, including procurement, project lifecycle maintenance, employee compensation, variation orders (VO's), project profitability, bill of quantity (BOQ) determination, minimum tenders' cost, and collaboration between disciplines. It encompasses expenditures related to reducing procurement costs, eliminating waste, establishing salary structures, decreasing variation orders costs, enhancing profitability, determining bill of quantity, setting minimum tenders' cost, and fostering collaboration.						
13.	The company reduces procurement costs.					
14.	The company eliminates waste project lifecycle maintenance.					
15.	The company determines a suitable salary structure for employees					
16.	The company decreases variation orders (VO's) costs.					
17.	The company increases project profitability					
18.	The company determines the bill of quantity (BOQ).					
19.	The company defines minimum tenders' cost.					
20.	The company enhances collaboration between disciplines.					
Innovation: refers to the process of generating novel ideas and implementing them to enhance productivity, find new solutions, increase responsiveness, improve interoperability, utilize databases for the diffusion of innovation (DOI), enable						

innovation in construction design, and foster teamwork for idea generation within a company.						
21.	The company gets new ideas to increase productivity					
22.	The company creates new solutions.					
23.	The company raises responsiveness.					
24.	The company raises interoperability.					
25.	The company utilizes databases for the diffusion of innovation (DOI).					
26.	The company enables innovation in construction design.					
27.	The company encourages teamwork to get new ideas.					
Quality: can be described as the standard of excellence maintained by a company, which includes adherence to international standards such as ISO, minimizing errors, establishing a robust documentation system, employing efficient tools and technologies, facilitating work-sharing, reducing environmental impact, and ensuring construction safety.						
28.	The company follows international standards (ISO).					
29.	The company reduces errors.					
30.	The company develops a documentation system.					
31.	The company uses it for work-sharing.					
32.	The company reduces the environmental impact.					
33.	The company ensures construction safety.					
Time: Time management within the company involves defining stages with allocated timeframes, setting milestones to track progress, raising conflict detection to resolve issues promptly, fostering collaboration between multidisciplinary teams to streamline processes, speeding up communication among stakeholders for efficient coordination, and controlling the progress of work to ensure timely completion of projects.						
34.	The company defines stages as time.					
35.	The company sets milestones.					
36.	The company raises conflict detection.					
37.	The company increases collaboration between multidisciplinary teams.					
38.	The company speeds the communication among stakeholders.					
39.	The company controls the progress of work.					
Reliability & Flexibility: Reliability in the company is upheld through various measures including ensuring effective communication between works management and suppliers, adherence to project standard requirements, accurate visualization of the entire project, reduction of variation in operations, and responsiveness to clients' changes. This ensures consistency, dependability, and trustworthiness in the company's processes and outcomes.						
40.	The company ensures communication between works management and suppliers.					
41.	The company adheres to project standard requirements.					
42.	The company ensures accurate visualization of the entire project.					
43.	The company reduces the variation in operations.					
44.	The company responds to clients' changes.					