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Transformation to Building Information Modeling in Construction Industry in Bahrain: Benefits and Barriers

The thesis submitted in partial fulfillment of the requirements for the
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Prepared by

Saleh Arafat Saleh Albdour

ID number: 20152809

Supervised by

Dr. Yusuf M. Al Malki

Assistant Professor

University of Bahrain

Kingdom of Bahrain

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University of Bahrain`
Deanship of Graduate Studies

Thesis Discussion Committee Decision

Student Name: Saleh Albdour	Student ID: 20152809
Department: Mechanical Engineering	College: Engineering
Program: M.Sc. in Engineering Management	
Thesis Title: Transformation to Building Information Modeling in Construction Industry in Bahrain: Benefits and Barriers	
Supervisor Name: Dr. Yusuf M. Al Malki	Student GPA: 3.43

The Discussion Committee met on _____ in campus/MS Teams. Upon discussing the student whose details are stated above in public, the discussion committee recommends the following:

The student awarded grade A In the thesis subject

Without making any changes to the thesis

After making the modifications attached with this decision.

Discussion Committee Members Approval:

Name Signature

1. Dr. Yusuf M. Al Malki (Advisor)
2. Dr. Venu Parameswaranpillai, College of Engineering, UOB(Internal Examiner)
3. Dr. Amine Moulayi, Royal University for Women, Kingdom of Bahrain
(External Examiner)

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Abstract

Building Information Modeling (BIM) is streaming into the world of the construction industry. It is a crucial tool that enhances construction project management through its multi-dimensional capabilities. BIM remains underutilized in Bahrain despite its global value, creating a gap between international best practices and local implementation. This study investigates why BIM adoption in Bahrain lags and explores ways to bridge that gap. This study investigates the adoption of Building Information Modeling (BIM) within Bahrain's construction industry, focusing on the benefits, barriers, and factors influencing its implementation.

Using a quantitative approach, data were collected from 247 construction professionals in Bahrain through structured questionnaires, with interviews conducted with selected professionals to validate questionnaire responses. The findings reveal a high level of BIM awareness (82%) among professionals. Still, there is a significant gap between knowledge and usage, with only 30.9% actively using BIM tools. Also, the findings indicate that while core BIM functionalities, such as 2D (drawings production) and 3D modeling (visualization), are commonly adopted, the integration of advanced BIM features—such as clash detection, budgeting, cost estimation, and facility management—remains limited (in other words, usage of BIM in Bahrain is limited to 2D & 3D adoption). However, there is a strong willingness to adopt BIM, with 81.51% of respondents to its implementation, especially among consulting firms and government entities. The study identifies that educational level and project scales

influence BIM knowledge and usage variations. For instance, professionals with higher academic qualifications, such as Master's and PhD holders, demonstrate greater engagement with BIM compared to their Bachelor's degree counterparts. Also, larger projects demonstrate higher adoption rates, with 38.89% actively using BIM tools and only 9.52% unaware of BIM, indicating that the demands of larger projects often drive the need for advanced solutions like BIM.

The study indicates several key benefits of BIM adoption, including improved productivity, enhanced work efficiency, better budget monitoring, reduced project duration, and improved documentation. However, it also highlights significant barriers to implementation, such as the lack of demand from project owners, high training costs, limited access to training, and low awareness of BIM's benefits.

The study concludes that government legislation and academic integration are crucial for successful BIM adoption in Bahrain, and they are key to overcoming challenges and facilitating effective BIM implementation. Aligning policies and incorporating BIM into curricula can increase owner demand and awareness, leading to a rise in BIM experts in Bahrain. Furthermore, redirecting internal resources towards building in-house expertise can reduce reliance on external consultants, promoting sustainable and efficient BIM practices within the industry.

Dedication

To my family and friends, as well as my academic mentors and colleagues, thank you for your unwavering support, guidance, and invaluable insights. Your expertise and encouragement have been instrumental in shaping this research.

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Abbreviations

Architecture, Engineering, And Construction (AEC)

Building Information Modeling (BIM)

Integrated Project Delivery (IPD)

Mechanical, Electrical, and Plumbing (MEP)

2D (Dimensions) Drawings

3D Modelling/ Presentation

4D (scheduling with time dimension)

5D (cost estimation incorporating time and costs)

6D (sustainability considerations in building management)

7D (building management, including the operational phase)

8D Safety hazards identification and emergency management

Associated General Contractors of America (AGC)

National Building Information Modeling Standards (NBIMS)

Internet of Things (IoT)

Chapter 1: Introduction to the Study

1.1 Introduction

Construction project management is a complex and complicated process, as it includes several phases and many participants in the construction project. During the construction stage, project stakeholders face many challenges in the coordination process to achieve the project requirements established by the client (Hjelmbrekke et al., 2014). The inability to meet the estimated budget for the project due to a wrong assessment of the project's cost or a project incomplete on schedule or plan may lead to holding or stopping the project. Sometimes, the risk in the project is high due to poor planning or mismanagement due to not understanding the correct perception of the project. Also, there may be a wrong perception of the project among the owners who are not familiar with technical matters, as the architect may draw the plan and create an approximate three-dimensional visualization of the project. They may find conflicting or clashing matters upon implementation as the coordination between the engineering drawings is inaccurate. Some unclear or missed details may change the project's character (Ohag et al., 2023). To avoid most of the problems related to construction project management, developing countries, including Bahrain, must attract new technologies such as Building information modeling "BIM" that help understand the barriers that prevent projects from being completed regarding schedule, cost, quality, and safety management. In particular, a lack of collaboration and

communication between project stakeholders has been identified as a significant obstacle to successful project delivery.

The Architecture-Engineering-Construction (AEC) industry is undergoing a significant transformation with the introduction of Building Information Modeling (Takim, 2013; Barki et al., 2015). It can be considered both a process and a technology (Azhar et al., 2015). Implementing BIM's technological component allows project stakeholders to visualize what will be constructed in a simulated environment, pinpointing any possible design, construction, or operational concerns. The process element fosters a culture of cooperation and promotes the integration of all stakeholders' responsibilities within a project, allowing them to work closely together.

This research aims to study the building information modeling process (BIM) and technology by identifying its benefits and barriers in the construction industry in Bahrain for addressing problems facing construction project management and resolving them using BIM, including the study of the transformation that we need in our day in order to reduce these problems that we face daily in construction projects, so there should be more effective and accurate communication methods that help stakeholders understand what the project requirements are and minimize changes during the project that will increase the duration or cost of the project. We can develop projects and communication using building information modeling, resulting in effective project planning. Building information modeling is a powerful tool and process for collaboration, efficiency, visualization, sustainability, and control that can be used for construction projects (Fadeyi et al., 2017).

1.2 Research Background

Building Information Modeling (BIM) has become a revolutionary influence on the worldwide architectural, engineering, and construction (AEC) industry. BIM has been extensively adopted to improve communication among project stakeholders, minimize the need for modifications, and ensure design accuracy (Azhar, 2012). To promote the standardization of processes among industry participants, national BIM requirements have been instituted in nations including the United Kingdom, Singapore, and the United States (Hore et al., 2017). These worldwide mandates are rational; they rectify a clear deficiency in the industry's endeavors to achieve digital transformation, which is urgently required.

The United Arab Emirates and Saudi Arabia are two nations within the Gulf Cooperation Council (GCC) area that are presently benefiting from Building Information Modeling (BIM), especially with substantial infrastructure projects and smart city programs (Almutiri et al., 2020). Their swift integration suggests that BIM offers advantages in project management and decision-making for substantial investments. Bahrain's construction sector is still in the early stages of absorbing BIM. As noted by (Ahmed et al. 2020), there is a high awareness of BIM with low usage and implementation of BIM. Nonetheless, no sector appears to be employing BIM in its complete form.

1.3 Research Problem

The research problem under investigation aims to comprehensively explore the multi-faceted challenges plaguing construction project management in developing countries, specifically focusing on Bahrain. These challenges create a web of complexities that significantly impact the effectiveness and efficiency of construction projects, often leading to cost overruns, delays, poor quality, and increased waste as Bahrain generates nearly 1.2 million tons of construction waste annually, representing almost 50% of its total waste (Alsaegh et al., (2019, November 18), Zafar, 2022)., and safety concerns. In light of these persistent issues, there is an emerging need for transformative approaches and technologies to improve the construction process, from planning to execution (IGA, 2024, July 11, Municipalities & Agriculture Ministry, 2025), by minimizing construction problems using different systems or changing the existing system (Traditional) to a new (system) or process more accurate can overcome the Construction problems by preplanning all construction requirements in a more realistic way such as building information modeling.

1.4 Research Objectives

The objectives of this research will be summarized as follows:

HB1. To study the construction project management challenges from the latest detailed literature review that building information modeling (BIM) can resolve in engineering firms.

HB2. To study the benefits of implementing BIM in engineering firms in Bahrain and from the latest detailed literature review.

HB3. To investigate the barriers to implementing BIM in engineering firms in Bahrain and from the latest detailed literature review.

HB4. To study the level of awareness of BIM in engineering firms in Bahrain.

HB5. To study the willingness and ability of the engineering firms in Bahrain to use BIM.

1.5 Research Questions

1. What is the current level of awareness and usage of Building Information Modeling (BIM) among construction professionals in Bahrain?
2. What are the benefits and barriers of implementing BIM among construction professionals in Bahrain?
3. What are the significant measures to overcome BIM adoption and implementation challenges and assess the transformation needed
4. Are engineering firms willing to adopt BIM technology?

1.6 Research Significance

This research can serve as a foundational study for enhancing construction project management practices in developing nations via the incorporation of BIM. By identifying challenges and proposing solutions, this study enables us to advance knowledge in construction project management, highlighting the role of BIM as it represents a transformative leap in construction methodologies, providing a roadmap that promotes better construction practices and project outcomes, also empowering stakeholders through informed choices that help in decision-making, and bridging the technology gap.

1.7 Research Gap & Limitations



Figure 2.2.1.1: Research Limitations

Implementing Building Information Modeling (BIM) in construction projects is a significant investment, and the cost is often a crucial limitation, especially in developing countries like Bahrain. BIM technology requires a lot of software that requires licensing fees, upgrading of existing systems, and maintenance. It also requires training and development for the staff, as we need specialized, skilled people to teach and maintain ongoing training.

Moreover, time investment during the transformation stage from standard traditional methods to a BIM-oriented approach will be time-consuming and expensive, impacting the project timeline initially. Recognizing the cost of BIM as a limitation is crucial for a holistic understanding of its implementation challenges, especially if resources may be more constrained.

On the other hand, the comparison between long-term benefits and short-term costs reveals that while Building Information Modeling (BIM) has the potential to generate cost savings over an extended period, the initial investment is substantial. Stakeholders might be uncertain regarding the timing and method of recouping their investment, leading to hesitation in adopting Building Information Modeling (BIM) technology. Especially for smaller projects, the instant discernibility of return on investment (ROI) may be less apparent, hence presenting challenges in substantiating the substantial initial expenditure required for Building Information Modeling (BIM) technology.

The Research Limitations (Figure 1.6.1) can be summarized as follows:

- Acquiring comprehensive and accurate information could create challenges, especially inside a developing country such as Bahrain, where the accuracy of record-keeping may not be on a level with that of more established nations.
- The restricted sample size is representative of the construction industry.
- The stakeholders involved may have varying levels of technological literacy, which can affect the effective response.
- The existence of resource limitations, particularly a lack of funding and resources, is one possible barrier to doing research and could limit the scope and size of the study.
- Building projects are long-term, so it may take some time to thoroughly assess the impact of BIM within the research's constrained period.

- The research relies on interviews and surveys, and the subjectivity or judgment of the Participants may influence the responses.

It is important to acknowledge that this study did not explore the cost and time implications related to the implementation of BIM technology. The costs and timeline for implementing BIM are essential factors that impact its adoption, necessitating a thorough examination of various elements, including software licensing, hardware upgrades, training, and operational expenses. Given these factors' intricate nature and breadth, they were not included in the present study. The objective was to provide practical insights that may lay the groundwork for subsequent investigations, mainly concentrating on BIM benefits aspects that can obtain added value once the transformation is fully completed, besides the obstacles for the adoption.

1.8 The Study's Setting

Chapter 1: Introduction to the Study

This chapter begins with an overview of Building Information Modeling, exploring the challenges of construction project management and the role of BIM in mitigating these challenges in the context of Bahrain. This is followed by a description of the problem. The research objectives, questions, significance, and terminology are also defined.

Chapter 2: Theoretical Framework and Literature Review

This chapter offers an overview of Building Information Modeling (BIM) in the context of constructing projects. It explores the current status of BIM globally and in Bahrain and the challenges and advantages of BIM for all parties involved.

Chapter 3: Research Methodology

This chapter discusses the mathematical and statistical analysis of the results through interviews and questionnaires.

Chapter 4: Data Collection Results, Analysis, and Results Discussion

This chapter discusses the statistical tests conducted on the survey findings, including the reliability test, normality test, descriptive statistics, hypothesis test, and the main findings that answer the study questions.

Chapter 5: Conclusion and Recommendations

This last chapter summarizes the conclusion and recommendations for future researchers on the subject.

Chapter 2: Literature Review

2.1 Introduction

Building Information Modeling (BIM) is streaming into the world of the construction industry. One of the crucial tools for ensuring sustainability in construction, which is an essential branch, is digital transformation (Azhar et al., 2012). It embraces technology and innovations throughout the delivery lifecycle, including design, building, infrastructure management, and post-construction operations. While BIM itself is a strong process, it is not limited to just building information modeling or the digital representation of physical and functional characteristics of structural elements together. The real benefit of BIM is its ability to stimulate collaboration, improve precision in project planning and execution, lead greater sustainable construction practices, and, for that reason, be an integral tool within the building trade (Akintoye et al., 2012). When it comes to BIM use in Bahrain, its adoption remains low, and further improvements need to be made despite the opportunities that go along with it. The Government of Bahrain is looking into methods to prepare a strategy for the implementation and construction information modeling to establish mechanisms related to the issuance of permits in the new version of the Benayat system (IGA, 2024, July 11), which strives to ease data-sharing processes, expedite mechanisms for verifying building requirements, save time and cost, as well as quality management within construction projects while reducing risks and obstacles during the execution stage (IGA, 2024, July 11).

This literature review supports our understanding of the current status of BIM adoption globally, specifically in Bahrain, which is the main focus of this study. It explores the benefits and barriers faced by the construction industry, drawing on insights from global, regional, and local studies to provide a comprehensive understanding of the challenges and opportunities presented by BIM in the Bahraini context. Its role in shaping our understanding of BIM adoption is significant, ensuring that we are well-informed and knowledgeable about this crucial aspect of the construction industry.

2.2 The Construction Industry and Project Management Context

Before exploring the concept of construction project management, it is important to define a construction project first. However, it is essential to comprehend the context of the construction industry in which such projects are conceived and executed.

2.2.1 The Construction Industry

The construction industry includes the development, execution, management, and maintenance of buildings and infrastructure. These structures are intended to fulfill human needs and improve societal welfare. The industry is essential for modernization, growth, and development, as its outputs are the most visible signs of progress in any society. Roads, airports, residential communities, hospitals, and commercial centers are tangible symbols of advancement, enhancing the quality of life for

individuals and the environment (Project Management Institute, 2017; Kerzner et al., 2017).

Due to the complexity and significance of construction projects, it became essential to manage these projects using established methodologies and principles. This necessity led to the emergence of Construction Project Management (CPM). This discipline manages a project from its inception to its ultimate delivery to the end user and extends into facility management.

2.2.2 Construction Project Management (CPM)

Construction project management involves systematically planning, coordinating, and supervising a project from conception to completion. The aim is to meet client requirements and objectives to produce a functionally and financially viable project delivered on time, within budget, and to the required quality standards. (Project Management Institute, 2017) highlights CPM as an integrative discipline requiring procurement, scheduling, cost management, stakeholder engagement, and risk analysis expertise. The evolution of CPM has paralleled advances in digital technologies, enabling more efficient management of complex projects.

2.3 Conceptual Overview of BIM:

Recently, the recognition and use of building information modeling in projects have been increasing considerably in construction. BIM is an innovative process that allows the integration of multiple attributes, domains, and systems of a facility into a unified digital model (Akintoye et al., 2012). It allows the stakeholders involved to collaborate more

effectively over the course of a project than other methods would allow, with better accuracy and speed. Building information modeling in construction projects involves balancing the three factors of project management enablers that provide maximum benefits to all stakeholders: quality, cost, and time (Fadeyi et al., 2017). In fact, finding a harmonious fusion of the three main branches of architecture, engineering, and construction (AEC) is incredibly difficult to achieve within the industry. The only way to obtain this balance is to implement new solutions, and building information modeling could be such a solution.

Considerable synergies can be attained by combining lean principles and building information modeling (Sbiti et al., 2021). Lean construction focuses on continuous process improvement and waste elimination during the entire project life cycle (Al Hattab al., 2013). Building Information Modeling data is also leveraged to improve overall project management during a project by improving planning in the design phase, managing teams, and making better decisions. Digitization of Lean methods and techniques is required to apply them in construction projects; this will significantly increase the effectiveness of their integration within Lean-BIM due to the increased integration of participants (Sbiti et al., 2021).

Despite having several advantages of Building Information Modeling and Lean-BIM approaches in construction projects, further investigation and study is needed (Sbiti et al., 2021). Most of the existing work focuses on improving the design stage, but we could expand these approaches to other project stages.

Building Information Modelling (BIM) is one of the most significant advancements in construction, enabling a digital virtual building model to be created (Autodesk, 2024). With accurate geometry and accurate data, this model acts as a true workhorse for procurement, fabrication, and construction. (Autodesk, 2024) pioneered implementing a coordinated and consistent use of computable information about a construction project during its design phase. BIM is a collaborative resource of information that helps to establish a strong foundation on which to base decisions throughout the entire life cycle of a project. BIM is really about the participation of different stakeholders in the various life cycle phases of a facility, and each participant's role in inserting (Akintoye et al., 2012), extracting, updating, or modifying information into BIM has an implication on its value. BIM is a shared digital representation based on open interoperability standards, facilitating information exchange among all project participants. Figure 2.2.1 (Akintoye et al., 2012) shows examples of how the BIM data are shared among several multidisciplinary stakeholders,

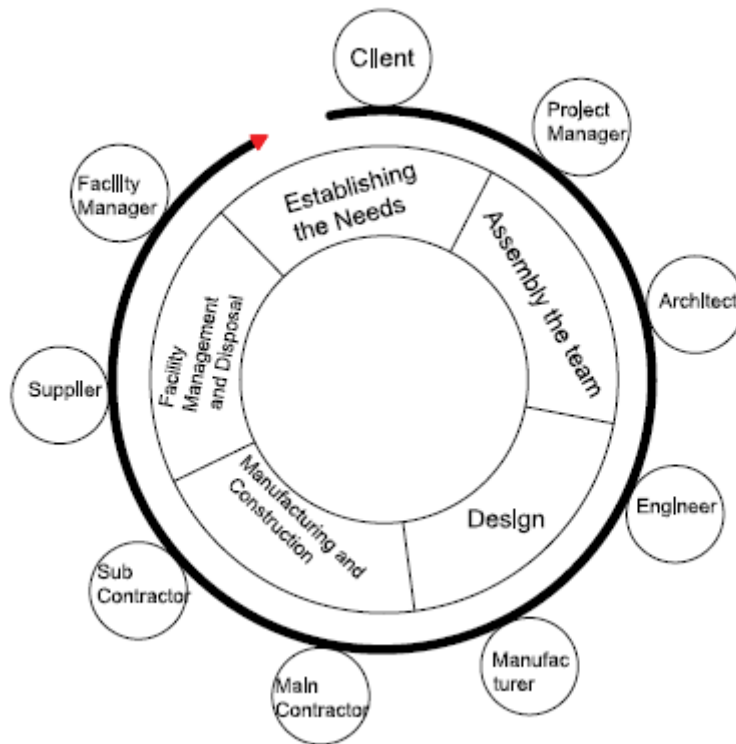


Figure 2.2.2.1: Stakeholder information sharing through BIM

In conclusion, adopting Building Information Modeling in Construction or Building projects offers advantages for all stakeholders as it defines the project scope, mitigates unrealistic scheduling and budgeting, reduces the risk, and enhances communication and coordination among project stakeholders (Akintoye et al., 2012).

2.3.1 BIM Globally

Building Information Modeling (BIM) is a renowned and fast-growing field globally, particularly in countries where governmental policies activated BIM development. A clear example of this is the UK, lately decided that all public sector construction agenda to be BIM level 2 (Hore et al., 2017). As a result, BIM has spread far beyond government projects into the rest of the construction industry. There are some familiar lessons

learned about the use of BIM that may be useful to our situation from the experiences of the United Kingdom.

According to (Hore et al., 2017), the private sector in the United States has played a crucial role in the adoption of BIM, with industry organizations such as the American Institute of Architects (AIA) promoting its implementation through established rules and best practices.

According to the survey (Edirisinghe et al., 2015), it is revealed that 75% of BIM contractors can recognize BIM as a tool for the collection of accurate and high-voluminous data. BIM has demonstrated impressive improvements in HVAC manufacturing efficiency, time, and money through case study projects like the City of Dreams Casino Macau. Substantial differences hinder the widespread adoption of BIM in national standardization and policy initiatives from country to country. BIM policies are not limited to a limited range. However, countries like Singapore, the UK, the US, and Finland are moving ahead with BIM policy laws by setting examples and paving the way for others to follow. The AEC sector rapidly adopts IT for better stakeholder cooperation, communication, and coordination. According to (Hore et al., 2017), The AEC industry is developing Building Information Modeling (BIM) as a major transformation in project life cycle (PLC) policies, procedures, and technology.

A survey conducted by (Edirisinghe et al., 2015) indicates that 50% of the 27 nations examined either had a regulatory mandate for BIM or intended to establish one in the future. This trend highlights the growing global significance of BIM within the construction sector.

Out of these assessed nations, over 50% of the nations have pursued ahead and formalized a manual/guide encouraging indigenous/local employment of BIM. The use of BIM for buildings has risen in North America to a moderate degree, with contractors very slightly outpacing architects. (Edirisinghe et al., 2015) Australia and New Zealand surveyed BIM utilizers in 2016 to find that over three-quarters (74%) of firms planned to implement the process on over thirty percent of their work going forward. At the same time, BIM technology is gaining greater acceptance in China, where officials predict that the number of architects using BIM will double within a few years. The UK government began requiring BIM to be used on all new public sector construction projects in April 2016. Across the EU, however, officials are starting to focus on understanding how BIM is being adopted throughout the different countries of the union (Hore et al., 2017). So, BIM has become influential, and it has led to the formation of a new engineering discipline: digital modeling and delivery. Major infrastructure projects have adopted BIM as a key method for project delivery (Edirisinghe et al., 2015).

2.3.2 BIM in the Middle East

Even with the numerous benefits of Building Information Modeling (BIM), such as improved project coordination, reduced errors, and enhanced collaboration, most Middle Eastern governments still need to fully embrace its deployment in their projects (Almutiri et al., 2020). However, the exclusive regulations for enforcing BIM, instituted by the Dubai Municipality in 2013, have set a commendable precedent. Dubai's leadership in this area is evident in numerous examples of BIM use in

projects around the Middle East, as depicted in Figure 2.2.2. The data also reveals that Bahrain secured the fifth position with 19%, trailing behind Qatar and Oman (Almutiri et al., 2020).

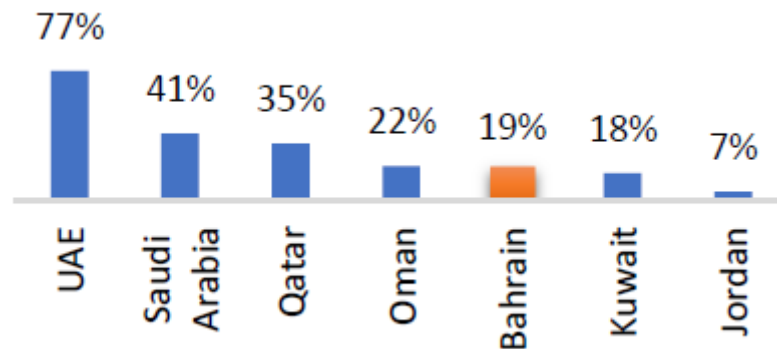


Figure 2.3.2.1: BIM in the Middle East (Almutiri et al., 2020)

In the Gulf Cooperation Council (GCC) region, BIM is still in the early stages of adoption. However, it is gaining momentum through its application in giga projects aligned with national development visions. For example:

- Saudi Arabia has mandated using BIM specifications instead of traditional AutoCAD drawings as of January 2024. BIM is now integrated into Saudi and Emirati building codes (Saudi Building Code National Committee, 2024).
- Projects such as NEOM, King Salman International Airport (set to be the largest airport in the world), and other Vision 2030 initiatives are leading the way in BIM implementation (Saudi Building Code National Committee, 2024).

- The UAE has also embraced BIM in landmark projects such as the Museum of the Future in Dubai and the Louvre Museum in Abu Dhabi (Dubai Municipality, 2022).

2.3.3 BIM in Bahrain

The building sector in Bahrain possesses significant potential, but it is encountering many constraints. Only a single study was identified about the exploration of building information modeling adoption within the Bahraini construction sector. (Ahmed et al., 2020) The study's findings indicated a substantial awareness of BIM among industry experts in Bahrain. Of the responses from 272 participants, 72% reported familiarity with BIM; however, only 39% actively utilized it. The disparity between BIM expertise and its implementation highlights a challenge for the building sector in Bahrain. As a result, the BIM Practice versus Expertise level of the construction sector in Bahrain is not agreed upon.

Bahrain predominantly employs building information modeling (BIM) to visualize and produce drawings. While these are essential functions, they represent only a small part of what BIM can do. Many professionals stick with 2D drawings when producing collaborative content and 3D models for the project design and production despite their being inefficient and time-consuming. This reliance on more traditional forms of content generation in projection space versus model space points to hesitation (or perhaps a lack of ability) to use BIM in ways that would "integrate." The BIM maturity level in Bahrain is classified as Stage 1, which means it is in a very early stage of development. The BIM processes currently in place mainly use essential modeling functions but do not have the type of

modeling necessary to call it truly collaborative. The BIM tools used are not integrative and do not have the functioning for which industry stakeholders hope when they adopt BIM. This BIM adoption in Stage 1 of maturity certainly does not have the potential to reach significant improvements in project outcomes that more advanced uses of BIM could offer. The study's results underscore a clear and urgent need for development in the industry. Despite some advancement in awareness and software availability, the actual on-the-ground implementation of BIM lags well behind what is acceptable for an industry that desperately needs to maximize its efficiency.

Although the adoption of BIM in Bahrain has been relatively slow, the country has made significant progress. Vision 2030 projects such as the Bahrain International Airport Modernization, the New Salman City housing initiative, and King Abdullah Medical City have introduced BIM. Initially used as a conceptual design tool, BIM is now being adapted as a core planning and management instrument, particularly valuable in fast-track projects that demand precision in cost, quality, and schedule (Prime Minister's Office, 2023).

In conclusion, while the knowledge of BIM in Bahrain is on the right track, BIM implementation remains limited. The urgent necessity for concerted efforts to bridge the gap between BIM knowledge and its practical implementation in the construction industry is underscored by this scarcity. It is time for us to act and make a difference.

2.4 Construction Project Management Challenges

Construction projects face numerous challenges, such as poor planning, insufficient project scope definition, unrealistic scheduling and budgets, and lack of communication and collaboration among stakeholders. These factors may significantly affect the project's outcomes and success. Insufficient planning can create uncertainty about project objectives, timelines, and resource allocation, resulting in delays and budget overruns. Enhanced identification of project scope is necessary to prevent scope creep, which arises when project requirements are beyond the initial plan, leading to delays and budget overruns. Unrealistic scheduling and budgeting may set unattainable expectations, leading to project delays and financial strain (Memon et al., 2011; Akhund et al., 2018; Gadisa & Zhou, 2019).

2.4.1 Poor Planning

Regarding building projects, schedule overruns have become a significant obstacle for both the contractors and the stakeholders involved in the project. The lack of adequate planning has been repeatedly identified as a critical factor contributing to these delays (Memon et al., 2011; Akhund et al., 2018; Gadisa & Zhou, 2019). This must be emphasized as a critical factor in the development and transformation of construction projects from traditional methods, which rely more on the experience of project managers or planners, to a more advanced technology that accurately assists in the comprehension of projects and the establishment of an integrated plan among project stakeholders.

2.4.1.1 Key Factors Contributing to Time Overruns through Insufficient Planning:

- Cash Flow and Financial Challenges: Inadequate fund allocation and ineffective strategic financial management often result in a cascading effect that disrupts the overall project timeline (Memon et al., 2011).
- Inadequate Site Management: According to (Akhund et al., 2018), ineffective on-site coordination and supervision are significant contributors to project delays, resulting in work backlogs and postponed project milestones.
- Lack of Contractor Experience: According to Memon et al. (2011), a lack of experience can exacerbate planning and execution flaws and cause delays in project completion. Inexperienced contractors may make expensive errors that take a lot of time and work to correct.
- Inadequate Project Scheduling: (Akhund et al., 2018) assert that the inability to develop or adhere to a feasible project timetable heightens the likelihood of experiencing delays. Time overruns can lead to increased financial costs due to prolonged resource consumption.
- Design Modifications: As stated by (Memon et al., 2011), frequent alterations to the initial design can significantly affect the punctual completion of a project, as such modifications often necessitate revisions and may result in resource shortages.
- Poor labor productivity: Insufficient labor planning and management adversely affect the project completion rate, often leading to diminished productivity that prolongs the project's duration (Gadisa et al., 2019).

- **Resource Shortages:** Inadequate planning may result in insufficient resources at critical times (Memon et al., 2011). The lack of critical supplies, equipment, or personnel may hinder the project's progress.
- **Neglecting Schedule Updates:** The lack of regular project program revisions exacerbates existing delays, fails to address unexpected obstacles, and increases the probability of not meeting contractual deadlines, hence potentially resulting in legal disputes (Gadisa et al., 2019).
- **Rework the work as a result of Errors:** Inadequate planning frequently results in errors that call for corrective actions; hence, the timeline for the project will be extended (Akhund et al., 2018).

The identified issues are due to insufficient planning. BIM (Building Information Modeling) is a crucial tool that improves construction planning through 3D visualization modeling, clash detection, quantity take-off, and simulation of construction processes. BIM enhances design quality and work efficiencies, which are essential for timely project completion and overall success.

2.4.2 Inadequate Project Scope Determination

Inadequate identification of project scope is a common issue in construction projects, resulting in complications such as budget overruns, extended timelines, and disputes. (Bin Seddeeq et al. ,2019) Identify client modifications to design and scope during the construction phase as a primary factor contributing to inadequate project scope assessment. This occurrence may result from the evolving nature of project requirements, shifting client preferences, or unforeseen events. Ambiguity in project

parameters and frequent modifications hinder effective strategizing and implementation, resulting in elevated costs and time delays.

Inadequate project scope determination is attributed to poor project planning and scheduling (Bin Seddeeq et al., 2019). Increased preparation can result in more defined project objectives, deliverables, and timelines. Scope creep arises when the project's scope expands beyond the original agreement, resulting in misunderstandings and inefficiencies.

Inadequate determination of project scope may result from design flaws (Bin Seddeeq et al., 2019); insufficient assessment and verification of the design can create discrepancies between the intended scope and actual requirements. Design defects necessitate additional work, result in delays, and incur increased costs to address the problems.

Inadequate determination of project scope often results from insufficient understanding of the work involved during the tendering phase, as noted by (Bin Seddeeq et al., 2019). Contractors may lack a clear grasp of project requirements and scope during the bidding process, leading to inaccurate cost estimates and impractical project plans. A lack of understanding may lead to gaps in the project's scope and misinterpretations, thereby hindering the execution phase.

The underestimation of costs and schedules and the overestimation of benefits are additional factors contributing to inadequate project scope assessment. The project team's insufficient assessment of required resources, time, and costs may result in unrealistic expectations and an inadequate definition of the project's scope. These factors may lead to

delays in project completion, budget overruns, and a reduction in overall project quality (Bin Seddeeq et al., 2019).

2.4.3 Unrealistic Scheduling in Construction Projects:

Unrealistic scheduling in building projects may stem from multiple sources. Insufficient project planning and scope delineation are commonly recognized causes leading to the emergence of this issue. (Kerzner et al., 2017) assert that a vital component of project management is the focus on thorough project planning and accurate scope definition, as these elements are critical for precisely calculating the duration required for each task. Unrealistic scheduling may be affected by external circumstances, such as client requests or contractual obligations (Turner, 2014). Clients may establish stringent deadlines without regard for the project's complexity or resource availability. The adoption of unfeasible schedules may result in adverse consequences for construction projects. A notable consequence is the heightened possibility of delays. When project timetables are considered unachievable, they have challenges in efficiently assigning resources and completing tasks within the time constraints. According to the (Project Management Institute, 2017) states that project delays can lead to several adverse effects, such as budget overruns, strained stakeholder relationships, and reputational harm to the project team. Moreover, it is crucial to recognize that impractical scheduling might adversely affect job quality. This occurs as employees may be compelled to hasten their tasks to fulfill imposed deadlines, which might subsequently increase the likelihood of errors.

2.4.4 Unrealistic Budgeting in Construction Projects:

Various factors can lead to a demand for more reliability in budgeting for construction endeavors. (Kerzner et al., 2017) asserts that project managers may underestimate costs associated with personnel, materials, equipment, and unforeseen circumstances.

2.4.5 Lack of Communication and Coordination between Stakeholders

Effective communication is crucial for successful construction projects, as it helps coordinate and reduce delays. Inadequate communication can lead to misalignment, conflict, and insufficient planning, which can hinder collaboration. Insufficient resource allocation, unclear roles, and inadequate monitoring can also contribute to delays. The absence of a formal communication system can exacerbate the issue. Delays in decision-making, inadequate communication, and conflicts can result in higher project expenditures, lower productivity, and reputational damage to stakeholders (Klaus et al., 2021).

We can summarize the Lack of communication and coordination between stakeholders led to the following (Bubshait et al., 2015):

- Scope creep: the phenomenon where a project's scope experiences frequent alterations without enough documentation or approvals, resulting in heightened costs and delays.
- The rising costs might be ascribed to miscommunication or insufficient coordination, leading to redundant efforts, resource depletion, and expensive rework.

- Delays in fulfilling deadlines can be ascribed to inefficient communication, which hinders the decision-making process and subsequently disrupts the workflow, resulting in an extension of the project's duration.
- The absence of clear and direct communication among stakeholders may lead to misinterpretation of project requirements, resulting in substandard work or failure to achieve established standards.
- Insufficient coordination may result in the unavailability of personnel, equipment, and resources when required, hence causing suboptimal utilization or waste.
- Missed Opportunities: A project devoid of adequate coordination may inadequately leverage the innovative ideas or solutions stakeholders propose.
- Decision-making delays may arise from insufficiently specified communication channels and standards, hindering the decision-making process and extending the project duration.

Effective communication and coordination are essential for the successful completion of construction projects. Collaborative software, frequent meetings, clear documentation, and delineated roles and duties can alleviate communication difficulties. Effective stakeholder management, characterized by open and transparent communication, facilitates the smooth advancement of a project while fostering trust and collaborative problem-solving (Bubshait et al., 2015).

2.5 BIM Definition and Concept

Unfortunately, there is indeed a lack of a universally accepted definition of Building Information Modeling (BIM). Figure 2.4.1 shows the simple definition of BIM as a term, and Figure 2.4.2 shows the information obtained. BIM has been characterized by various specialists in different ways, depending on their area of expertise or their specific objectives. Multiple perspectives and interpretations exist regarding the concept of BIM (Azhar, 2012), with different stakeholders emphasizing different aspects of this technology (Olatunji et al., 2021).

According to Kocakaya's research conducted in 2019, BIM enables the linking, storage, and reuse of information regarding the attributes and properties of a particular building component within a computer-generated three-dimensional model, which is unprecedented in the history of construction. This increases off-site and on-site collaboration and coordination to improve efficiency, effectiveness, and productivity. This model, which is frequently called a "digital twin," contains almost all the necessary data attributes for construction and planning. Furthermore, it can be utilized for operation and maintenance with the appropriate data structure (Kocakaya et al., 2019).

As previously stated (Bubshait et al., 2015), "BIM, as a term, refers to both a building information model and a collaborative methodology utilized by various project stakeholders."

As per Smith's research conducted in 2014, Building Information Modeling (BIM) is a significant improvement over the traditional method of project

participants working on separate information that often uses incompatible software technologies. BIM provides a fully integrated platform that allows individuals to collaborate and share identical information.

BIM is both a process and a technology. The technology aspect of Building Information Modeling (BIM) allows project stakeholders to visualize the planned structure in a simulated environment. This enables the detection of any possible design, construction, or operating problems (Azhar, 2012).

In the mid-2000s, the architectural engineering construction sector started to use Building Information Modeling (BIM) effectively in projects. BIM relies on the cooperation of multiple parties involved in different stages of a building's lifespan to input, extract, update, or alter information in the BIM system to align with and represent each party's responsibilities (Azhar, 2012).

Moreover, BIM was specifically designed to address the challenges of collaboration, managing large volumes of information, minimizing project expenses and time, and enhancing construction efficiency. Its ability to efficiently handle large volumes of information is a testament to its robust capabilities (Hjelmbrekke et al., 2014; Azhar et al., 2015; Barki et al., 2015).

Building Information Modeling (BIM) is not just an innovative process and technology but a transformative force that has rapidly revolutionized the conceptualization, design, construction, and operation of buildings. Its potential to reshape the construction industry is truly inspiring and offers a hopeful vision for the future of the field (Azhar, 2014).

The National Building Information Modeling Standards (NBIMS) committee of the United States of America defines BIM as a digital representation of a facility's functional and physical characteristics. BIM is a repository of shared knowledge for facility-related data that provides a dependable foundation for decision-making throughout the facility's life cycle (Sacks et al., 2018).

Building Information Modeling (BIM) can be defined in two key ways. Firstly, it can be described as a collection of technologies, processes, software, and policies that interact. Secondly, it can be seen as an interconnected integration of many technologies, procedures, applications, and policies that work together (Forbes et al., 2020). BIM is a virtual procedure that encompasses all aspects, disciplines, and systems of a facility in a single model. This model is shared with all stakeholders throughout the project's lifespan, making it both a process and a technology (Takim, 2013).

The American Institute of Architects (AIA) defines Building Information Modeling (BIM) as "a technology that uses a model-based approach connected to a database of project information." (Forbes et al., 2020).

According to (Autodesk, 2024)., the leading software supplier for Building Information Modeling (BIM), BIM is a sophisticated process that utilizes intelligent 3D models to enhance the planning, design, construction, and management of buildings and infrastructure. It provides architecture, engineering, and construction (AEC) professionals with valuable insights and tools to improve efficiency.

According to the Associated General Contractors of America (AGC), Building Information Modeling (BIM) consists of creating and utilizing a computer software model that simulates a facility's operational and construction phases (Sacks et al., 2018).

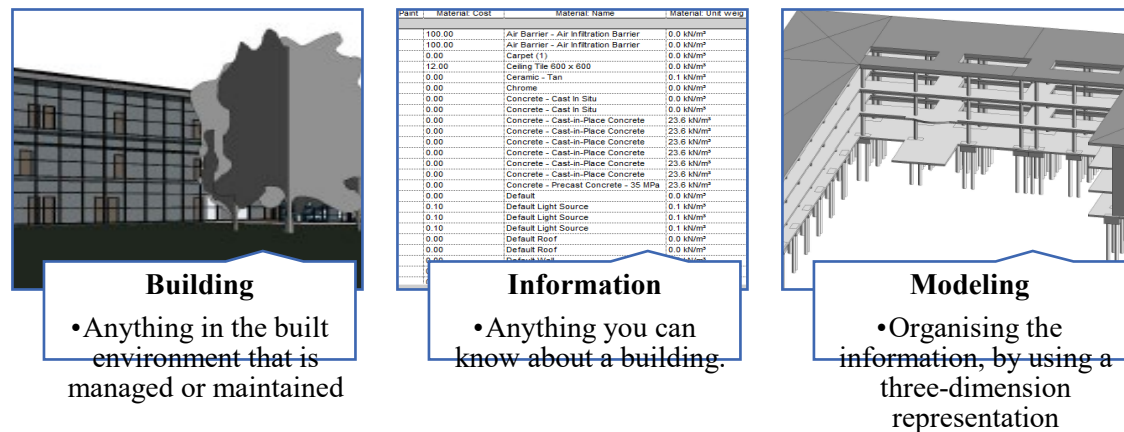


Figure 2.4.5.1: BIM Definition

2.5.1 BIM as Technology:

BIM technology is a project simulation that includes 3D representations of project components linked to all critical information pertinent to planning, design, construction, or operation, as seen in (Figure 2.4.2). Technology underpins Building Information Modeling (BIM) operations, elucidating the complete lifespan of the project. BIM processes, spanning conceptual design to construction, operations, and maintenance, are directed by a range of digital tools and software intended to facilitate the generation, management, and utilization of building information models (Matarneh et al., 2017). It deviates from traditional 3D CAD, representing a structure using separate 3D perspectives, potentially resulting in inaccuracies and inadequate documentation. BIM models establish the characteristics of objects based on building elements and systems, enabling the inclusion of

intelligent contextual semantics. For example, the BIM model encompasses air conditioning units, suppliers, operation procedures, flow rates, and clearance requirements. However, some digital models do not fit into the BIM classifications, including those that solely contain 3D data, lack support for behavioral aspects, or incorporate multiple 2D CAD reference files (Azhar et al., 2012).

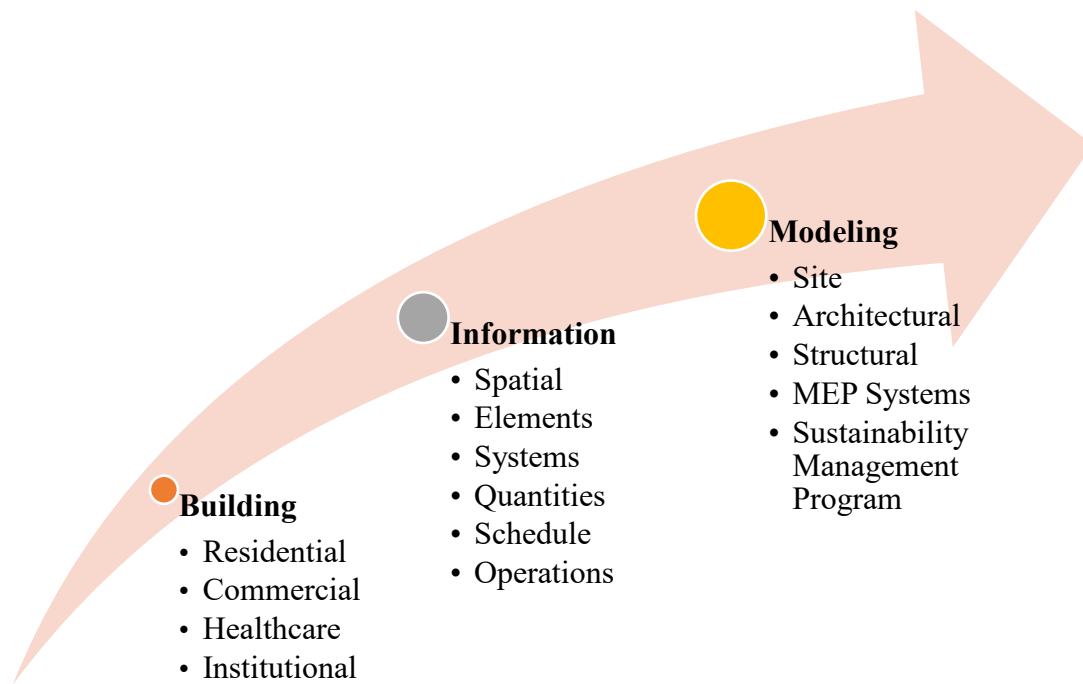


Figure 2.5.1.1: BIM Information

Essential Components of BIM as a Technological System:

- **3D Modeling:** BIM technology generates intricate and precise three-dimensional (simulation) representations of buildings (Figure 2.4.3)

and infrastructure. These models are comprehensive data repositories, encompassing detailed information regarding the building's components, materials, dimensions, and performance qualities rather than solely visual representations (Lee et al.,2023). The simulations, supported by the accuracy of BIM, enable architects, engineers, and builders to refine the design and guarantee that the project's performance will meet expectations upon completion (Zhang et al., 2017).



Figure 2.5.1.2: 3D model

- **Data Integration:** A fundamental attribute of BIM technology is its holistic nature, enabling the amalgamation of diverse data into a singular model. This encompasses architectural design data, structural and MEP (Mechanical, Electrical, and Plumbing) engineering data, along with data pertaining to costs, timelines, and building operations. Its capacity to manage various kinds of data instills assurance in its efficacy and security (Lee et al., 2023).
- **Cooperation and synchronization:** BIM technology enhances collaborative workflows by allowing multiple stakeholders to work together on the same model, often in real-time, due to its efficiency.

The ability to cooperate is crucial for efficiently managing complex projects and reducing errors and the necessity for extra work (Zhang et al., 2017).

- **Clash detection:** It is an essential aspect of BIM technology that identifies conflicts among different building systems (Figure 2.4.4), including structural components and HVAC systems, at the first phases of the design process. This reduces the likelihood of expensive modifications during the construction phase (Matarneh et al., 2017).

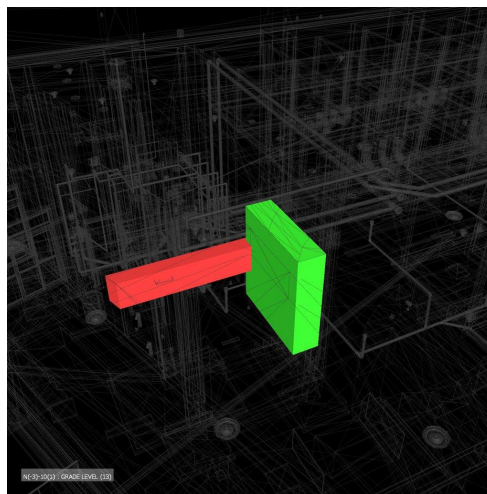


Figure 2.5.1.3: Clash beams are not connected

- **Lifecycle Management:** Building Information Modeling (BIM) is crucial for building lifecycle management, covering conceptual, design, construction, and post-completion stages. It organizes vast amounts of data into a comprehensible format, aiding facility management and providing a historical record of the structure (Wong et al., 2015).
- **Cloud-based:** BIM technology has evolved to offer cloud-based collaboration, enabling stakeholders to effortlessly access and interact on models from any place. This promotes collaboration on international

efforts and offers significant adaptability in project management, affording stakeholders greater freedom in their tasks (Lee et al., 2023; Matarneh et al., 2017).

2.5.2 BIM as Process:

Building Information Modeling (BIM) involves the collaborative and coordinated use of digital technologies to create and manage building information throughout the entire lifespan of a project. BIM encompasses creating and managing digital representations of a facility's physical and operational attributes. This process facilitates the exchange of information among project stakeholders. It involves all project disciplines, such as project planning, design, preconstruction, construction, and post-construction (operations and maintenance) stages, from the start to the end of the useful life of any project (Figure 2.4.5).



Figure 2.5.2.1: Project Lifecycle

Throughout the creation of the model, the project team members will continuously enhance and modify their respective parts by project specifications and design modifications, aiming to maximize the model's accuracy before the commencement of the physical construction phase. The early involvement of all project stakeholders is crucial for successfully implementing BIM, so the traditional project delivery systems, such as design-bid-build, have a significantly restricted role and are limited

compared to the Integrated project delivery "IPD" system generated using BIM as Traditional projects frequently need help with efficient dissemination and exchange of information. In contrast, BIM-based projects offer more flexibility and overlapping interactions. BIM facilitates collaboration among design teams by utilizing a dynamic version of the building model, enabling a more accurate evaluation of modifications in real-time (Al Hattab et al., 2013).

2.5.3 BIM and Traditional Project Management: Achieving the Iron Triangle of Time, Cost, and Quality

Building Information Modeling (BIM) and traditional project management aims to manage the iron triangle of time, cost, and quality, but they approach this goal at different levels. Project management provides the strategic and procedural framework to plan and control these constraints (Project Management Institute, 2017). In contrast, BIM acts as a technological enabler within this framework. It facilitates and supports project management objectives by providing advanced visualization, simulation, and data integration tools through different BIM dimensions. These tools not only improve forecasting accuracy but also significantly reduce clashes and rework by identifying design and construction conflicts early in the process. This emphasis on error reduction and delay minimization instills confidence in the reliability of BIM, fostering collaboration and communication among all project participants. Therefore, BIM enhances project management by markedly improving the efficiency and efficacy of monitoring and regulating time, cost, and quality.

This yields enhanced resource allocation and decision-making, ultimately increasing project management efficiency (Azhar et al.,2012).

2.5.4 BIM Dimensions – 3D, 4D, 5D, 6D, 7D, and 8D

Building Information Modeling (BIM) encompasses more than just 3D modeling; it offers tangible advantages that enhance project management and results (Charef et al., 2018). It includes multiple dimensions: 4D for time, 5D for cost, 6D for operation, 7D for sustainability, and 8D for safety. The multifaceted characteristics of BIM facilitate the amalgamation of different variables, instilling assurance and trust in project planning and implementation.

- **The third dimension (3D):** As stated above, 3D technology is employed to visualize and simulate BIM models. It enables the crew to see the building's specifics within its physical surroundings, encompassing both graphical and non-graphical data (Charef et al., 2018; Zhraan et al., 2024).
- **The fourth dimension (4D)** is a scheduling instrument that utilizes temporal data to enable teams to monitor their projects and graphically assess the most critical components of such projects. BIM improves this methodology by enabling the amalgamation of project schedules with previously segregated design and construction processes (Charef et al., 2018; Zhraan et al., 2024).
- **The fifth dimension (5D)** pertains to the financial component of BIM technology. In the design process, this technique ascertains the quantities and costs of materials. It provides precise cost data and

generates a take-off of the required materials (Charef et al., 2018; Zhran et al., 2024).

- **The sixth dimension (6D)** is essential for the operation and maintenance of the building. This concept enables efficient and precise modifications to the fundamental structure during construction and throughout the building's life cycle. It results in considerable long-term savings and guarantees the building's sustainability (Sbiti et al., 2021).
- **The seventh dimension (7D):** In facility management, it is essential to determine equipment locations within and outside a building. It is utilized to oversee items over their complete operational lifecycle. The 7D framework facilitates the extraction and storage of data assets, encompassing the object's state, technical specifications, maintenance schedule, technical reviews, manuals, and relevant warranty period. Implementing this methodology for facility management enhances the overall process and elevates the quality of services rendered (Sbiti et al., 2021).
- **The eighth dimension (8D),** Building Information Modeling (BIM), integrates the identification of safety threats and the management of crises. It enhances safety during both the construction and operational phases by identifying potential dangers, simulating emergencies, and formulating effective plans to address them. This facet of Building Information Modeling (BIM) facilitates proactive risk management, ensures compliance with regulations, and, crucially, improves communication among stakeholders. This improved communication promotes teamwork and enhances safety and preparation for emergencies in building projects. Although BIM 8D has benefits, its

implementation can be complex and costly, requiring specific knowledge and data management proficiency (Hire et al., 2024).

2.6 Building Information Modeling (BIM) Benefits

The construction sector has recently undergone significant changes due to rapid technological advancements, with Building Information Modeling (BIM) standing out as one of the most transformative innovations. Implementing BIM across various stages of a project's lifecycle, from the initial pre-construction phase to the post-construction phase, has provided numerous benefits. These benefits include enhanced project quality, efficiency, and collaboration, offering solutions to many traditional challenges in the construction industry and a hopeful outlook for the future.

A. Pre-Construction Phase (Initiation stage): In the pre-construction phase, BIM offers significant benefits, especially in project planning and visualization (Memon et al., 2011). The implementation of BIM facilitates the creation of intricate and precise 3D models, providing an exhaustive perspective of the project prior to the commencement of physical construction. As stated by Kerzner et al. (2017), this competence improves planning processes by allowing stakeholders to anticipate possible problems and conflicts, resulting in enhanced decision-making and risk management. Furthermore, BIM's capacity to visualize the complete project facilitates the alignment of expectations among all stakeholders, guaranteeing that the project is conceived in a practical and feasible manner.

- BIM is very beneficial when applied to the construction industry (Memon et al., 2011; Kerzner et al., 2017).

B. Design Phase: BIM is essential for improving project quality control and predictability in the design phase. According to (Azhar et al.,2012), BIM's capacity to consolidate diverse design components into a unified model enhances collaboration among architects, engineers, and other stakeholders. This integration is revolutionary, facilitating the early identification and resolution of potential design conflicts, therefore enhancing the predictability of project results. Moreover, BIM's automated computation of the Bill of Quantities (BOQ) guarantees enhanced precision in cost estimation, hence diminishing the probability of budget overruns (Al Hattab et al., 2013). Moreover, BIM significantly decreases project length by enhancing the scheduling process. (Wong et al.,2015) examine how BIM's distinctive capacity to simulate construction sequences and visualize project timelines facilitates more effective planning and execution. This enhanced efficiency not only reduces project duration but also improves task completion speed, visualization, and overall project structure. BIM enhances collaboration and communication, hence reducing the risks of delays and cost overruns, resulting in more predictable and successful project outputs' that can enhance project quality control, improve predictability, and increase accuracy (Azhar et al., 2012).

- Reducing the project duration improves turnover, visualization, efficiency, and scheduling (Wong et al.,2015).
- BIM quantifies the Bill of Quantity preparation automatically, which increases the level of accuracy (Azhar et al., 2012).

C. Design and Construction Phase: As projects progress from the design to the building phase, the value of BIM becomes apparent in markedly

enhancing productivity and operational efficiency. Sacks et al. (2018) emphasize that BIM enables the efficient transmission of design information to the construction phase, maintaining alignment with the original design purpose. This integration yields significant time and cost efficiencies by mitigating possible concerns prior to their effect on the construction process. A primary advantage of BIM in this phase is its capacity to manage and alleviate design modifications (Kocakaya et al., 2019). Smith's 2014 research elucidates that BIM's dynamic environment facilitates real-time evaluation of design alterations, hence diminishing the time and expenses linked to these modifications and permitting rapid adjustments.

- BIM can significantly boost productivity and work efficiency in the construction industry, resulting in significant time and cost savings (Sacks et al., 2018).
- BIM assists in managing time and cost associated with design changes and enhances the resolution of design clashes (Smith, 2014).

D. Construction Phase: In the construction phase, the advantages of BIM are particularly evident, especially in reducing delays and waste and improving project understanding. (Alreshidi et al., 2016) examine how Building Information Modeling (BIM) enhances material delivery planning and coordination, assuring the prompt availability of materials and minimizing the risk of delays. Furthermore, BIM reduces material waste by offering precise quantity assessments and enabling just-in-time supply. As stated by (Bin Seddeeq et al., 2019), Building Information Modeling (BIM) improves comprehension of active projects by offering current and comprehensive information that is

readily accessible to all stakeholders. (Bubshait et al., 2015) This degree of transparency enhances communication and collaboration among all stakeholders, guaranteeing that all parties strive towards common objectives. Moreover, BIM facilitates coordinated communication, ensuring that all stakeholders are apprised of project advancements, thereby mitigating the potential for misunderstandings and disputes.

- BIM can reduce delays in construction materials delivery and waste (Alreshidi et al., 2016).
- BIM makes it easier to understand the ongoing project (Bubshait et al., 2015).
- BIM can improve multi-party communication and maintain synchronized communication (Alreshidi et al., 2016).

E. Construction & Post-Construction Phase: BIM illustrates its worth as the project advances toward completion by enabling budget control, monitoring, and management (Akhund et al., 2018). (Durdyev et al., 2022) Examined how BIM facilitates real-time monitoring of expenses and advancement, assisting project managers in adhering to budgets and preventing cost overruns, which is essential for the achievement of extensive and intricate initiatives. BIM is essential for tracking building progress and guaranteeing compliance with the predetermined schedule (Akhund et al., 2018). The technology facilitates the identification of potential delays and permits prompt remedial measures by offering a thorough and precise picture of the project's state. Furthermore, (Fadeyi et al., 2017) emphasize that Building Information Modeling (BIM) markedly enhances safety conditions at

building sites through improved planning and coordination of safety protocols. BIM can monitor, track, and control project budgets (Durdyev et al., 2022).

- BIM can monitor and track progress during construction and avoid slippage (Durdyev et al., 2022).
- BIM can significantly improve safety conditions at construction sites (Fadeyi, 2017).

F. Design, Pre-Construction, Construction, and Post-Construction

Phase: BIM promotes a collaborative culture among all project stakeholders throughout the whole project lifecycle. (Sacks et al., 2018) demonstrate that BIM serves as a platform that enhances communication and cooperation, fostering teamwork and common objectives. This collaborative environment results in more successful project outcomes since a more unified project team improves decision-making processes. Furthermore, BIM enhances project documentation by providing a consolidated and readily available store of project information. It is imperative that all stakeholders have access to current and precise information to uphold consistency and accuracy throughout the project.

- BIM fosters a culture of collaboration among project stakeholders, enhancing teamwork and shared goals throughout the project lifecycle (Sacks et al., 2018).
- BIM improves project documentation (Sacks et al., 2018).

2.7 Building Information Modeling (BIM) Barriers

- A. **Personal barriers:** often stem from individuals' resistance to change and a lack of knowledge or skills. For example, individuals who resist changing their current process may believe that learning BIM software is difficult, lack BIM training, lack seniors or BIM experts within the company, have poor awareness of the benefits of BIM, or lack knowledge about BIM, which is the strongest barrier, as it makes a lot of sense that as long as the practitioners are not aware of something, they will not adopt it (Durdyev et al., 2022; Elhendawi et al., 2018).
- B. **Organizational barriers:** High introductory expenses associated with software, computer hardware, training, and human resources are a substantial barrier to the adoption of Information Modeling (BIM) by smaller organizations with limited budgets. The problem is compounded by the long training times required for current staff and the inadequate support and resources provided by top management. Without the right resources—training programs and technical support—organizations will find it difficult to adopt BIM. Moreover, in the absence of a supportive environment, the employees who are attempting to implement the new systems and processes will face additional challenges (Durdyev et al., 2022; Elhendawi et al., 2018).
- C. **Process barriers:** According to (Durdyev et al., 2022; Elhendawi et al., 2018), the disruption of existing workflows and the need for standardization can complicate the implementation of BIM across different projects and stakeholders.
- The application of BIM will affect the current process practice.

- The construction market is not ready for BIM technology.
- Resistance to change the current construction industry culture.
- Lack of data sharing (collaboration with other professionals).

This resistance to change in the construction industry culture is prevalent, with poor data sharing making collaboration with other professionals even more difficult. These processes associated with BIM can create a lot of friction between the team members and stakeholders involved in a construction project, making it difficult, if not impossible, for them to arrive at a cohesive plan for management and execution (Durdyev et al., 2022; Elhendawi et al., 2018).

D. External Barriers: Most small enterprises, typically with small staff members, reported a need for more client demand for BIM (Building Information Modeling). For these reasons, they saw no necessity in investing in BIM. Also, there is insufficient support and participation from the government, as no legislation forces stockholders to use BIM, there are no proper training institutes for BIM, and there is no financial support for implementing BIM. These barriers can leave small businesses feeling pretty unsupported in their efforts to adopt up-to-date technology like BIM (Durdyev et al., 2022; Elhendawi et al., 2018).

E. Additional barriers:

- **Small Organizations and Project Scale:** There are two main reasons why small organizations are not using Building Information Modeling (BIM). The first is their belief that the nature of their projects does not require BIM and that they can get by without it. The second reason is

the perception that BIM is only useful for large-scale, complex projects and that using it on small, uncomplicated projects would yield no dividends. In fact, "small" and "simple" are relative terms. A certain degree of complexity underlies even the simplest projects, and BIM is powerful enough to handle projects of any scale and any level of complexity (Elhendawi et al., 2018).

- **Legal matters:** present a considerable barrier to the application of Building Information Modeling (BIM), and these primarily arise from the deterioration of information and concern over liability (Azhar, 2012). Standardized legal documents are an absolute necessity if we want to enable the collaborative work of all AEC industry teams (Elhendawi et al., 2018).

2.8 BIM Application Software

Building Information Modeling (BIM) software has revolutionized the architecture, engineering, and construction industries by providing a comprehensive platform for effective supervision of building design, construction, and operation. BIM software improves productivity, facilitates stakeholder communication, and encourages sustainable practices at every project stage (Latiffi et al., 2013). However, successful implementation requires overcoming obstacles such as compatibility, choosing the right tools, and integrating BIM with other technologies. New software is emerging daily, and existing BIM software is being improved daily. Without stopping many programs that appear daily, finding the right software that suits the type of work as a professional in the industry can be challenging. This challenge depends on several factors, not just the

program alone. Each program offers distinct services, training methodologies, learning curves, and associated expenses (Azhar et al., 2012). Consequently, it is essential to select an appropriate application for the organization that offers services at a competitive price and is user-friendly to simplify training.

Numerous BIM technologies have been developed to improve the BIM process. These listed technologies are renowned for their robust features and intuitive interface, having been effectively adopted by engineering and architectural departments worldwide:

BIM tools are essential for various industries, including architectural design, structural engineering, and MEP engineering. AutoCAD, Revit, Bentley, Tekla, Navisworks, ArchiCAD, and BIM 360 are all powerful software tools that help in producing precise 2D and 3D drawings and complex models. AutoCAD is user-friendly ((AutoCAD, Autodesk, 2024), 2024) and interoperable with other software, while Revit Architecture aids in architectural design, structural engineering, and MEP engineering (Revit, Autodesk, 2024), 2024). Bentley software supports complex and large-scale projects with advanced modeling capabilities (Bonsu et al., 2021), while Tekla Structures excels in structural design for buildings and bridges (Tekla, 2024). Navisworks is a key component of the BIM ecosystem (Tsay et al., 2024; Azhar, 2012; Navisworks 3D Viewer, Autodesk. 2024)., offering a user-friendly interface for project-model viewing, thorough project evaluation, and conflict identification. ArchiCAD is a user-friendly BIM software solution that facilitates efficient design work, enables alterations and updates, and generates customized

objects and components (Elmualim et al., 2014). BIM 360 is an internet-based platform that enables genuine project administration, with BIM 360 Docs serving as the primary connection for project documentation (BIM 360 Autodesk, 2023; Daniel, 2023). These tools are essential in the construction industry, where even the slightest mistake can result in expensive conflicts and delays.

2.9 Bridging the Literature with Field Evidence

This literature review identifies and synthesizes the benefits and barriers of Building Information Modeling (BIM) as reported in both global and regional academic sources (Chapter 2). However, it does not accurately reflect the current realities or perceptions of Bahrain's construction sector. The data collection phase (Chapter 4) enhances this understanding by:

- Empirically validating the extent to which the benefits and barriers identified in the literature are experienced in Bahrain.
- Measuring the level of agreement or disagreement regarding each factor across different types of organizations (government, contractors, consultants).
- Allowing local professionals to rank the most significant benefits and barriers based on their authentic responses.
- Conducting hypothesis testing using statistical methods to validate or invalidate established relationships, such as the correlation between education level and the likelihood of adopting BIM.

While the literature review provides general knowledge, the data collection illustrates specific events occurring in Bahrain, thus bridging the gap between theory and practice.

Chapter 3: Research Methodology

3.1 Introduction

This chapter will examine the research framework, aims, objectives, methodology, and hypotheses that serve as the foundation for this study. Furthermore, this paper will include a comprehensive description of the study design, data collection methodologies, and population sampling algorithms to delineate the thorough and rigorous trajectory this research takes to accomplish its objectives, instilling confidence in the study's findings.

3.2 Research Framework

The research framework of this study aims to investigate various factors influencing the adoption of Building Information Modeling (BIM) in Bahrain's construction sector. The study will follow these steps, as illustrated in Figure 3.2.1:

1. Define the research problem, aim, and objectives based on a thorough review of the most recent literature.
2. Conduct a comprehensive literature review of previous and recent studies to gather data on key BIM-related factors.
3. Design a questionnaire that includes information on BIM factors and general details about the Participants.
4. Distribute the questionnaire in a pilot study to validate its design and ensure it covers all relevant aspects of BIM knowledge.
5. Distribute the validated questionnaire to contractors and consultants in both private and government sectors within Bahrain's public

construction industry, particularly in building construction, to collect and rank significant factors and gather additional data.

6. Employ a quantitative methodology to analyze the collected data using statistical software (e.g., SPSS).
7. Discuss the results, generalize the findings, and provide valuable conclusions and recommendations based on the analysis.

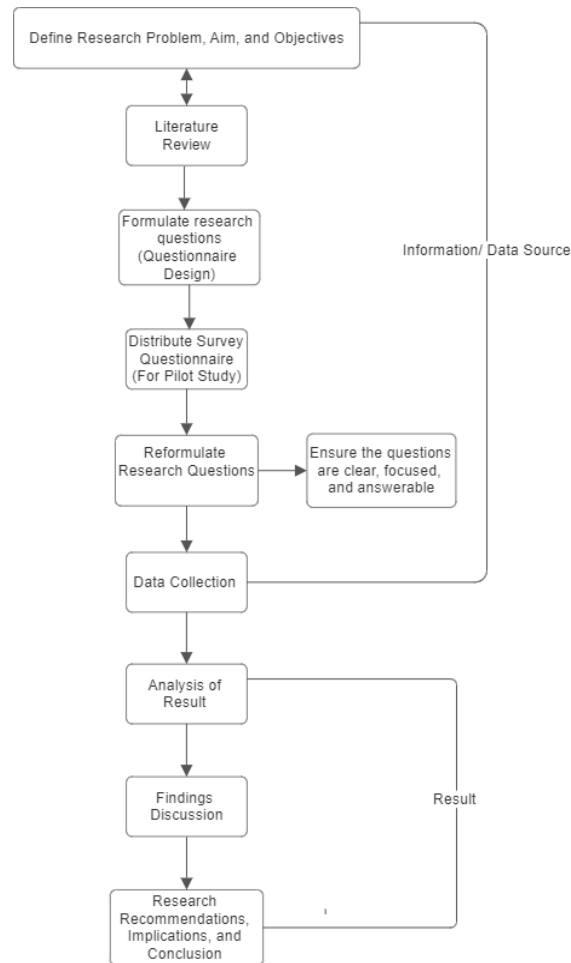


Figure 2.5.4.1: Research Framework

3.3 Research Methodology

Methodology is the systematic approach to address the study problem (Verma et al., 2024). It encompasses the researcher's systematic approach to investigating the research problem and its underlying rationale. Our research for this dissertation used both exploratory and descriptive research methodologies.

3.4 Research Design Approach: Quantitative approach

A quantitative methodology is adopted in this study to collect numerical data on BIM awareness, usage, benefits, and barriers among construction professionals in Bahrain. This approach enables objective measurement across a broad sample and supports statistical analysis through descriptive and inferential methods. It helps identify trends and relationships that inform evidence-based improvements in BIM adoption practices (Al-Khalili, 2012).

3.5 Research Hypotheses

3.5.1 Level of Awareness of Building Information Modeling.

HB1. Null Hypothesis (H0): The construction industry in Bahrain indicates a low level of awareness and usage of Building Information Modeling (BIM), as most organizations lack knowledge about BIM.

3.5.2 Building Information Modeling Software/Tool Usage Level.

HB2. Null Hypothesis (H0): There is no significant difference in the software usage listed in Bahrain (AutoCAD, Revit, Bentley, ArchiCAD, BIM 360, etc.).

3.5.3 Purpose of BIM Usage:

HB3. Null Hypothesis (H0): In Bahrain's construction industry, basic BIM functions like 2D Drawings, 3D Modeling/Presentation, Construction/As-Built Drawings, and Site Logistics are more frequently used than advanced BIM functions.

3.5.4 Benefit Factors of BIM Adoption

The following benefit factors were tested as hypotheses to assess the extent to which BIM is beneficial (Table 3.5.1)

HB4. BIM Benefits

Table 3.5.1: Benefit Factors of BIM Adoption Hypothesis

<i>Benefits Factor of BIM Adoption</i>	<i>Null Hypothesis (H0):</i>
<i>HB4A. BIM is very beneficial when applied to the construction industry.</i>	BIM does not provide any significant benefits when applied to the construction industry.
<i>HB4B. BIM can promote early and accurate decision-making and reduce disputes between the parties involved.</i>	BIM does not promote early and accurate decision-making or reduce disputes between the parties involved.
<i>HB4C. BIM can enhance project quality control, improve predictability, and increase predictability.</i>	BIM does not improve project quality control or predictability.
<i>HB4D. Reducing the project duration improves turnover, visualization, efficiency, and scheduling.</i>	Reducing the project duration does not improve turnover, visualization, efficiency, or scheduling.

Benefits Factor of BIM Adoption

HB4E. BIM quantifies the Bill of quantity preparation automatically, which increases the level of accuracy.

HB4F. BIM can significantly boost productivity and work efficiency in the construction industry, resulting in significant time cost savings.

HB4G. BIM is a tool that assists the time and cost of design changes and eliminates and enhances design and resolution clashes.

HB4H. BIM can reduce delays in construction materials delivery, waste

HB4I. BIM makes it easier to understand the ongoing project.

HB4J. BIM can improve multi-party communication and maintain synchronized communication.

HB4K. BIM can monitor, track, and control project budgets.

HB4L. BIM can monitor and track progress during construction and avoid slippage

HB4M. BIM can significantly improve safety conditions at construction sites.

HB4N. BIM fosters a culture of collaboration among project stakeholders, enhancing teamwork and shared goals throughout the project life cycle.

HB4O. BIM improves project documentation.

Null Hypothesis (H0):

BIM does not improve the accuracy of Bill of Quantity preparation.

BIM does not significantly boost productivity or work efficiency, nor does it result in significant time and cost savings

BIM does not assist in managing the time and cost of design changes or resolving clashes.

BIM does not reduce delays in construction materials delivery or waste.

BIM does not make it easier to understand the ongoing project.

BIM does not improve multi-party communication or maintain synchronized communication.

BIM does not effectively monitor, track, or control project budgets.

BIM does not effectively monitor or track progress during construction, nor does it help avoid slippage.

BIM does not significantly improve safety conditions at construction sites.

BIM does not foster a culture of collaboration among project stakeholders or enhance teamwork.

BIM does not improve project documentation.

3.5.5 Challenges of BIM adoption and implementation

HB5. BIM Barriers Factors

The following barrier factors were tested as hypotheses to assess the challenges BIM faces at different levels: personal, organizational, process, and external (see Table 3.5.2)

Table 3.5.2: Barriers Factors of BIM Adoption Hypothesis

<i>Barriers Factors of BIM Adoption</i>	<i>Null Hypothesis (H0):</i>
<i>HB5A. BIM's software is complicated to learn.</i>	BIM's software is complicated to learn.
<i>HB5B. Lack of training on BIM.</i>	Sufficient training on BIM is available.
<i>HB5C. Lack of BIM experts within the firm.</i>	Firms do not experience a lack of BIM experts.
<i>HB5D. Poor awareness of BIM benefits</i>	There is adequate awareness of BIM benefits in the construction industry.
<i>HB5E. Lack of knowledge about BIM.</i>	Construction industry professionals have sufficient knowledge about BIM.
<i>HB5F. BIM's software is expensive and requires a high initial cost.</i>	BIM's software is not expensive and does not require a high initial cost.
<i>HB5G. Long-term training is required for current staff.</i>	Long-term training is not required for current staff to use BIM.
<i>HB5H. High cost of training current staff.</i>	The cost of training current staff on BIM is not high.
<i>HB5I. Insufficient support from top managers.</i>	There is sufficient support from top managers for BIM implementation.
<i>HB5J. The application of BIM will affect the current process practice.</i>	The application of BIM will not affect the current process practice.
<i>HB5K. The construction market is not ready for BIM technology.</i>	The construction market is ready for BIM technology.
<i>HB5L. Resistance to change the current construction industry culture.</i>	There is no resistance to change in the current construction industry culture.
<i>HB5M. Lack of data sharing (collaboration with other professionals).</i>	There is sufficient data sharing and collaboration with other professionals in the construction industry.
<i>HB5N. Insufficient support and participation from the government.</i>	There is sufficient support and participation from the government in the adoption of BIM.
<i>HB5O. Lack of demand by owners.</i>	There is sufficient demand for BIM by project owners.

3.5.6 Measures to Overcome BIM Adoption Challenges:

HB6. Null Hypothesis (H0): Increasing government support, improving access to BIM software, integrating BIM into academic programs, and Participation in relevant professional organizations will significantly enhance the adoption of BIM in Bahrain's construction industry.

3.5.7 General Question (Willing to Adopt BIM)

HB7. Higher Education Levels Are Associated with a Greater Willingness to Change

- **Null hypothesis (H0):** There is no significant difference in willingness to change between respondents with higher and lower education levels. Population Size and Sample Determination

3.5.8 Sources of Data and Population

The representative population targeted in this research were Engineers, architects, engineering managers, or any others who (were) playing the roles of contractor, consultant, or government in the contracting process from the public, semi-public, and private sectors building construction projects in the Kingdom of Bahrain.

The population included engineers registered with the Council for Regulating the Practice of Engineering Professions (CRPEP) in the Kingdom of Bahrain. This group comprises 2,390 engineers from engineering offices, 2,515 from contractors and other sectors, and 1,985 from government roles, for a total of 6,890 registered engineers (CRPEP, 2023). The following table (Table 3.5.3) illustrates the engineers by discipline.

Table 3.5.3: Licensed Engineers by Discipline (CRPEP, 2023).

Discipline	No. of Licenses Engineers	Ratio
Civil Engineers	2330	34 %
Architects	1060	15 %
Chemical Engineers	240	3 %
Electrical Engineers	1067	15 %
Mechanical	1062	15 %
Land Surveyors	76	1 %
Landscape Architects	6	0 %
Project Managers	78	1 %
Quantity Surveyors	132	2 %
Interior Designers	115	2 %
Computer Engineers	48	1 %
Electronics Engineers	210	3 %
Petroleum Engineers and National Gas	33	0 %
Process & Instrumentation	76	1 %
Urban Planners	72	1 %
Other	285	4 %
Total	6890	100%

Number of Licensed Engineers by Discipline

3.5.9 Target Population

This research refined the target population by excluding specializations that did not deal with construction or construction management or related to our target population. As a result, the total population consisted of 6,096 engineers, as shown in the following (Figure 3.6.3.1). Additionally, BIM specialists and facility engineers were included in the survey despite not having a specific category in the CRPEP (CRPEP, 2023) or SIJILAT records from the Ministry of Industry and Commerce (MOIC, 2024). To ensure that the survey responses accurately reflected the perspectives of expert professionals in the built environment, we included screening questions at the beginning of the questionnaire. Participants were asked to provide information about their current involvement in construction-related initiatives, years of experience, and job titles. Responses from individuals who were not familiar with Building Information Modeling (BIM) were excluded during the data cleansing process. Furthermore, we calculated the percentage of each discipline to maintain homogeneity in the

responses, considering the required sample size, as shown in Figure 3.5.1. This refining process preserved the integrity of the data, allowing the analysis to be based on the expertise of stakeholders actively engaged in the construction sector.

3.5.10 Sample Size Determination

The sample size was used to get a sufficiently representative portion of the population, enabling researchers to extrapolate their results to the larger population. A sample refers to a selected group of individuals from the larger population of interest. However, the literature on sample size is inconsistent; it generally indicates a minimum sample size of 100 people for survey studies (Al-Khalili, 2012). The objective of sampling is to provide a sample that precisely mirrors the attributes of the population from which it was selected. To accurately analyze the study's results, verifying that the sample accurately reflects the whole population is crucial. Multiple formulae exist to determine the suitable sample size. The present work employed the methodology introduced by Cochran's formula (1963) (Nanjundeswaraswamy et al., 2021) to determine the sample size for a referenced population.

$$n = \frac{z^2 p x (1 - p)}{E^2}$$

Equation 3.5.10-1: Cochran's formula

Adjust for finite population.

$$n_{adjusted} = \frac{n}{1 + (\frac{n - 1}{N})}$$

Equation 3.5.10-2: finite population

Where:

- n = sample size
- Z = Z-score for the chosen confidence level
- p = estimated proportion (0.5 is often used if unknown variability)
- E = margin of error (usually 0.05 for $\pm 5\%$)
- N = population size
- Population Size (N): The total number of individuals in the target group is 6,096 engineers.
- Confidence Level (Z-score): The level of certainty that the true population parameter lies within the sample estimate's range. Confidence level is 95%.
95% confidence level $\rightarrow Z = 1.96$.
- Margin of Error (E): The acceptable amount of error in the sample estimate, usually expressed as a percentage (e.g., $\pm 5\%$).
- Standard Deviation (p): The variability in the population is often estimated at 0.5 (which provides the maximum variability and, hence, the most conservative estimate for sample size).

1. Using the general formula for sample size:

$$n = \frac{1.96^2 \times 0.5 \times (1 - 0.5)}{0.05^2} = 384.16$$

Equation 3.5.10-3: Using Cochran's formula

2. Adjust for the finite population size (6,096):

$$n_{adjusted} = \frac{384.16}{1 + \left(\frac{384.16 - 1}{6096}\right)} = 361.44 \approx 362$$

Equation 3.5.10-4: finite population size (6,096)

So, the adjusted sample size would be approximately 362 Participants (Nanjundeswaraswamy et al., 2021).

This confirms the Sample Size Determination. Using the Krejcie and Morgan Table (Bukhari et al., 2021; Al-Khalili, 2012), the sample size for a population of 6000 is 361 sample sizes.

3.5.10.1 Sample Size Covered by the Research

$$\text{Sample size covered by the research} = \frac{\text{Target Sample size}}{\text{expected response rate}}$$

$$\text{Sample size covered by the research} = \frac{361}{60\%} = 601.6 \cong 602$$

Equation 3.5.10-5: Sample size covered by the research

So, in this research, we need to contact approximately 602 people to achieve a sample size of 361 responses, assuming a 60% response rate.

(Figure 3.5.1) Refer to represent how many engineers the researcher should target from each discipline to achieve the desired sample size for the study.

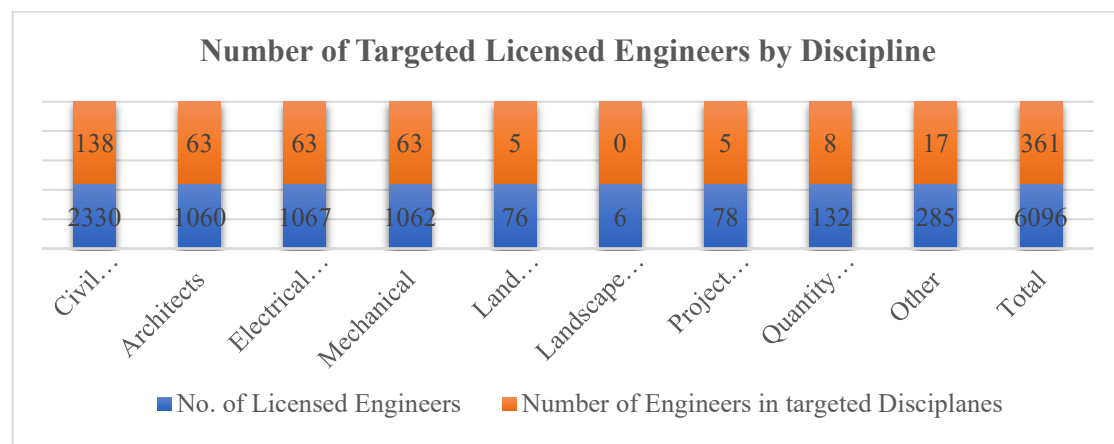


Figure 3.5.1: Number of Targeted Licensed Engineers by Discipline

3.6 Data Collection Method

The primary technique used for collecting data in this study was a structured questionnaire (survey) designed to gather quantitative information on BIM awareness, usage, benefits, and barriers. In addition, interviews were conducted solely to validate the clarity and relevance of the questionnaire items, ensuring that respondents interpreted the questions correctly and provided reliable answers. While the study remains firmly quantitative in nature, the limited use of interviews served as a supporting tool for instrument validation rather than a qualitative data source. This combined approach enhanced the overall data reliability and ensured a comprehensive understanding of BIM adoption in Bahrain's construction industry.

3.6.1 Interview Method

This approach relies on presenting oral or verbal data obtained through face-to-face or telephone interviews, in which an interviewer asks questions and acquires responses from the other person being questioned. This approach is appropriate for subjective objectives and when thorough inquiry is necessary (Al-Khalili, 2012).

3.6.2 Questionnaire Method (Survey)

The questionnaire or survey approach is widely utilized by researchers when there is a requirement to collect a substantial number of Participants within a restricted period (Al-Khalili, 2012). The questionnaire approach provides the following advantages:

- Cost-effective even when the number of targeted responses is substantial.
- The survey can be readily disseminated across many geographical locations.
- The participants are provided with sufficient time to provide their responses.

A structured questionnaire was distributed to a wider sample of construction professionals to gather quantitative data on their awareness, usage, and perception of BIM. The survey, which consisted of Likert-scale questions to enable statistical analysis, was distributed to engineering construction companies in Bahrain through direct personal contact, email, and internet (online) interfaces.

3.6.3 Questionnaire Development

The questionnaire items were developed based on the literature review in Chapter 2, particularly the identified BIM benefits and barriers. The studies helped shape the survey's structure, ensuring alignment with internationally recognized BIM adoption factors while tailoring the questions to reflect Bahrain's construction sector context. Also, the questionnaire was distributed using three methods: face-to-face to construction companies, via email, and through online forms. A total of 800 questionnaires were distributed, and the expected sample size covered by the research is 602 to reach the target sample size of 361. The number of responses to the questionnaire was 247, as shown in the following Table

(Table 3.6.1), illustrating the total responses versus different distribution methods.

Table 3.6.1 Distribution Breakdown of Questionnaire:

<i>Distribution Method</i>	<i>Total Responses</i>	<i>Consultant/Engineering Offices</i>	<i>Contractor & Other</i>	<i>Government</i>	<i>Response rate</i>
<i>Face to Face & by Call</i>	32	15	13	4	12.95%
<i>Online (Form) & by E-mail</i>	215	95	69	51	87.04%
<i>Total</i>	247	110	82	55	100%

$$\text{Response Rate} = \frac{247}{361} \times 100 = 68.42\%$$

Equation 3.6.3-1: Response Rate

68.42% response rate is very positive and indicates good data collection for the study (Dillman et al., 2014).

3.6.3.1 Questionnaire Structure: Interview Questions Development (Pilot Study Purpose)

As part of the pilot study phase, two types of interviews were conducted to support the development of the survey questionnaire. First, ten semi-structured interviews were conducted with BIM specialists from Bahrain, Egypt, Jordan, and Saudi Arabia. These professionals provided expert insights into the components of BIM, perceived benefits, implementation barriers, and factors influencing adoption. These interviews aimed to identify key thematic areas based on real-world industry practices and challenges. The feedback gathered was used to formulate survey questions

reflecting the academic literature and practical experiences within the construction sector.

Second, a preliminary version of the questionnaire was tested with a small group of non-specialized individuals, including engineers and project team members not directly involved in BIM. This step aimed to validate the survey items' clarity, readability, and structure. Based on their feedback, adjustments were made to question wording, sequence, and formatting to ensure that the final questionnaire would be easy to understand and accessible to a broad professional audience. Together, these two piloting phases strengthened the reliability and relevance of the questionnaire, ensuring it was both technically accurate.

3.6.4 Measures to Increase the Response Rate

In this study, several deliberate and systematic steps were implemented to improve the survey response rate (Sammur et al.,2021). Refer to (Figure 3.6.1):

- **Personalized Invitations:** Invitations were tailored to each company, addressing them by name and highlighting the critical role their responses play in the research. The importance of their input was emphasized and underscored, with an explanation of how their feedback could positively influence the construction sector. (Sammur et al.,2021).
- **Device Accessibility:** The questionnaire was prepared not just for user-friendliness but also with paramount concern for the comfort and ease of the participants. The questionnaire was readily accessible on all smart devices, having been initially built on Google Forms before

being transitioned to Microsoft Forms for more transparency and improved mobile accessibility. A direct link to the survey was provided to facilitate a convenient and smooth experience for participants (Sammur et al.,2021).

- **Strategic Reminders:** Multiple reminders were sent at different times over several weeks to encourage participation. On average, reminders were sent once per week. For example, in the first week, the invitation was sent on Sunday at 10 AM, followed by a simplified reminder the following Sunday at 4 PM. Subsequent reminders were sent towards the end of the week to maintain engagement (Sammur et al.,2021).
- **Confidentiality Assurance:** Confidentiality was assured for all responses, and participants received a letter from the university stating the survey would only be used for academic and scientific purposes. This measure was a formality and a reassurance that ensured participants felt secure and comfortable sharing their insights (Sammur et al.,2021).
- **Survey Customization:** The survey was tailored to match Participants' knowledge and experience. For example, the survey would end if participants indicated unfamiliarity with information modeling. If a respondent had knowledge but did not use it, additional questions appeared to assess future usage intentions. No further questions were presented about whether the respondent had knowledge and was already using the technology (Sammur et al.,2021).
- **Progress Updates:** Participants received information regarding the outstanding replies required to finalize the study, providing real-time

updates to foster a sense of advancement and promote ongoing involvement.

- **Extended Survey Duration:** The initial survey period, set at two months, was extended to 92 days to provide participants with additional time to respond, ensuring they had ample opportunity to complete the questionnaire.

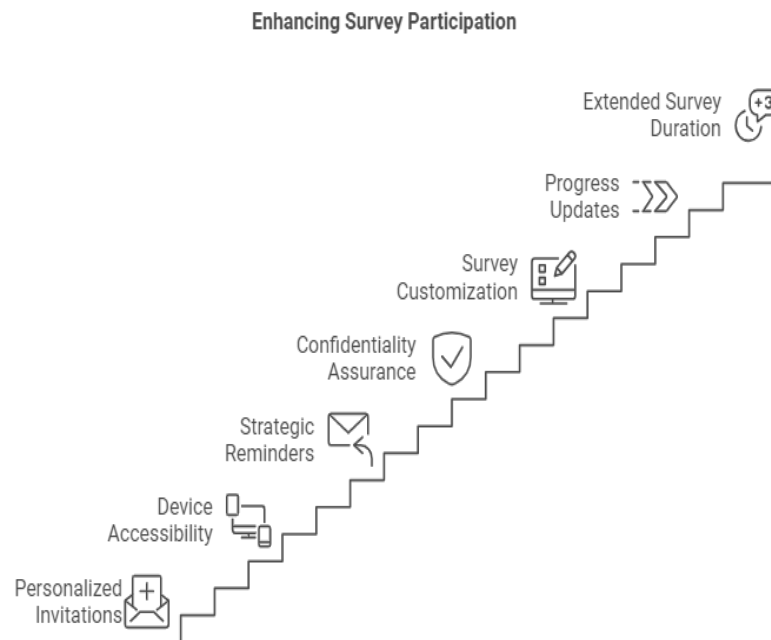


Figure 3.6.4.1: Measures to Increase the Response Rate

3.7 Questionnaire Structure

3.7.1 Demographical

This section's inquiries seek to gather demographic and background information regarding participants, encompassing their level of education, years of experience, and positions within the construction business in Bahrain. This also encompasses information regarding the value of the construction projects they have undertaken, offering context for their industry participation. These data were utilized to evaluate the impact of specific demographic characteristics on BIM awareness and utilization.

3.7.2 The Awareness of the BIM Process and Usage Level

This section aims to evaluate the construction sector's comprehension of building information modeling (BIM) procedures and technology and the clarity of BIM features. Furthermore, we want to find out how widespread the use of BIM functionalities is and how often different BIM software/tools are utilized.

3.7.2.1 BIM Implementation in Construction Projects

Participants were asked about their firm's use of BIM tools, such as AutoCAD, Revit, and Navisworks, and the extent to which they employ BIM for various functions, such as 3D modeling, 4D scheduling, and clash detection.

3.7.3 Benefits of BIM adoption and implementation

The objective of this section is to assess the benefits associated with adopting and implementing Building Information Modeling (BIM) in the

construction industry for those who are knowledgeable or engaged in implementing BIM within their organizations.

3.7.4 The Barriers to BIM Implementation

This section is an essential part of data collection as it requires the Participants to assess the Barriers and Factors of Building Information Modeling (BIM) and identify the primary obstacles hindering the adoption of BIM implementation, such as cost, lack of training, and resistance to change.

3.7.5 Measures to overcome BIM adoption and implementation challenges and assets the transformation needed (Adoption Factors).

This section is also an essential part of data collection as it requires the participants to assess the measures needed to overcome BIM adoption and implementation challenges and assets needed for the transformation.

3.7.6 General Question

The general question about technology adaptation in the construction industry applies only to organizations that do not use BIM processes or technology. This section is specifically designed to assess the respondent's opinion regarding their organization's willingness to transition from traditional/manual approaches to BIM, given the opportunity and support.

3.8 Data Analysis Method and Tools

The data collected from the questionnaires and interviews were analyzed using statistical software such as SPSS and Microsoft Excel. Descriptive statistics summarized the demographic data and responses, while inferential statistics were used to test the research hypotheses.

3.9 Statistical Methods

3.9.1 Shapiro-Wilk Normality Test

The analytical choice of statistics is made based on the data. If the data were up-normal, nonparametric methods were employed to analyze. If the data were normal, then the data would follow a normal distribution (normality-based) procedure to conduct our analyses. Thus, determining the data's normality is a fundamental step in data analysis. Several statistical tests were used to assess the data's normality. The Shapiro-Wilk test has frequently assessed data normality. The Shapiro-Wilk test compares the null hypothesis that the data are normally distributed to the alternative hypothesis that the data are not (Aslam et al., 2020). Data were normally distributed when the value of Sig > 0.05.

3.9.2 Reliability Test

Reliability refers to the consistency of a measure; if another researcher were to apply the same methods or approaches to collect data under identical circumstances at a different time (Al-Khalili, 2012), the results should be similar. Ensuring reliability is crucial to guarantee that the findings are not random. Several methods to assess reliability include test-

retest reliability, internal consistency (Cronbach's coefficient alpha), split-half reliability, and parallel form reliability.

In this study, Cronbach's coefficient alpha was used to determine the reliability of the data. This method is widely regarded as a reliable measure of internal consistency, ensuring that the items in the survey or instrument consistently measure the intended construct.

Cronbach's coefficient alpha Range:

Cronbach's alpha values range from 0 to 1.

A higher value indicates greater internal consistency. Generally:

- $\alpha \geq 0.9$: Excellent reliability.
- $0.8 \leq \alpha < 0.9$: Good reliability.
- $0.7 \leq \alpha < 0.8$: Acceptable reliability.
- $0.6 \leq \alpha < 0.7$: Questionable reliability.
- $\alpha < 0.6$: Poor reliability.

3.9.2.1 Internal Consistency Technique

In this study, the Internal consistency technique was incorporated into the survey to ensure the reliability and consistency of the participants' responses. This was done by repeating specific questions in different contexts. Such techniques are commonly used in surveys to measure the consistency of responses, which helps assess the reliability of the collected data (Kennedy et al.,2022).

For example, in the BIM Benefit Table:

"BIM can monitor, track, and control project budgets."

"BIM is capable of overseeing, tracking, and managing project budgets."

By repeating questions with slightly varied wording, the researcher aimed to identify inconsistencies in responses, which could indicate a lack of attention or reliability in the answers. This approach is instrumental in surveys focused on attitudes and perceptions, such as those related to adopting BIM (Building Information Modeling), where accurate data is crucial for understanding participant views.

3.9.3 Validity Test

To ensure the validity of the research, the questionnaire underwent a pilot test to identify and refine any ambiguous questions and confirm the knowledge covered. In addition, the researcher employed a comprehensive approach by using multiple data collection methods, including questionnaires and interviews. This triangulation of findings will enhance the overall validity and robustness of the results, giving the audience confidence in the thoroughness of the research (Al-Khalili, 2012).

3.9.4 Chi-Square Goodness-Of-Fit Test

Pearson's key contribution to modern statistics is the creation of the Chi-square distribution and test, often known as the goodness-of-fit test and the test of independence. The significance of Pearson's Chi-square model is that it allows researchers to analyze results using statistical methods that do not rely on a normal distribution (Rana et al., 2015).

The Chi-square test is a non-parametric method used to evaluate the hypothesis that there is no relationship between two or more categories,

groups, or criteria (i.e., to test the independence of two variables) (Rana et al., 2015). The hypotheses are:

- Null Hypothesis (H0): The first and second variables are independent.
- Alternative Hypothesis (H1): The first and second variables are related.

3.9.5 Conclusion

This chapter presents a comprehensive overview of the research design, encompassing the research framework, methodology, hypotheses, data collecting techniques, and statistical data methods employed to investigate the implementation of BIM in Bahrain, focusing on the benefits, barriers, and measures to overcome the barriers, by adopting a quantitative methodology to comprehensively investigate the implementation of Building Information Modeling (BIM) in the construction industry of Bahrain (Al-Khalili, 2012). The quantitative component involves using structured surveys and rigorous statistical analyses, including hypothesis testing, to assess the levels of BIM awareness, usage, perceived benefits, barriers, and measures to overcome the barriers. This study adopts a quantitative methodology, using structured surveys and statistical analyses, including hypothesis testing, to evaluate BIM awareness, usage, perceived benefits, and challenges. Professional feedback was also gathered during the pilot study to refine the questionnaire. The subsequent chapters present the outcomes of the quantitative analysis and discuss the findings in light of the reviewed literature.

Chapter 4: Data Collection Results, Analysis, and Result Discussion

4.1 Introduction

This chapter analyses and discusses the questionnaire findings, including the reliability test, the Internal consistency technique, the normality test, descriptive statistics, and hypothesis testing.

4.2 Reliability Test (Cronbach's coefficient Alpha)

As stated in the methodology chapter, several methods are available for assessing the dependability of data. However, the coefficient of reliability (Cronbach's Alpha) was used in this study. The consistency of the acquired data was quantified using the reliability coefficient, also known as Cronbach's Alpha. (Creswell, 2009) recommended that data be considered reliable at an acceptable level of 0.80.

Table 4.2.1: Coefficient of Reliability

<i>Reliability statistics</i>	<i>Total Value</i>
<i>Cronbach's Alpha</i>	0.913

The data presented in Table 4.2.1 were analyzed using the statistical software package SPSS. The analysis revealed a Cronbach's alpha reliability coefficient of 0.913, indicating that the survey questions are highly consistent and dependable.

4.2.1 Internal Consistency Technique

As outlined in the methodology chapter, the Internal consistency technique is a key method for enhancing data reliability. It's important to note that this test is not about catching Participants in lies but rather about ensuring the data we collect is as reliable as possible.

Participants may not always provide accurate responses due to potential misunderstandings or lack of attention. To address this, the researcher has developed an Excel formula to identify and remove such responses, thereby enhancing the reliability of the data under certain conditions:

1. If the responses are the same, the formula returns "consistent." For example, if the respondent answered "Agree" for both questions, their answers are aligned, which is expected and logical.
2. Neutral paired with Agree/Disagree: If one response is "neutral" and the other is either "agree" or "disagree," this is still considered "consistent" because it's logical that a neutral position can align with moderate agreement or disagreement.

Flagging Inconsistencies:

1. If the responses do not follow the expected pattern, such as: One response is "neutral," while the other is "strongly agree" or "strongly disagree." considered "inconsistent,"
2. If the two responses are different (for example, "Agree" and "Disagree"). considered "inconsistent,"

According to the conditions above, 14 responses were excluded from the survey data, and the new reliable adjusted sample size would be 233 Participants.

Excel Formula for Internal consistency technique as shown in the equation 4.2.1-1

Equation 4.2.1-1: Excel Formula for Lying test

```
=IF(OR(AJ2="", AS2=""), "EMPTY",
    IF(OR(AND(AJ2="Neutral", OR(AS2="Agree", AS2="Disagree")),
        AND(AS2="Neutral", OR(AJ2="Agree", AJ2="Disagree"))), "Consistent",
        IF(OR(AJ2<>AS2,
            AND(AJ2="Neutral", OR(AS2="Strongly Agree", AS2="Strongly Disagree")),
            AND(AS2="Neutral", OR(AJ2="Strongly Agree", AJ2="Strongly Disagree"))),
            "Inconsistent",
```

4.3 Normality Test

The normality of the distribution was assessed using the Shapiro-Wilk test, and the results indicate that the data do not follow a normal distribution. The test results consistently show a P-value that is significantly below 0.05. Upon recognizing the non-normal distribution of the measured data, the researcher used non-parametric approaches to examine them, ensuring the validity of the analysis.

4.4 Descriptive Statistics

Statistical analysis, summary, and presentation of data set results were performed using descriptive statistics. As previously stated, the questionnaire included six main sections. The purpose of each section was to gather necessary data for the research analysis and to address all research goals and objectives. The question data were presented in graphical and tabular formats to facilitate understanding and evaluation of the comments that follow the results of each question.

4.4.1 Section A: Demographic Questions

A total of six questions (A to F) were created to gather demographic and proficiency data from the participants and to provide insight into their historical backgrounds. The results, along with a discussion on each question, are presented on the following pages.

4.4.1.1 A: Education Level

Questionnaire: Question 1: What is your Education Level?

The findings (Table 4.4.1) revealed that individuals with a bachelor's degree had the highest participation rate at around 55.4 percent. Those with a master's degree participated at 27.9 percent, while 10.7 percent had a diploma. The lowest education level among the participants was six percent, who held a PhD degree (Figure 4.4.1), which depicts the participants' educational achievement in the survey.

Table 4.4.1: Education Level of Participants

<i>Education Level</i>	<i>Total Number (n)</i>	<i>Percentage (%)</i>
<i>Diploma</i>	25	10.7
<i>Bachelor's degree</i>	129	55.4
<i>Master's degree</i>	65	27.9
<i>PhD degree</i>	14	6.0
<i>Total</i>	233	100.0

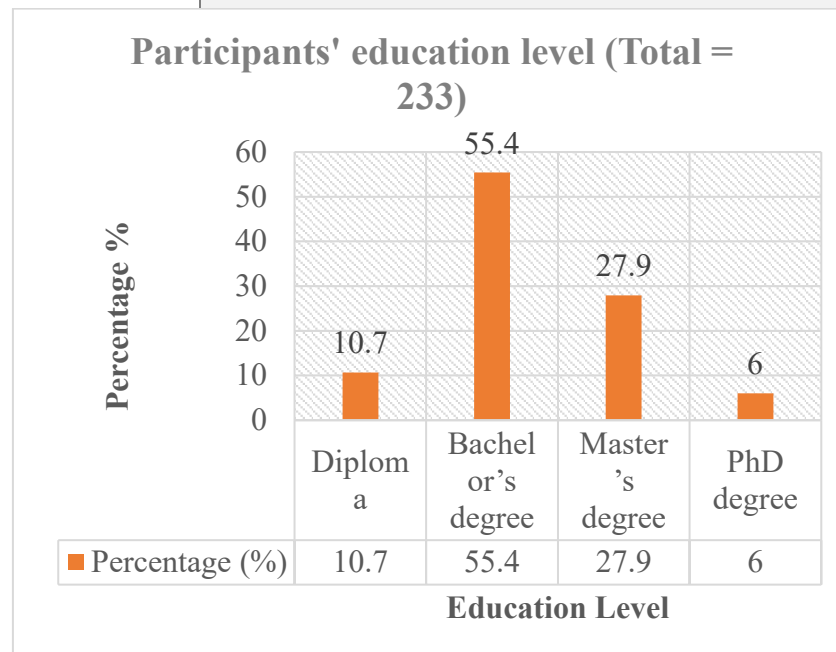


Figure 4.4.1.1: Participant's Education Level

4.4.1.2 B: Type of Business

Questionnaire: Question 2: *What type of business are you engaged in for your current job?*

The results show (Table 4.4.2) that consultant/engineering offices had the highest level of participation, with 101 Participants accounting for 43.3 percent. Contractors & others followed with 77 Participants, representing

33 percent. The government had the lowest participation, with only 55 Participants, equaling 23.6 percent see (Figure 4.4.2).

Table 4.4.2: Business Types of Participants.

<i>Type of Business</i>	<i>Total Number (n)</i>	<i>Percentage (%)</i>
<i>Engineering Offices</i>	101	43.3
<i>Contractor & Other</i>	77	33.0
<i>Government</i>	55	23.6
<i>Total</i>	233	100.0

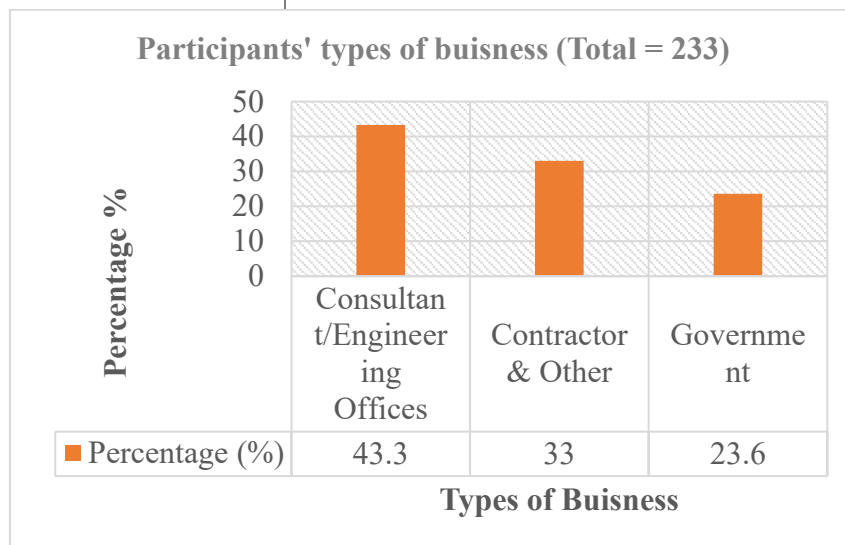


Figure 4.4.1.2: Business Types of Participants:

4.4.1.3 C: Duty Position

Questionnaire: Question 3: *What is your role within your organization?*

Survey participants were queried about their employment roles. The data shown in (Table 4.4.3) indicates that civil engineers constitute the overwhelming majority of participants, with 100 replies accounting for 42.9%. Although the participation of project managers is relatively low compared to civil engineers, with 45 Participants (19.3%), architects

occupy the third place with 40 Participants (17.2%). According to (Figure 4.4.3), there are 15 BIM specialists (6.4%) and five facility engineers (2.1%) remaining in Bahrain, whereas 28 electrical and mechanical engineers (12.07%) are part of the remaining workforce.

Table 4.4.3: Duty Position of Participants

<i>Duty Position</i>	<i>Total Number (n)</i>	<i>Percentage (%)</i>
<i>Civil Engineer</i>	100	42.9
<i>Architect</i>	40	17.2
<i>Project Managers</i>	45	19.3
<i>Surveyor Engineer</i>	8	3.4
<i>Electrical Engineer</i>	13	5.6
<i>Mechanical Engineer</i>	7	3.0
<i>Facility Engineer</i>	5	2.1
<i>BIM Specialist</i>	15	6.4
<i>Total</i>	233	100.0

4.4.1.4 D: Total Years of Experience

Questionnaire: Question 4: How many years of experience do you have?

Table 4.4.4: Experience Years of Participants

<i>Years of Experience</i>	<i>Total Number (n)</i>	<i>Percentage (%)</i>
<i>Less than five years</i>	56	24.0
<i>6-10 years</i>	64	27.5
<i>11-15 years</i>	53	22.7
<i>16-20 years</i>	29	12.4
<i>More than 20 years</i>	31	13.3
<i>Total</i>	233	100.0

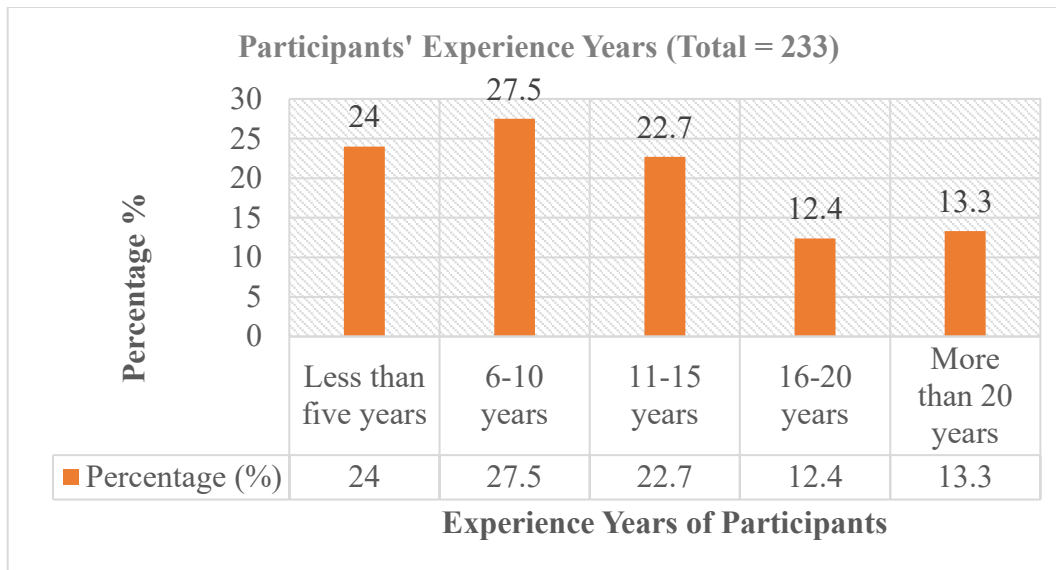


Figure 4.4.1.3: Experience Years of Participants

(Table 4.4.4, Figure 4.4.3) illustrates the years of experience of survey participants in the Contractor & Other Consultant/Engineering Offices and Government sectors. The overall respondent count is 233. Most participants, precisely 64 Participants, have professional experience ranging from six to ten (6-10) years. Among these Participants, contractors accounted for 17, consultants for 31, and government for 16. The next group comprises individuals with fewer than five years of experience, comprising 56 Participants (24%) (26 contractors, 25 consultants, and five government employees). Participants with professional experience ranging from eleven to fifteen (11-15) years make up 22.7% of the total, with 53 Participants (23 contractors, 16 consultants, 14 government entities). There are 31 Participants, comprising contractors (4), consultants (16), and government (11), who have more than twenty years of experience, accounting for 13.3% of the total study participants. With 29 Participants accounting for 12.4% of the total, the smallest category comprises people with sixteen to

twenty (16-20) years of experience (contractors: 7, consultants: 13, Government: 9) refer to (Table 4.4.5).

Table 4.4.5: Experience Years for different Business Types

<i>Years of Experience</i>	<i>Consultant/ Engineering Offices</i>	<i>Contractor & Other</i>	<i>Government</i>	<i>TOTAL</i>
<i>Less than five years</i>	25	26	5	56
<i>6-10 years</i>	31	17	16	64
<i>11-15 years</i>	16	23	14	53
<i>16-20 years</i>	13	7	9	29
<i>More than 20 years</i>	16	4	11	31

4.4.1.5 E: Organization Sector

Questionnaire: Question 5: *In which sector does your organization operate?*

Table 4.4.6: Organization Sector for different Business Type

<i>Organization Sector</i>	<i>Consultant/ Engineering Offices</i>	<i>Contractor & Other</i>	<i>Government</i>	<i>TOTAL</i>	<i>Percentage (%)</i>
<i>Public Sector</i>	16	0	33	49	21.09
<i>Private Sector</i>	68	62	21	151	64.80
<i>Public & Private Sectors (Both)</i>	17	15	1	33	14.16

(Table 4.4.6) illustrates the distribution of participants according to their employment sector, particularly consultant/engineering offices, contractor & other, and government positions. The overall respondent count is 233. About 64.8% of the total Participants, which amounts to 151 individuals, are employed in the private sector. Within this group, 68 individuals are

engaged in consultant/engineering offices, 62 in contractor/other positions, and 21 in government positions.

Notably, the public sector, with 49 Participants, makes up 21% of the total. Among them, 33 participants are in government roles, and 16 are in consulting/engineering offices. It's interesting to note that none of the Participants are involved in contractors or other positions.

Thirty-three Participants, accounting for 14.16% of the sample, are employed in both the public and private sectors, showcasing a balanced distribution. Within this classification, 17 individuals were engaged in consultant/engineering offices, 15 in contractor & other positions, and just one in government occupational capacity.

4.4.1.6 F: Size of Current Project

Questionnaire: Question 6: *What is the scale of the ongoing project/s that your organization is currently engaged in?*

Table 4.4.7: Project Scale for different Business Types

Project Scale	Consultant/ Engineering Offices	Contractor & Other	Government	TOTAL	(%)
Small (Less than 500,000 BD)	7	10	4	21	9.01
Medium (Above 500,000 BD – 1,000,000 BD)	33	15	14	62	26.61
Large (Above 1,000,000 BD – 2,000,000 BD)	24	23	15	62	26.61
Very Large (Above 2,000,000 BD)	37	29	22	88	37.76

This (Table 4.4.7) illustrates the allocation of participants among various project scales and the organizational type they employ. Out of the total

Participants, 88 individuals, representing 37.76% of the group, are engaged in large projects. Equal numbers of participants, 62 responders each, make up 26.61% of the total for both medium and big initiatives. The predominant group of participants in these categories consists of individuals employed in consulting/engineering offices, with contractor & other government positions following accordingly.

Conversely, the smallest fraction, accounting for just 9.01% of the total, consists of 21 persons engaged in tiny initiatives. Significantly, a more significant proportion of professionals in the occupations of consultant/engineering offices and government are involved in small projects, while the overall level of involvement is notably lower in comparison to larger-scale initiatives (Table 4.4.8).

This distribution demonstrates a distinct pattern in which the majority of professionals are involved in larger-scale projects, especially extremely big projects, while a lesser number of professionals are engaged in smaller-scale initiatives.

Table 4.4.8: Project Scale of Participants

<i>Project Scale</i>	<i>TOTAL</i>	<i>Percentage (%)</i>
<i>Small (Less than 500,000 BD)</i>	21	9.01
<i>Medium (Above 500,000 BD –1,000,000 BD)</i>	62	26.61
<i>Large (Above 1,000,000 BD –2,000,000 BD)</i>	62	26.61
<i>Very Large (Above 2,000,000 BD)</i>	88	37.77

4.4.2 Section B: The Awareness of the BIM and Usage Level

4.4.2.1 BIM Awareness Level

Questionnaire: Question 1: What is your level of knowledge of BIM?

Table 4.4.9: Awareness Level for Different Business Types

<i>Awareness Level</i>	<i>Consultant/ Engineering Offices</i>	<i>Contractor & Other</i>	<i>Government</i>	<i>TOTAL</i>
<i>Not aware of BIM</i>	18	18	6	42
<i>Fair knowledge of BIM</i>	17	16	10	43
<i>Well-informed about BIM but no usage.</i>	34	27	15	76
<i>Aware and currently using BIM tools.</i>	32	16	24	72
<i>TOTAL</i>	101	77	55	233

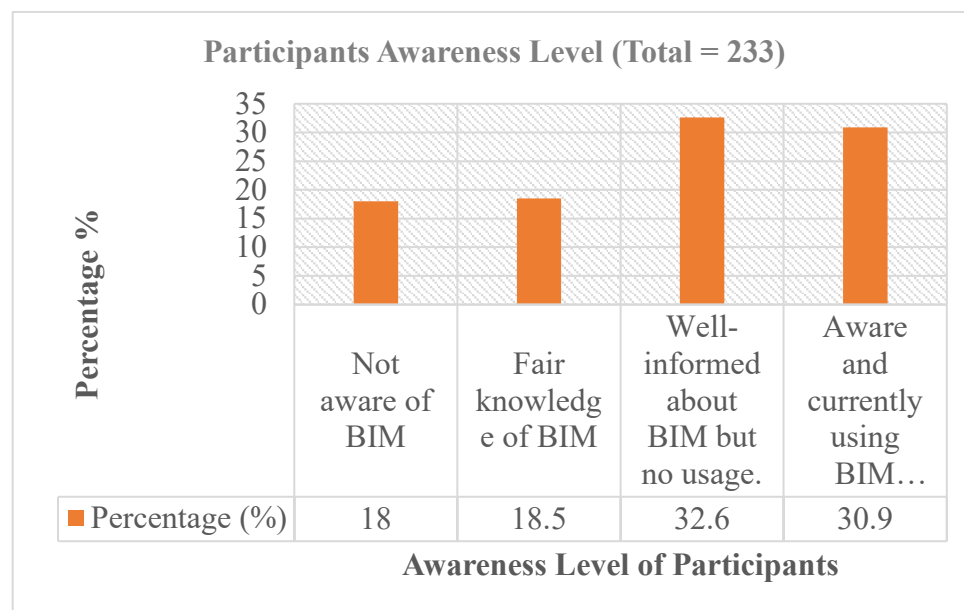


Figure 4.4.2.1: Awareness Level of Participants

- **BIM Awareness Level**

(Table 4.4.9, Figure 4.4.4) illustrates the following.

A. Consultant/Engineering Offices

- **High Awareness (51 individuals out of 101, about 46.36%):** A large proportion of individuals in this sector are either aware of BIM but not using it (34 individuals well-informed but not using, about 30.90%) or (aware and currently using BIM tools.) actively using it (32, about 29.09%). Together, these two groups make up nearly half of the consultant sector. This indicates that BIM has become a central topic, although some individuals still refrain from practical application.
- **Fair Knowledge of BIM (17 individuals; 16.83%):** A significant portion of consultants have a basic or fair understanding of BIM. This indicates that while they are familiar with the concept, they may not have in-depth knowledge of its full capabilities and benefits. (Implying that their knowledge is limited to the surface level).
- **Not Aware of BIM (18 individuals; 17.82%):** Almost 18% of consultants/engineering professionals remain unaware of BIM. This indicates that while BIM is widely discussed in the industry, some professionals or smaller firms have not yet been exposed to it.

B. Contractor & Other

- **Well-Informed but No Usage (27 individuals; 35.06%):** More than a third of contractors are well-informed but not using BIM. This could indicate practical barriers, such as difficulties in adopting BIM into the construction phase or a perceived complexity in its application.

- **Fair Knowledge of BIM (16 individuals; 20.78%):** A significant portion of contractors has basic knowledge of BIM. However, this may not translate into understanding the full range of applications, especially in on-site management and construction processes.
- **Not Aware of BIM (18 individuals; 23.38%):** Contractors show a higher level of unawareness compared to consultants. This could be due to their focus on practical, on-site tasks rather than design or project planning, where BIM is more commonly utilized.

C. Government

- **Well-informed but No Usage (15 individuals; 27.27%):** Over a quarter of government individuals are well-informed but not using BIM. This could indicate that despite awareness, there may be challenges in implementing BIM at scale in government projects, possibly due to budget constraints or government policy.
- **Fair Knowledge of BIM (10 individuals; 18.18%):** A smaller but notable group in the government sector has a fair knowledge of BIM. These individuals may be familiar with BIM from a policy or planning perspective but lack a detailed understanding of its technical applications.
- **Not Aware of BIM (6 individuals; 10.91%):** The government sector has the lowest level of individuals unaware of BIM, likely due to public initiatives or policies promoting BIM for infrastructure projects. However, a small percentage is still unfamiliar with the technology.

- **BIM Usage Level**

(Table 4.4.9) illustrates the following.

A. Consultant/Engineering Offices

Using BIM Tools (32 individuals; 31.68%): A significant portion of consultants (nearly one-third) are using BIM tools. This reflects the centrality of BIM in the design, planning, and project management stages of construction. More importantly, it shows how BIM has become a key tool for improving coordination and reducing errors, demonstrating its practical benefits and potential impact.

B. Contractor & Other

Using BIM Tools (16 individuals; 20.78%): Contractors, who currently have a lower adoption rate compared to consultants, face valid challenges in implementing BIM. These challenges, such as the practical difficulties during the construction phase or the perception that BIM is more relevant in the design stage than on-site execution, are real and should be acknowledged. Understanding these challenges is the first step towards finding solutions and increasing BIM adoption in the contractor sector.

C. Government

Using BIM Tools (24 individuals; 43.64%): The government sector has the highest adoption rate, likely influenced by public policies or regulations that encourage or mandate the use of BIM for infrastructure and urban planning projects. This high adoption rate underscores the importance of BIM for large-scale, public-sector projects that require extensive

coordination and long-term asset management and its potential to bring significant value to these projects.

- **High Awareness but Varying Depth:** Across all sectors, awareness of BIM is relatively high, with a substantial portion of individuals either having fair knowledge or being well-informed about BIM. The Consultant/Engineering Offices and Government sectors show particularly strong awareness. This underscores the increased importance of BIM in project planning and public infrastructure, where design and coordination are of utmost importance. However, a noticeable portion of individuals, particularly in the Contractor sector, either lack awareness or have only a basic understanding of BIM. This indicates that BIM's penetration has been slower in sectors that are more focused on hands-on construction tasks.
- **Significant Gap Between Awareness and Usage:** A critical finding is the gap between awareness and actual usage of BIM. A large proportion of individuals across all sectors are well-informed about BIM but are not yet using it in practice. In the Contractor sector, over a third are well-informed but do not use BIM. This reflects the particular challenges contractors face, such as integrating BIM into daily construction operations or seeing its value beyond the design phase. Even in the Consultant/Engineering Offices, where BIM usage is relatively high, about 34% of individuals are well-informed but not using the technology, indicating room for growth.
- **Summary:**
 - Awareness does not guarantee usage, especially in sectors like contracting, where practical challenges may limit adoption. Closing

this gap will require addressing specific barriers through targeted training, cost-sharing, or providing clear examples of BIM's practical benefits for on-site work.

- Government and consultant sectors are leading the way in BIM usage, driven by policy initiatives and the inherent benefits of using BIM for large, complex projects. These sectors could serve as models for broader BIM adoption across the industry.
- Contractors need to catch up in adoption, indicating the need for more targeted efforts to show how BIM can benefit not just the design phase but also the execution phase of construction projects.

While BIM awareness is relatively high across all sectors, there is still a significant gap in its practical application, particularly among well-informed individuals who have yet to adopt it. The potential for broader BIM adoption and enhanced efficiency in the construction industry can be realized by addressing each sector's specific needs and challenges, especially contractors.

4.4.2.1.1 BIM Knowledge by Education Level

Table 4.4.10: BIM Knowledge by Education Level

<i>Education Level</i>	<i>Diploma</i>	<i>Bachelor's degree</i>	<i>Master's degree</i>	<i>PhD degree</i>
<i>BIM Knowledge</i>	Freq. %	Freq. %	Freq. %	Freq. %
<i>Not aware of BIM</i>	2 4.76	32 76.19	8 19.05	0 0.00
<i>Fair knowledge of BIM</i>	0 0.00	30 69.77	13 30.23	0 0.00
<i>Well-informed about BIM but no usage.</i>	6 7.89	48 63.16	20 26.32	2 2.63
<i>Aware and currently using BIM tools.</i>	17 23.61	19 26.39	24 33.33	12 16.67

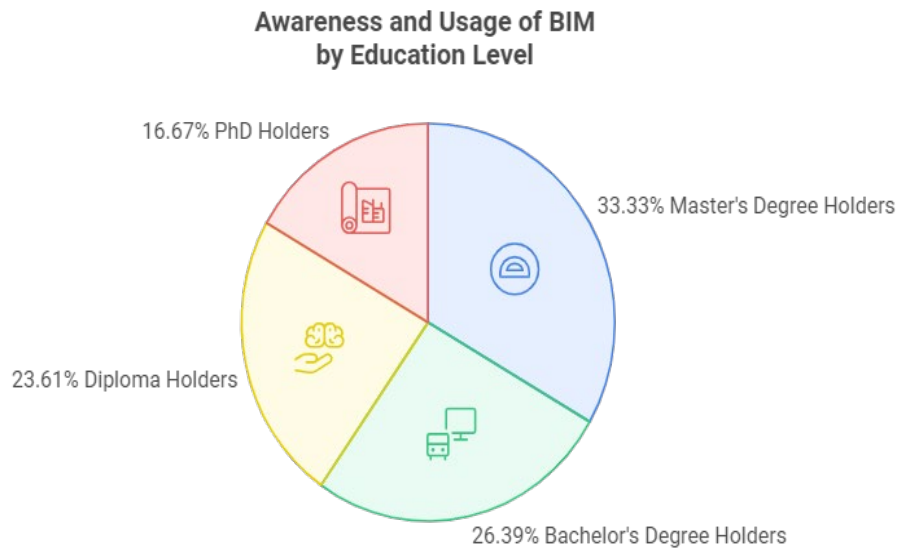


Figure 4.4.2.2: Awareness and Usage of BIM by Education Level

When designing the survey questionnaire, the varying educational levels of the participants were carefully considered. Recognizing the potential differences in responses due to these educational variations, the questionnaire was tailored to accommodate these levels. To address the possibility of random responses or human errors, the questionnaire also included methods for internal verification, ensuring that the answers were consistent and not randomly generated. The results show a noticeable gap between educational levels and awareness of BIM as both a process and technology. This gap could be reduced by incorporating BIM into educational curricula. (Table 4.4.10, Figure 4.4.5) illustrates the following:

- Diploma Holders (Rank 3, Adoption Level):** Most diploma holders are surprisingly engaged (23.61%) and actively use BIM tools, with 17 out of 25 currently using BIM, despite their lower formal education level than degree holders. This indicates that vocational training and hands-on work experience can lead to more direct engagement with BIM technologies than theoretical education in bachelor's programs. At

the same time, a small percentage (4.76%) are not aware of BIM. There is a noticeable gap between awareness and active usage, indicating a generally positive adoption rate among diploma holders.

- **Bachelor's Degree Holders (Rank 2):** Many bachelor's degree holders lack awareness of BIM, with only 26.39% currently using BIM tools. This indicates that there is a need for improvement in providing exposure to BIM in undergraduate programs. Additionally, 69.77% have only fair knowledge of BIM, and 63.16% are well-informed but do not use BIM, indicating a lack of practical opportunities to apply their knowledge.
- **Master's Degree Holders (Rank 1):** Among master's degree holders, awareness and usage rates are much higher compared to those with a bachelor's degree. A significant portion (33.33%) is actively using BIM tools, and fewer respondents (19.05%) are completely unaware of BIM. This indicates better integration of BIM knowledge at higher education levels.
- **PhD Holders (Rank 4):** PhD holders exhibit the highest rates of BIM usage (16.67%), and none of the respondents are unaware or have only fair knowledge. This demonstrates the deep integration of BIM into the work of highly educated individuals, likely because of their exposure to research and complex projects that benefit from BIM.
- **Total Adoption and Awareness:** Out of the total respondents, 42 individuals are not aware of BIM, 43 have fair knowledge, 76 are well-informed but not using BIM, and 72 are actively using BIM tools. This shows that while awareness is spreading, there is still a significant portion of individuals (62.30% of respondents) who are either not using

BIM or are unaware of its benefits, and only 37.70% of respondents are aware and using BIM.

4.4.2.1.2 BIM Knowledge by Profession

Table 4.4.11: BIM Knowledge by Profession

Profession	Civil Engineer	Architect	Project Managers	Surveyor	Electrical Engineer	Mechanical Engineer	Facility Engineer	BIM Specialist
BIM Knowledge	Freq.	Freq.	Freq.	Freq.	Freq.	Freq.	Freq.	Freq.
	%	%	%	%	%	%	%	%
Not aware of BIM	26	4	7	2	1	0	2	0
	61.90	9.52	16.67	4.76	2.38	0.00	4.76	0.00
Fair knowledge of BIM	22	5	9	2	1	2	1	1
	51.16	11.63	20.93	4.65	2.33	4.65	2.33	2.33
Well-informed about BIM but no usage.	29	15	15	0	8	4	2	3
	38.16	19.74	19.74	0.00	10.53	5.26	2.63	3.95
Aware and currently using BIM tools.	23	16	14	4	3	1	0	11
	31.94	22.22	19.44	5.56	4.17	1.39	0.00	15.28

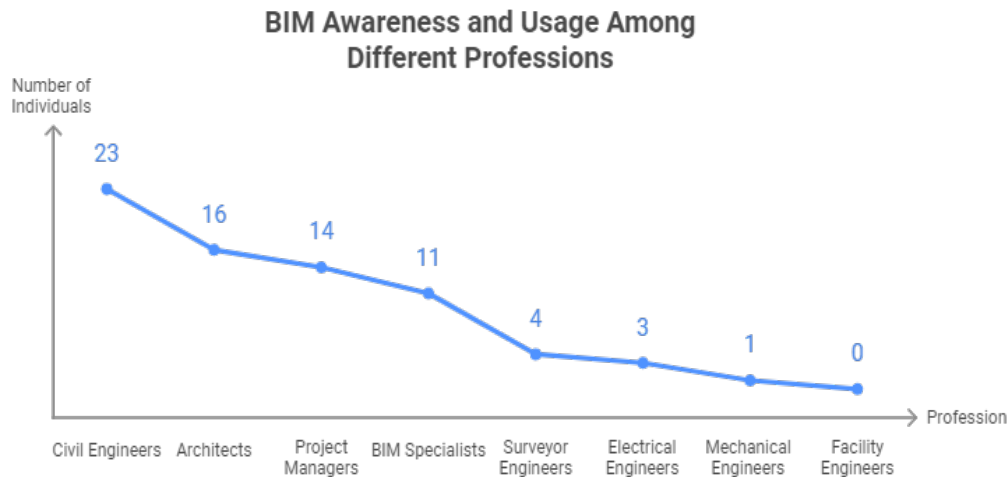


Figure 4.4.2.3: BIM Knowledge by Profession

The following Profession levels are used to evaluate the degree of awareness and usage, which will lead to identifying the areas of focus at each Profession level (Table 4.4.11, Figure 4.4.6).

- **Civil engineers and project managers** need more targeted training and practical exposure to BIM, as a large portion of them are well-informed but do not use BIM tools.
- **Architects** show higher engagement, but there is still room to transition the well-informed group to active users through project-based BIM initiatives.
- **Electrical and Mechanical Engineers** have the highest percentage of individuals who are well-informed but not using BIM, indicating a strong need for practical training to move from awareness to implementation.
- **Facility engineers** have no active BIM usage, which represents a significant opportunity for awareness and training programs, especially in the context of facility management.

- **BIM Specialists** are leading the way in BIM adoption, with the highest active usage rate among all professions. They are in an ideal position to guide other professionals in adopting BIM tools effectively.

4.4.2.1.3 BIM Knowledge by Experience Level

Table 4.4.12: BIM Knowledge by Experience Level

Experience Level	Less than five years	6-10 years	11-15 years	16-20 years	More than 20 years
<i>BIM Knowledge</i>	Freq.	Freq.	Freq.	Freq.	Freq.
<i>Not aware of BIM</i>	%	%	%	%	%
	14	12	8	4	4
	33.33	28.57	19.05	9.52	9.52
<i>Fair knowledge of BIM</i>	16	9	5	4	9
	37.21	20.93	11.63	9.30	20.93
<i>Well-informed about BIM but no usage.</i>	12	23	21	11	9
	15.79	30.26	27.63	14.47	11.84
<i>Aware and currently using BIM tools.</i>	14	20	19	10	9
	31.94	27.78	26.39	13.89	12.50

Summary (Table 4.4.12, Figure 4.4.7):

- **Younger professionals (less than five years)** have a higher percentage of fair knowledge and active BIM usage compared to more experienced professionals. BIM is becoming more integrated into early-career education and training programs.

- **Mid-career professionals (6-10 years and 11-15 years)** show a large group of well-informed individuals who are not using BIM, indicating a gap between knowledge and practical application. This group could benefit from targeted hands-on training or incentives to encourage BIM usage.
- **Professionals with 16-20 years of experience and more than 20 years** show lower levels of BIM engagement, indicating that senior professionals may require specialized training to transition from traditional methods to modern BIM-based processes.

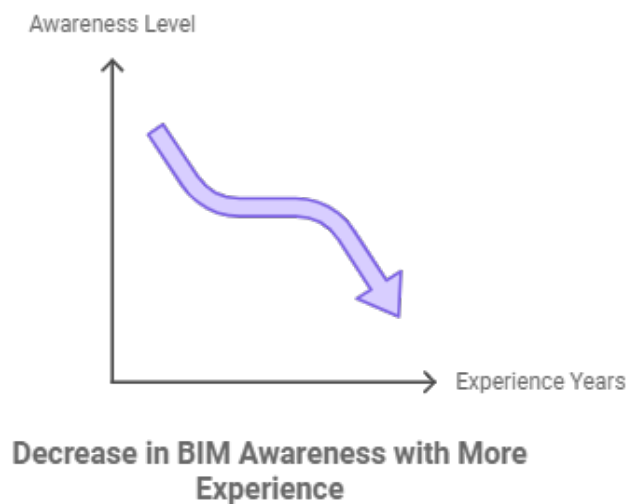


Figure 4.4.2.4: Decrease in BIM Awareness with More Experience

4.4.2.1.4 BIM Knowledge by Sector

Table 4.4.13: BIM Knowledge by Sector

<i>Sector Operate</i>	<i>Public Sector</i>	<i>Private Sector</i>	<i>Public & Private Sector (Both)</i>
<i>BIM Knowledge</i>	Freq. %	Freq. %	Freq. %
<i>Not aware of BIM</i>	7 16.67	24 57.14	11 26.19
<i>Fair knowledge of BIM</i>	11 25.58	21 48.84	11 25.58
<i>Well-informed about BIM but no usage.</i>	14 18.42	55 72.37	7 9.21
<i>Aware and currently using BIM tools.</i>	17 23.61	51 70.83	4 5.56

- **Summary (Table 4.4.13, Figure 4.4.8):**

- **Private Sector Leading BIM Usage:** The Private Sector has the highest percentage of individuals currently using BIM tools (70.83%). However, there is still a significant group (72.37%) that is well-informed but not actively using BIM, which signals a gap in practical application.
- **Public Sector Opportunities:** The Public Sector shows a lower adoption rate (23.61%) compared to the private sector. There is a sizable portion (25.58%) with fair knowledge of BIM, indicating that there is room for increased training and more public projects using BIM.
- **Public & Private Sector (Both) Shows the Lowest BIM Adoption:** Individuals working across both sectors have the lowest BIM usage (5.56%), with a considerable percentage of individuals either not aware of or having fair knowledge of BIM. This group might face challenges

in adopting BIM practices due to the nature of their work, which spans across two sectors with different demands.

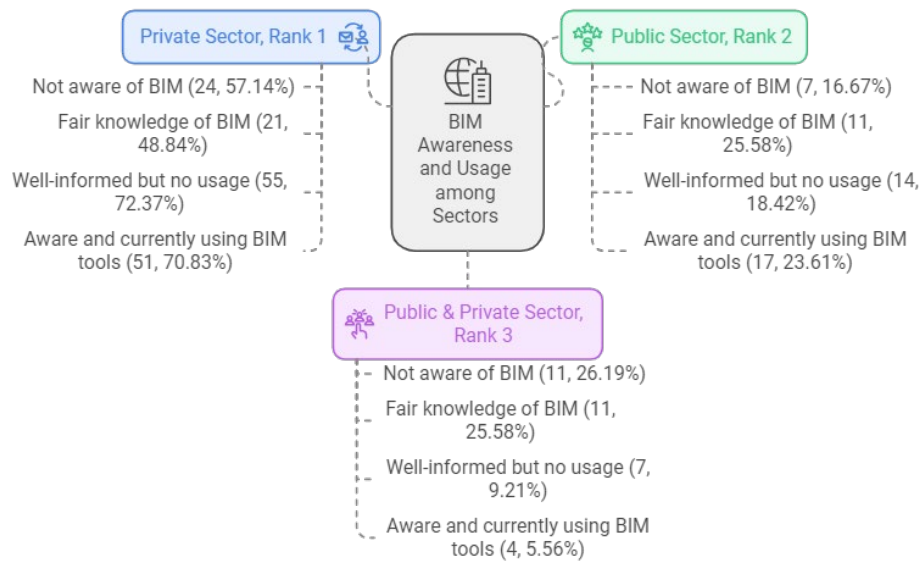


Figure 4.4.2.5: BIM Knowledge by Sector

4.4.2.1.5 BIM Knowledge by Project Scale

Table 4.4.14: BIM Knowledge by Project Scale

Project Scale	Small (Less than 500,000 BD)	Medium (Above 500,000 BD –1,000,000 BD)	Large (Above 1,000,000 BD –2,000,000 BD)	Very Large (Above 2,000,000 BD)
BIM Knowledge	Freq.	Freq.	Freq.	Freq.
	%	%	%	%
Not aware of BIM	9	10	4	19
	21.43	23.81	9.52	45.24
Fair knowledge of BIM	9	13	8	13
	20.93	30.23	18.60	30.23
Well-informed about BIM but no usage.	1	25	22	28
	1.32	32.89	28.95	36.84
Aware and currently using BIM tools.	2	14	28	28
	2.78	19.44	38.89	38.89

Summary (Table 4.4.14, Figure 4.4.9):

- **Smaller projects** (less than 500,000 BD) have the lowest BIM adoption (2.78%). These projects may not see the immediate value of BIM due to their scale or may lack the resources to implement it.
- **Medium-sized projects** (above 500,000 BD – 1,000,000 BD) show an increase in BIM usage (19.44%), though there is still a substantial group well-informed but not using BIM (32.89%). This indicates that while BIM is recognized, practical challenges in adoption remain.
- **Large projects** (above 1,000,000 BD – 2,000,000 BD) see significantly higher adoption (38.89%), showing that BIM becomes a more valuable tool for coordination, collaboration, and project management as project complexity increases.
- **Very large projects** (above 2,000,000 BD) also show 38.89% BIM usage, but the high percentage of respondents unaware of BIM (45.24%) is concerning. This indicates that despite the scale of these projects, there are gaps in BIM knowledge that need to be addressed.

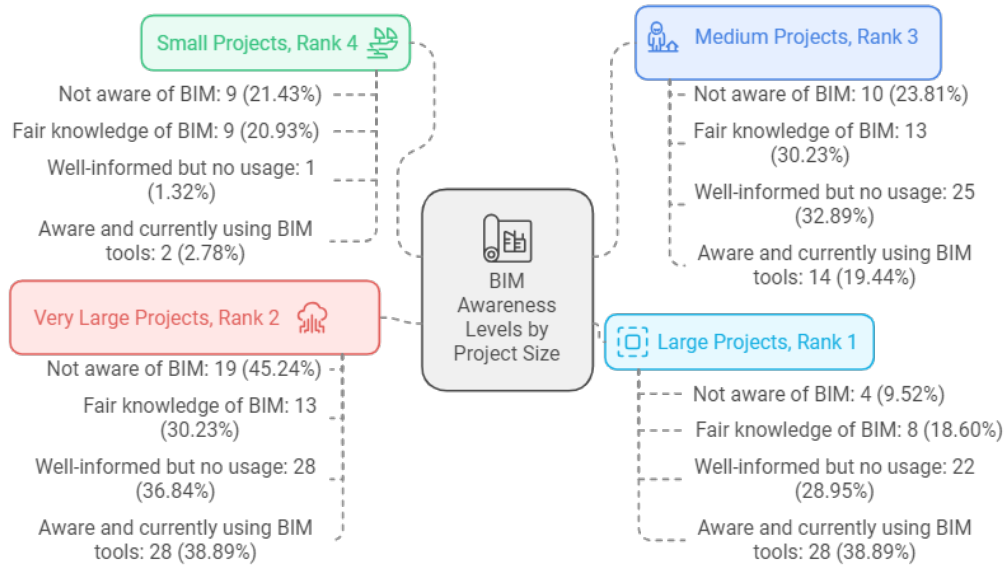


Figure 4.4.2.6: BIM Knowledge by Project Scale

4.4.2.2 Software Usage Level

Questionnaire: Question 2: What is your organization's usage level of the following BIM Software/Tool?

Table 4.4.15: Software Usage Level

Software Usage Level	Never	Rarely	Occasionally	Frequently	Very Frequently	Weighted Mean	Ranking	The General Trend
	Frq.	Frq.	Frq.	Frq.	Frq.			
	%	%	%	%	%			
AutoCAD Architecture	8	13	17	104	49	3.906	1	Agree
	4.19	6.81	8.90	54.45	25.65			
Autodesk Revit	12	34	29	25	91	3.780	2	Agree
	6.28	17.80	15.18	13.09	47.64			
Autodesk Navisworks	47	19	24	72	29	3.089	5	Agree
	24.61	9.95	12.57	37.70	15.18			
Bentley	48	22	22	20	79	3.314	3	Agree
	25.13	11.52	11.52	10.47	41.36			
Tekla	54	24	25	71	17	2.859	7	Disagree
	28.27	12.57	13.09	37.17	8.90			
ArchiCAD	51	23	24	22	71	3.204	4	Agree
	26.70	12.04	12.57	11.52	37.17			
BIM 360	56	24	19	69	23	2.890	6	Disagree
Avg Weighted Mean						3.292		Agree

191 Responded, 42 Skipped

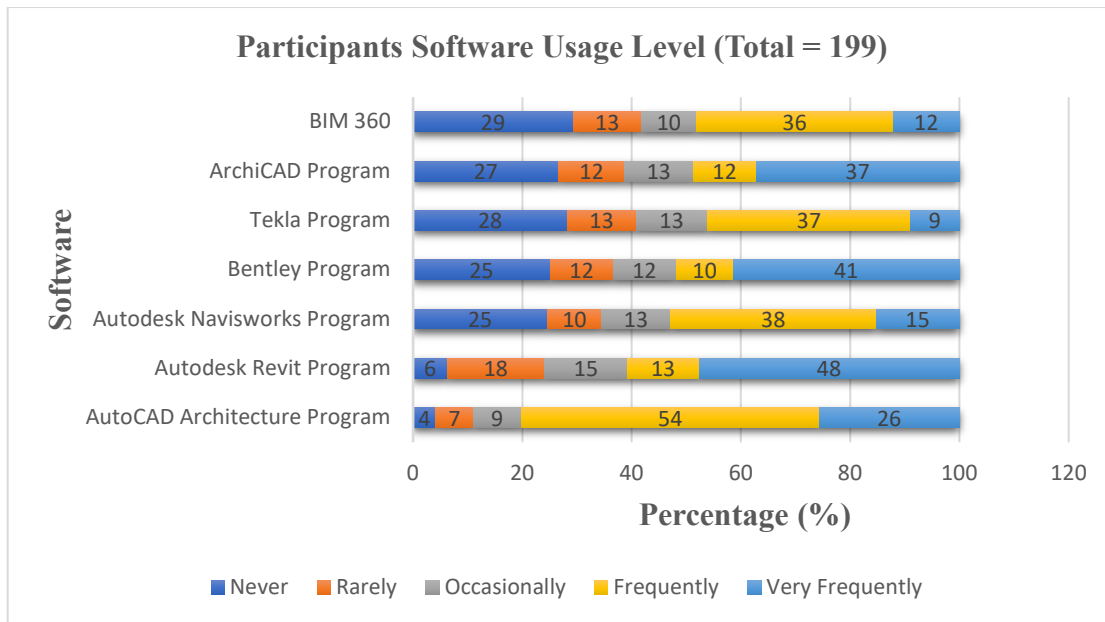


Figure 4.4.2.7: Participants' Software Usage Level
 (Table 4.4.15, Figure 4.4.10) illustrate clear patterns of usage frequency and overall ranking.

Summary:

- **AutoCAD Architecture Program (Rank 1) and Autodesk Revit Program (Rank 2)** are the most frequently used software, showing high adoption across the field. However, AutoCAD has more significant variability in usage, indicating that some users do not use it as frequently.
- **Bentley Program (Rank 3) and Autodesk Navisworks (Rank 5)** show moderate usage, with many users engaging with these programs. However, both programs have a notable percentage of Participants who either rarely or never use them, and Bentley shows more variability in usage patterns.
- **ArchiCAD Program (Rank 4)** shows moderate usage, with 37.17% of participants using it frequently. However, 26.70% of participants

never use it, and an additional 12.04% use it rarely. This means that nearly 39% of participants fall into the "never" or "rarely" categories, highlighting a gap in adoption.

- **Tekla Program (Rank 7) and BIM 360 (Rank 6)** are the least frequently used programs, with significant portions of Participants never or rarely using them.

4.4.2.3 BIM Functions Adoption

Questionnaire: Question 3: *For what purpose do you use BIM Application Software in your Organization? (BIM Functions Adoption)*

Table 4.4.16: BIM Functions Adoption Level

<i>BIM Functions Adoption</i>	<i>Never</i>	<i>Rarely</i>	<i>Occasionally</i>	<i>Frequently</i>	<i>Very Frequently</i>	<i>Weighted Mean</i>	<i>Ranking</i>	<i>The General Trend</i>
	Frq	Frq	Frq	Frq	Frq			
	%	%	%	%	%			
2D Drawings	11	21	20	43	96	4.005	1	Agree
	5.76	10.99	10.47	22.51	50.26			
3D Modeling	14	12	18	80	67	3.911	3	Agree
	7.33	6.28	9.42	41.88	35.08			
As-Built	14	10	39	43	85	3.916	2	Agree
	7.33	5.24	20.42	22.51	44.50			
4D Scheduling	40	20	38	67	26	3.099	8	Agree
	20.94	10.47	19.90	35.08	13.61			
5D Cost Estimation	51	19	34	29	58	3.126	7	Agree
	26.70	9.95	17.80	15.18	30.37			
6D Sustainability	54	27	21	60	29	2.911	11	Disagree
	28.27	14.14	10.99	31.41	15.18			
7D Management	65	22	18	31	55	2.942	10	Disagree
	34.03	11.52	9.42	16.23	28.80			
Clash Detection	42	24	29	60	36	3.126	6	Agree
	21.99	12.57	15.18	31.41	18.85			
Visualization	26	18	25	39	83	3.707	4	Agree
	13.61	9.42	13.09	20.42	43.46			
Site Logistics	40	23	25	69	34	3.178	5	Agree
	20.94	12.04	13.09	36.13	17.80			
Performance Analysis	57	22	27	28	57	3.031	9	Agree
	29.84	11.52	14.14	14.66	29.84			
8D Safety	62	19	24	64	22	2.817	12	Disagree
	32.46	9.95	12.57	33.51	11.52			
<i>Avg Weighted Mean</i>						3.314		Agree

191 Responded 42 Skipped.

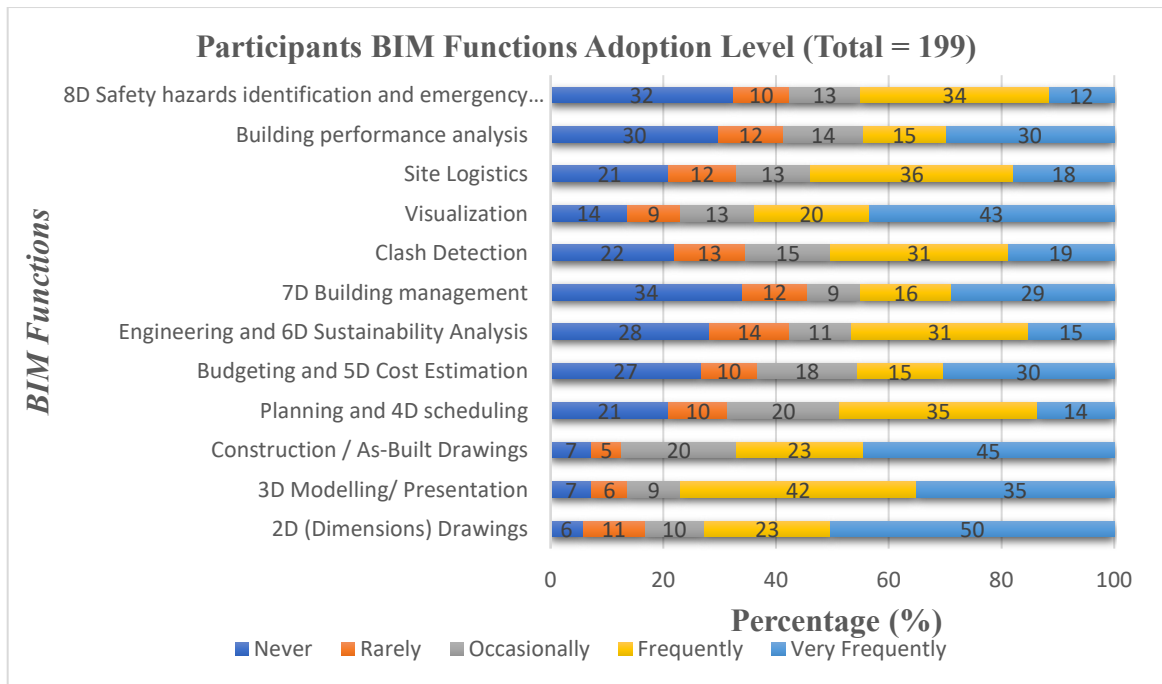


Figure 4.4.2.8: Participants' BIM Functions Adoption Level

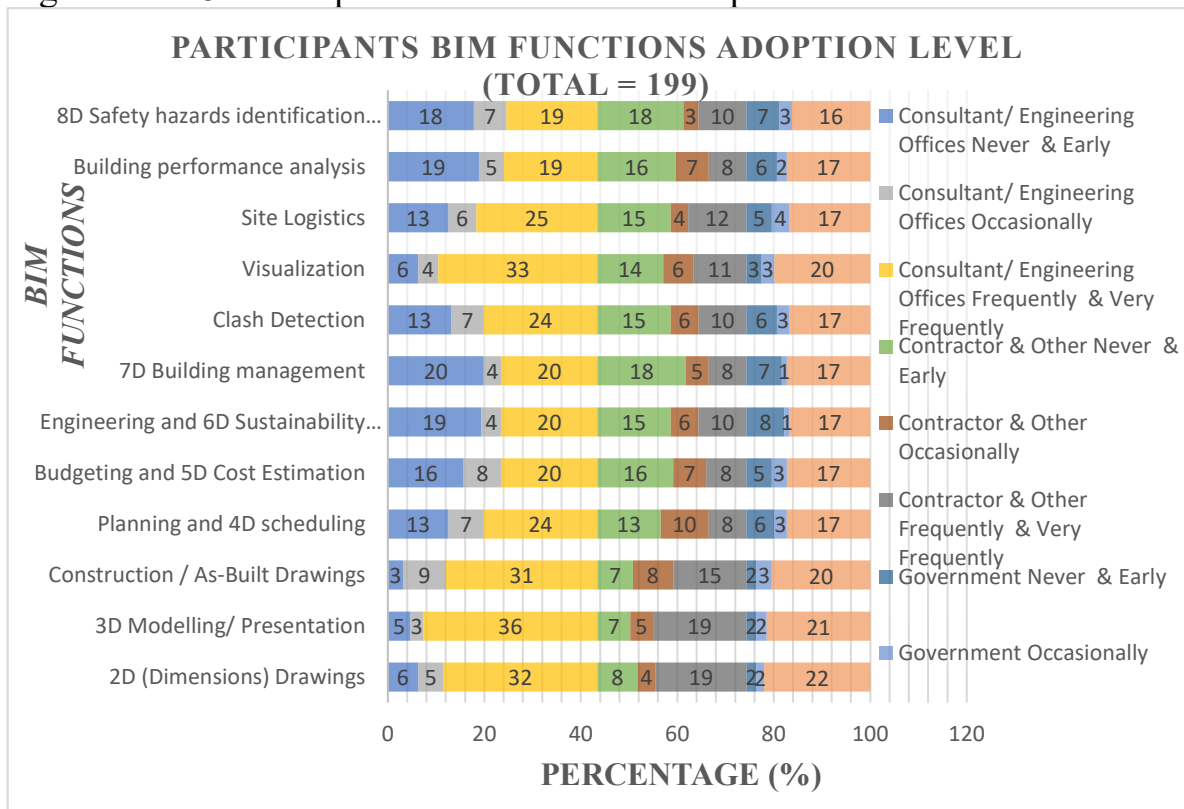


Figure 4.4.2.9: BIM Functions Adoption Across Different Sectors

The following analysis examines the current levels of adoption of BIM functions across different business types—consultant/engineering offices,

contractors and others, and government—based on frequency of use, weighted means, and general trends, as shown in the above (Table 4.4.16) and (Figure 4.4.11, Figure 4.4.12)

A. High Adoption Functions (Weighted Mean > 3.9)

- **2D Drawings (Rank 1, Weighted Mean: 4.005, Trend: Agree):** 2D Drawings Show the highest adoption, with more than 73% (32% of consultants, 22% of government, and 19% of contractors) of respondents from the sectors using 2D drawings very frequently or frequently. This high adoption rate indicates the continued importance of 2D drawings in the industry despite being an older method. In comparison, only 16% never or rarely use it. 2D Drawings remain essential for many basic design and documentation tasks.
- **As-Built Drawings (Rank 2, Weighted Mean: 3.916, Trend: Agree):** This function shows significant adoption across all sectors, with more than 66% of respondents using it frequently or frequently, proving critical for final project documentation, especially among consultants and government users, with 31% using it very frequently among consultants. (31% of consultants, 20% of government, and 15% of contractors), In comparison, only 16% never or rarely use it.
- **3D Modeling (Rank 3, Weighted Mean: 3.911, Trend: Agree):** Consultants and government users lead adoption, with 36% of consultants using 3D modeling frequently and 21% of government users doing the same. Contractors show less frequent use, with only respondents (19%) using it Very Frequently. With 76.96% using it frequently or significantly frequently, 3D Modeling is a key function

in most BIM workflows. In comparison, only 14% never or rarely use it.

B. Moderate Adoption Functions (Weighted Mean between 3.0 and 3.9) These functions are moderately adopted, showing they are essential but have yet to integrate fully into all projects across business types.

- **Site Logistics (Rank 5, Weighted Mean: 3.178, Trend: Agree):** While consultants and Government entities report higher usage of Site Logistics, with 42.0 % using it frequently, the adoption rate among Contractors is significantly lower, with only 12.0% adopting this function. This discrepancy is evident in the total 54% of respondents using it frequently or frequently, while only 33% never or rarely use it. Site Logistics, crucial for coordinating construction site activities, is in need of more comprehensive adoption in the contractor sectors.
- **5D Cost Estimation (Rank 7, Weighted Mean: 3.126, Trend: Agree):** The consultant sector leads the adoption of 5D Cost Estimation, with (20.0%) frequently using it, and the government (17.0%). However, Contractors show lower use, with (8.0%) frequently using it and adopting this function. More than 45% of respondents use it frequently. In comparison, only 34% never or rarely use it. While there is a need for budgeting and cost management, 5D Cost Estimation remains underutilized by some sectors that focus less on financial modeling.
- **Clash Detection (Rank 6, Weighted Mean: 3.126, Trend: Agree):** Adoption is higher among Consultants and Government, with 41.0% of both groups using it Frequently (24% of consultants, 17% of

government). Contractor's lag (10%); more than 51% of respondents use it frequently or frequently. In comparison, only 34% never or rarely use it, and the majority are contractors (15%). It has been moderately adopted but has room for improvement in sectors that have not fully integrated it.

- **4D Scheduling (Rank 8, Weighted Mean: 3.099, General Trend: Agree)** Adoption: 49% use 4D scheduling frequently or very frequently. However, 32% reported never or rarely using it. Consultants (24%) and government (17%) report better usage, and contractors report lower adoption (8.0%). 4D Scheduling has a moderate adoption rate, but many sectors have yet to fully incorporate it into their workflows.
- **Performance Analysis (Rank 9, Weighted Mean: 3.03, Trend: Agree):** Consultant entities are the most frequent users of this function, with (19.0%) using it Frequently, while the government lags slightly (17.0%). Contractors show the lowest adoption, with 13.0% using it. More than 64% of respondents use it frequently or frequently. In comparison, only 23% never or rarely use it.

C. Low Adoption Functions (Weighted Mean < 3.0)

- **7D Building Management (Rank 10, Weighted Mean: 2.942, Trend: Disagree):** Many respondents from all sectors never use this function, with 18% of contractors reporting no usage. Government sectors show slightly better adoption (7%), and consultants (20%) never use it, but 7D management is vastly underused overall. More than 46% of respondents never or rarely use it. In comparison, only 45% frequently and very frequently it. 7D Building Management, which

focuses on post-construction operations, is significantly underused, especially in sectors that do not emphasize lifecycle management.

- **6D Sustainability (Rank 11, Weighted Mean: 2.911, Trend: Disagree):** This function shows low adoption across all sectors, with 19.0% of consultants never using it and 15% of Contractors doing the same; also, the government (8.0%). More than 42% of respondents never or rarely use it. In comparison, only 47% frequently and very frequently it. Despite its importance for sustainable construction, 6D Sustainability remains underutilized.
- **8D Safety Hazards Identification and Emergency Management (Rank 12, Weighted Mean: 2.817, Trend: Disagree):** 8D Safety has the lowest adoption rate across all sectors. 18% of consultants, 18% of contractors, and 7% of government officials report never using this function. 43% of respondents never or rarely use it. In comparison, only 45% frequently and very frequently it despite its critical role in ensuring safety on construction sites.

Summary: The analysis shows that while core BIM functions such as 2D drawings, 3D modeling, and as-built drawings are widely adopted, there are significant opportunities for improvement in the adoption of more advanced BIM functionalities.

4.4.3 Section C: Benefits of BIM Adoption and Implementation

4.4.3.1 Perceived Benefits of BIM

Questionnaire: Question 1: Evaluate the following benefits of implementing BIM?.

Table 4.4.17: Benefit Factors of BIM Adoption

Benefit Factors of BIM Adoption	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Weighted Mean	Ranking	The General Trend
	Frq %	Frq %	Frq %	Frq %	Frq %			
BIM is very beneficial when applied to the construction industry.	1	1	24	114	51	4.115	11	Agree
	0.52	0.52	12.57	59.69	26.70			
BIM can significantly boost productivity and work efficiency in the construction industry, resulting in significant time & cost savings.	1	0	20	60	110	4.455	1	Agree
	0.52	0.00	10.47	31.41	57.59			
BIM is a tool that assists the time and cost of design changes and eliminates and enhances design and resolution clashes.	0	1	24	101	65	4.204	8	Agree
	0.00	0.52	12.57	52.88	34.03			
Reducing the project duration improves turnover, visualization, efficiency, and scheduling.	1	2	24	65	99	4.356	3	Agree
	0.52	1.05	12.57	34.03	51.83			
BIM quantifies the Bill of quantity preparation automatically, which increases the level of accuracy.	1	1	26	108	55	4.126	10	Agree
	0.52	0.52	13.61	56.54	28.80			
BIM can monitor and track progress during construction and avoid slippage	1	1	36	60	93	4.272	6	Agree
	0.52	0.52	18.85	31.41	48.69			
BIM can reduce delays in construction	0	7	30	106	48	4.021	15	Agree
	0.00	3.66	15.71	55.50	25.13			

materials delivery, waste								
Benefit Factors of BIM Adoption	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Weighted Mean	Ranking	The General Trend
	Frq %	Frq %	Frq %	Frq %	Frq %			
BIM can monitor, track, and control project budgets.	0	1	18	70	102	4.429	2	Agree
	0.00	0.52	9.42	36.65	53.40			
BIM can improve multi-party communication and maintain synchronized communication	0	0	35	109	47	4.063	14	Agree
	0.00	0.00	18.32	57.07	24.61			
BIM fosters a culture of collaboration among project stakeholders, enhancing teamwork and shared goals throughout the project life cycle	2	2	36	56	95	4.257	7	Agree
	1.05	1.05	18.85	29.32	49.74			
BIM can promote early and accurate decision-making & reduce disputes between the parties involved.	1	0	35	97	58	4.105	12	Agree
	0.52	0.00	18.32	50.79	30.37			
BIM can enhance project quality control, improve predictability, and increase predictability.	0	2	22	76	91	4.340	4	Agree
	0.00	1.05	11.52	39.79	47.64			
BIM can significantly improve safety conditions at construction sites.	0	3	35	99	54	4.068	13	Agree
	0.00	1.57	18.32	51.83	28.27			
BIM improves project documentation.	0	2	30	64	95	4.319	5	Agree
	0.00	1.05	15.71	33.51	49.74			
BIM makes it easier to understand the ongoing project.	0	1	22	109	59	4.183	9	Agree
	0.00	0.52	11.52	57.07	30.89			
Avg. Weighted mean						4.221		Agree
191 Responded 42 Skipped								

The above (Table 4.4.17) illustrates the benefit based on the ranking of the weighted mean, as observed in all participants' responses; generally, the overall trend is "Agreed" across all benefits, with an average weighted mean of 4.221. While respondents generally agree on the benefits of BIM, there are a few areas with slight disagreements or neutral responses.

Top 5 Benefits (Rank 1-5):

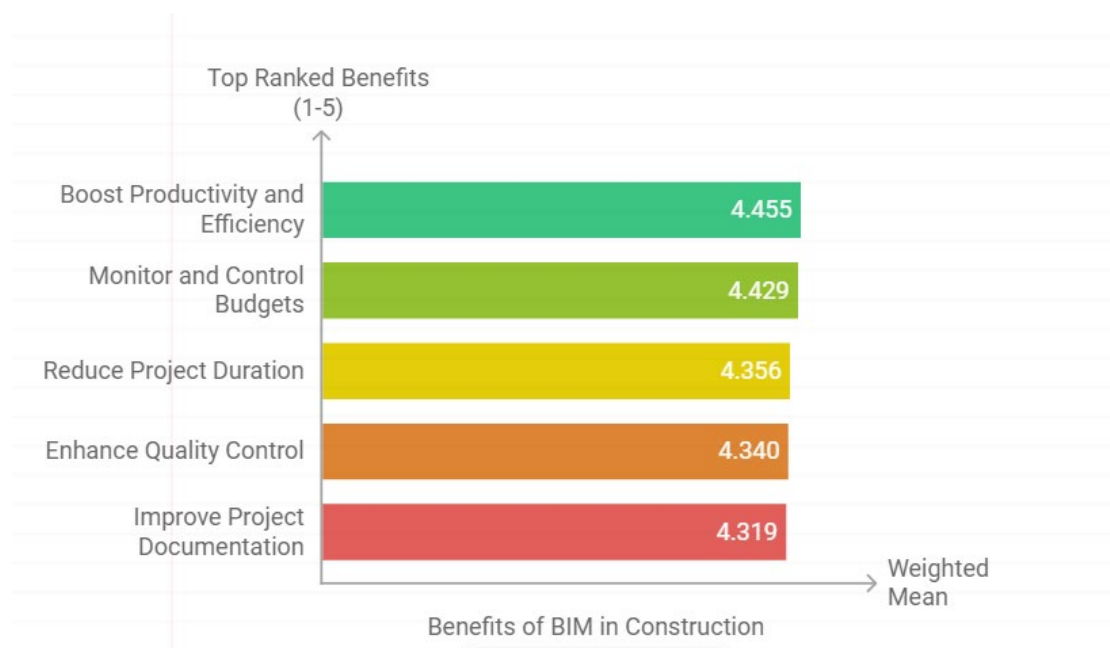


Figure 4.4.3.1: Top-Ranked Benefits (1-5)

- Overall Positive Perception of BIM

The overall trend is “Agreed” across all benefits, with an average weighted mean of 4.221. This robust consensus underscores BIM's high value within the construction industry, particularly in enhancing efficiency, cost savings, and stakeholder collaboration.

A. Top Benefits Reflect Core Strengths of BIM

The top 5 benefits (Figure 4.4.13) are all tied to BIM's ability to enhance core project operations like productivity, budget control, reducing project duration, improving quality control, and project documentation. These benefits have the highest agreement rates, indicating that participants consistently view BIM as an essential tool for:

- Boosting productivity (Rank 1, 89% agree),
- Monitoring and controlling budgets (Rank 2, 90.05% agree),
- Reducing project duration (Rank 3, 85.86% agree).

B. Budget Control, Project Productivity, and Efficiency are Key Drivers of BIM Adoption

The highest-ranked benefits underscore the importance of BIM in boosting productivity and monitoring project budgets. These two factors are critical in ensuring project success, especially in the construction industry, where cost overruns and time delays can lead to significant issues. The high percentage of respondents who “strongly agree” or “agree” (above 85% for these benefits) underscores the importance of these features in BIM adoption, providing a sense of security to the audience.

- Key Points:

- **Productivity and Budget Control** are the most substantial benefits of BIM, with high agreement and low variability. These are critical drivers for BIM adoption.
- **Mid-ranked benefits** like tracking progress and fostering collaboration show more variation in opinions, indicating that the success of these aspects may depend on the context or the project's complexity.

- **Lower-ranked benefits** still show overall positive agreement but have more mixed opinions, especially in areas like reducing material delays and improving safety.
- **There is substantial agreement on BIM's role** in improving quality control and documentation, reflecting BIM's core value in enhancing transparency, accuracy, and efficiency in the construction process.
- **Collaboration and communication improvements** through BIM are recognized, but their effectiveness varies based on organizational adoption levels, indicating that more standardized implementation could improve these perceptions.

4.4.3.2 Consultant/ Engineering Offices Perspective

- **Top-Ranked Factors:**
 1. BIM can monitor, track, and control project budgets (Weighted Mean: 4.458, Rank: 1, Agree)
 2. BIM can significantly boost productivity and work efficiency (Weighted Mean: 4.434, Rank: 2, Agree)
 3. BIM improves project documentation (Weighted Mean: 4.361, Rank: 3, Agree)
 4. BIM fosters a culture of collaboration among project stakeholders (Weighted Mean: 4.329, Rank: 4, Agree)
- **Lower-Ranked Factors:**
 1. BIM can promote early and accurate decision-making & reduce disputes (Weighted Mean: 4.084, Rank: 13, Agree)
 2. BIM can significantly improve safety conditions at construction sites (Weighted Mean: 4.036, Rank: 14, Agree)

3. BIM can reduce delays in construction materials delivery & waste
(Weighted Mean: 4.024, Rank: 15, Agree)

4.4.3.3 Contractor and Other Perspectives

- **Top-Ranked Factors:**

1. BIM makes it easier to understand the ongoing project (Weighted Mean: 4.271, Rank: 1, Agree)
2. BIM can significantly boost productivity and work efficiency
(Weighted Mean: 4.220, Rank: 2, Agree)
3. BIM can monitor, track, and control project budgets (Weighted Mean: 4.186, Rank: 3, Agree)
4. BIM is a tool that assists with design changes and resolution clashes
(Weighted Mean: 4.186, Rank: 4, Agree)

- **Lower-Ranked Factors:**

1. BIM can reduce delays in construction materials delivery and waste
(Weighted Mean: 3.966, Rank: 13, Neutral)
2. BIM fosters a culture of collaboration among project stakeholders
(Weighted Mean: 3.966, Rank: 14, Neutral)
3. BIM improves project documentation (Weighted Mean: 3.949, Rank: 15, Neutral)

4.4.3.4 Government Perspective

- **Top-Ranked Factors:**

1. BIM can significantly boost productivity and work efficiency
(Weighted Mean: 4.776, Rank: 1, Strongly Agree)
2. BIM can reduce project duration (Weighted Mean: 4.714, Rank: 2, Strongly Agree)

3. BIM can enhance project quality control predictability (Weighted Mean: 4.694, Rank: 3, Strongly Agree)
4. BIM improves project documentation (Weighted Mean: 4.694, Rank: 4, Strongly Agree)

- **Lower-Ranked Factors:**

1. BIM can reduce delays in construction materials delivery waste (Weighted Mean: 4.082, Rank: 13, Agree)
2. BIM can improve multi-party communication and maintain synchronization (Weighted Mean: 4.082, Rank: 14, Agree)
3. BIM can significantly improve safety conditions at construction sites (Weighted Mean: 4.082, Rank: 15, Agree)

4.4.3.5 Comparison among Different Sectors.

Figure 4.4.14 illustrates the benefits across different Sectors based on different usage of BIM.

- **BIM is very beneficial when applied to the construction industry.**

All sectors rank this factor similarly, with contractors showing a slightly higher agreement.

- **BIM can significantly boost productivity and work efficiency.**

This benefit is consistently ranked high by all sectors. The government sees the highest benefit in productivity gains, likely due to the scale of public projects. Consultants and contractors also value BIM's impact on productivity and efficiency.

- **BIM assists with the time and cost of design changes and eliminates design clashes.**

Contractors rank this benefit higher, likely because resolving design clashes and reducing design changes impacts their execution efficiency. **Government and Consultants** rank it lower, indicating that while important, other factors may take priority for them.

- **Reducing project duration improves turnover, visualization, and scheduling.**

The government ranks this factor very highly, reflecting their focus on timely project completion, which is crucial for public projects. Consultants and contractors rank it slightly lower but still consider it important.

- **BIM quantifies the Bill of quantity preparation automatically, increasing accuracy.**

Contractors rank this higher than the government or consultants, likely due to its direct impact on their procurement and construction workflows. The government sees less priority in this, possibly because they focus on broader project management aspects.

- **BIM can monitor and track progress during construction and avoid slippage.**

The government and consultants emphasize monitoring and avoiding slippage (Rank 7) more than contractors, who rank it lower.

- **BIM can reduce delays in construction materials delivery and waste.**

This factor ranks low across all sectors, with Contractors and Consultants placing even less importance on it. The government gives

it a slightly higher priority, but BIM's role in reducing material delivery delays and waste is not seen as a significant benefit.

- **BIM can monitor, track, and control project budgets.**

This factor is the top priority for Consultants (Rank 1), reflecting their responsibility for managing financial aspects of projects. Governments and contractors also value it but to a slightly lesser degree, ranking it 5th and 3rd, respectively.

- **BIM can improve multi-party communication and maintain synchronized communication.**

The government places the least emphasis on this factor, ranking it 14th, while Contractors and Consultants rank it similarly but slightly higher. Multi-party communication is generally seen as a less critical benefit across the board.

- **BIM fosters a culture of collaboration among project stakeholders.**

There is a noticeable divergence here. Consultants rank collaboration quite highly (Rank 4), while Contractors give it a much lower priority (Rank 14). This reflects the 'Consultants' need for collaborative work in design phases, while Contractors focus more on execution. The government also ranks this higher, reflecting the complexity of managing multiple stakeholders in public projects.

- **BIM can promote early and accurate decision-making and reduce disputes.**

There is consensus across sectors on this benefit, with all ranking it around the middle. Consultants rank it lower, while Government and Contractors value early decision-making to a higher degree, likely reflecting the complexity and coordination required in their projects.

- **BIM enhances project quality control and predictability.**

The government places significant importance on project quality control, ranking it 3rd. This is likely due to the need for high-quality public infrastructure. Consultants also value this, though Contractors rank it lower, indicating that while important, it is not their top priority.

- **BIM can significantly improve safety conditions at construction sites.**

Contractors emphasize BIM's role in improving safety conditions (Rank 7), likely because safety directly impacts their on-site work and overall project success. Government and Consultants rank it lower, with the government placing the least importance on safety improvements (Rank 15). This could be because they rely more on external safety protocols or see safety as being managed outside the scope of BIM tools.

- **BIM improves project documentation.**

A substantial disparity exists here. Consultants prioritize enhancing project documentation significantly (Rank 3), as they depend extensively on precise and comprehensive documentation to prevent expensive mistakes. The government likewise prioritizes this advantage (Rank 4), presumably because of the significance of transparency and accountability in public initiatives. In contrast, Contractors rank this much lower (Rank 15), indicating that documentation is less critical than actual project execution and on-site management.

- **BIM makes it easier to understand the ongoing project.**

This factor is the top priority for Contractors (Rank 1), as understanding the ongoing project in real-time is crucial for their daily work on-site. Government and Consultants rank it lower (Rank 10), as their roles may rely less on the immediate on-the-ground understanding of the project and more on broader strategic oversight or financial management.

Summary:

A. Top Priorities by Sector:

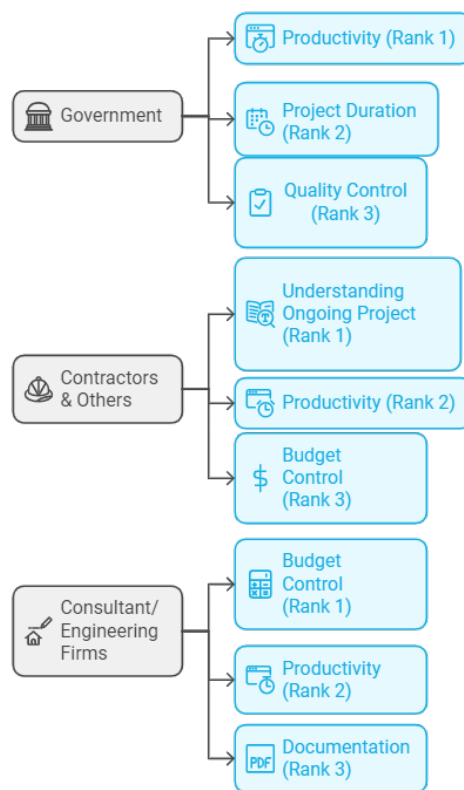


Figure 4.4.3.2: Top Priorities by Sector (Benefits)

B. Differences in Priorities:

- **Understanding the Ongoing Project:** This is the highest priority for contractors but much less critical for governments and consultants, who likely deal with more long-term planning than real-time project execution.
- **Collaboration:** Contractors are ranked much lower compared to consultants and government, indicating that contractors focus more on individual task execution and rely less on multi-party collaboration.
- **Safety:** Contractors rank BIM's role in improving safety higher, reflecting their direct involvement with on-site conditions. Government and Consultants rank it lower, indicating that safety may be managed through other tools and processes outside of BIM.
- **Documentation:** This is highly important for consultants and the government but is ranked the lowest by contractors. The observed discrepancy indicates that Contractors emphasize operational clarity, whereas Consultants and Government entities prioritize accurate documentation for accountability and planning.

4.4.4 Section D: Barriers Factors of BIM Adoption

4.4.4.1 Perceived Barriers to BIM

Questionnaire: Question 1: What challenges does your firm face in adopting and implementing BIM?

Table 4.4.18: Barriers Factors of BIM Adoption

Barriers Factors of BIM Adoption	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Weighted Mean	Ranking	The General Trend
	Frq. %	Frq. %	Frq. %	Frq. %	Frq. %			
<i>BIM's software is expensive and requires a high initial cost.</i>	2	8	35	122	24	3.827	13	Neutral
	1.05	4.19	18.32	63.87	12.57			
<i>BIM's software is complicated to learn.</i>	7	13	47	46	78	3.916	11	Neutral
	3.66	6.81	24.61	24.08	40.84			
<i>Lack of BIM experts within the firm</i>	3	6	36	94	52	3.974	7	Neutral
	1.57	3.14	18.85	49.21	27.23			
<i>Lack of training on BIM.</i>	4	6	34	57	90	4.168	4	Agree
	2.09	3.14	17.80	29.84	47.12			
<i>Long-term training is required for current staff.</i>	3	6	34	104	44	3.942	8	Neutral
	1.57	3.14	17.80	54.45	23.04			
<i>High cost of training current staff.</i>	2	6	38	54	91	4.183	3	Agree
	1.05	3.14	19.90	28.27	47.64			
<i>Lack of knowledge about BIM.</i>	3	3	27	107	51	4.047	6	Agree
	1.57	1.57	14.14	56.02	26.70			
<i>Lack of demand by owners.</i>	2	3	40	50	96	4.230	1	Agree
	1.05	1.57	20.94	26.18	50.26			
<i>Resistance to change the current construction industry culture.</i>	11	6	32	98	44	3.827	14	Neutral
	5.76	3.14	16.75	51.31	23.04			
<i>The application of BIM will affect the current process practice.</i>	15	11	32	51	82	3.911	12	Neutral
	7.85	5.76	16.75	26.70	42.93			
<i>The construction market is not ready for BIM technology.</i>	15	16	39	88	33	3.565	15	Neutral
	7.85	8.38	20.42	46.07	17.28			
<i>Lack of data sharing (collaboration with other professionals)</i>	4	7	43	55	82	4.068	5	Agree
	2.09	3.66	22.51	28.80	42.93			
<i>Insufficient support from top managers.</i>	4	10	31	95	51	3.937	9	Neutral
	2.09	5.24	16.23	49.74	26.70			
<i>Poor awareness of BIM benefits</i>	3	7	28	59	94	4.225	2	Agree
	1.57	3.66	14.66	30.89	49.21			
<i>Insufficient support and participation from the government.</i>	5	5	40	91	50	3.921	10	Neutral
	2.62	2.62	20.94	47.64	26.18			
Avg. Weighted Mean						3.983		Neutral
191 Responded 42 Skipped								

The above table illustrates the barriers based on the ranking of the weighted mean, as observed in all participants' responses; generally, the overall trend is more "Neutral" than "Agree." This implies that some barriers may have higher significance for some respondents across all barrier factors, with an average weighted mean of 3.983, as shown in (Table 4.4.18). Most participants neither strongly agreed nor strongly disagreed with the barriers overall.

A. Top-ranked Barriers to BIM Adoption (1-6):

These barriers have the highest weighted means, meaning respondents perceive them as significant challenges to BIM adoption.

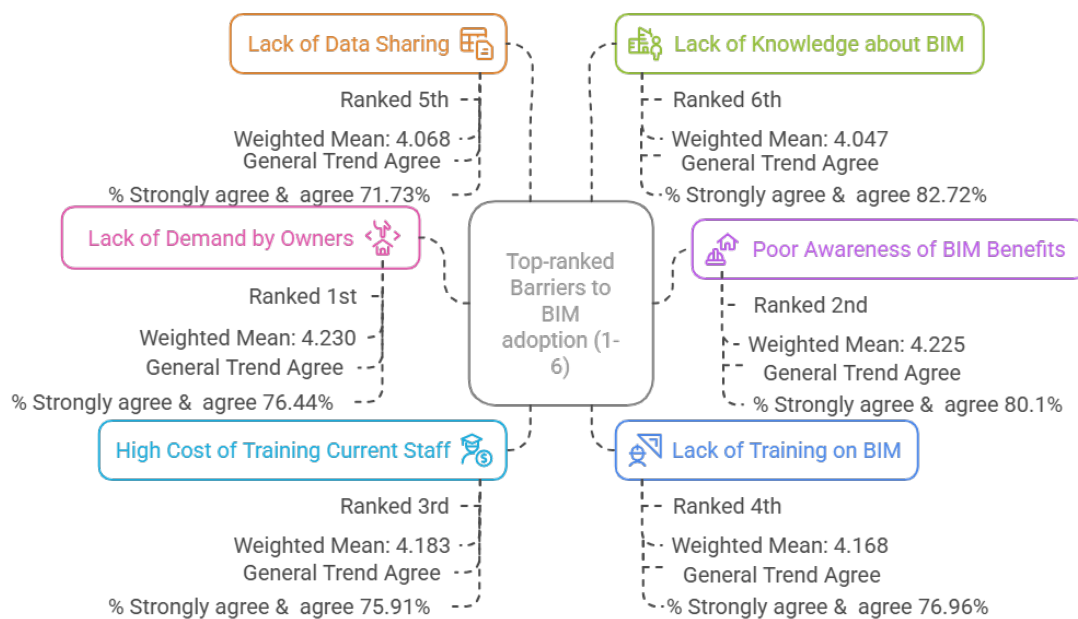


Figure 4.4.4.1: Top-ranked Barriers to BIM adoption (1-6)

Summary:

- **Top-ranked barriers** (Figure 4.4.15), such as lack of demand by owners, poor awareness of BIM benefits, and high training costs, are widely agreed upon as significant obstacles to BIM adoption.
- **Mid-ranked barriers** like lack of internal BIM experts, long-term training requirements, and insufficient support from managers are acknowledged but with more variability in opinions. These barriers reflect organizational challenges that may vary depending on the firm's structure, resources, and readiness to adopt BIM.
- **Lower-ranked barriers**, including BIM software costs, cultural resistance, and market readiness, are seen as less critical while still recognized as obstacles.
- **The average weighted mean** of 3.983 indicates a neutral trend across each barrier. This indicates that although certain obstacles are widely regarded as problems, there is no general agreement that any singular element constitutes the primary barrier to BIM adoption. This neutral trend indicates that an integrated strategy tackling multiple barriers is essential for effective BIM adoption.

4.4.4.2 Consultant/ Engineering Offices Perspective

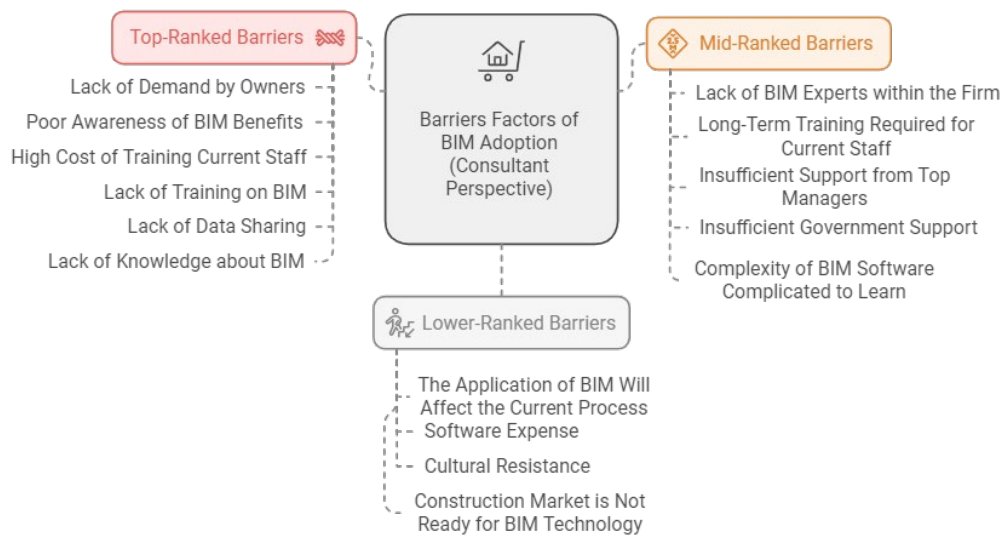


Figure 4.4.4.2: Barriers Ranking Consultant Perspective

- **Top-ranked barriers**, (Figure 4.4.21) Illustrate that Consultants' successful adoption of Building Information Modeling (BIM) faces a combination of external and internal barriers. The most critical challenges are external factors, such as the lack of demand from project owners and the poor awareness of BIM benefits. Consultants find it difficult to justify investing in BIM without strong demand and understanding from clients and stakeholders. These factors are compounded by internal barriers related to the high cost of training staff and the limited availability of effective BIM training programs. These barriers must be addressed to facilitate widespread BIM adoption.
- **Mid-ranked barriers**, such as the lack of in-house BIM experts, long-term training requirements, and insufficient support from top management, while acknowledged, are seen as manageable. Most consulting firms seem to be in the process of adapting to these challenges and implementing strategies to mitigate their impact. This

could include relying on external expertise or developing ongoing training initiatives to keep up with technological advancements.

- **Lower-ranked barriers**, such as the cost of BIM software, resistance to cultural change, and the market's readiness for BIM technology, are considered less critical by consultants. These barriers are perceived as manageable and, in some cases, are no longer viewed as significant obstacles. This indicates a growing industry-wide acceptance of BIM and a general readiness for its adoption.
- **In summary**, for consultants to fully adopt BIM, the key challenges to focus on are increasing external demand, improving stakeholder awareness of BIM benefits, and addressing the financial and logistical hurdles of training. Internal barriers such as the availability of BIM experts and managerial support are important but secondary to the need for stronger client-driven demand. Lower concerns, such as market readiness and cultural resistance, show that the industry is evolving positively towards embracing BIM technology. Still, continued education and structured training remain crucial for successful implementation.

4.4.4.3 Contractor and Other Perspective

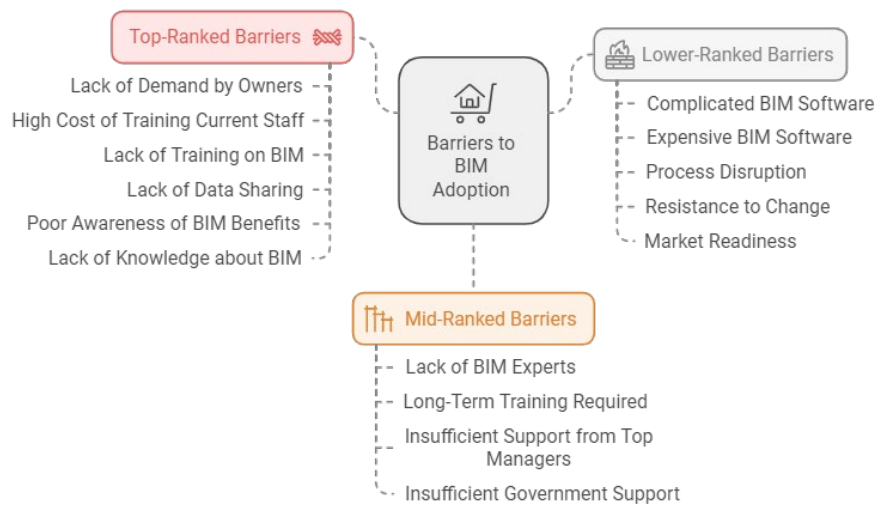


Figure 4.4.4.3: Barriers Ranking Contractor Perspective

- **Top-ranked barriers**, the most significant barriers to BIM adoption for contractors (Figure 4.4.25), are external demand (lack of owner-driven requests for BIM) and internal resource challenges (high costs and lack of training). While contractors recognize the importance of collaboration and raising awareness about BIM's benefits, these barriers rank just below the most critical barriers.
- **Mid-ranked barriers**, such as the lack of BIM experts, managerial support, and long-term training needs, are acknowledged but not considered urgent. Contractors are managing these challenges, expecting to be addressed over time.
- **Lower-ranked barriers**, like software costs, resistance to cultural change, and market readiness, indicate that contractors feel the industry is ready for BIM and are well-positioned to adopt the technology as long as the critical barriers of demand and training are addressed.

4.4.4.4 Government Perspective

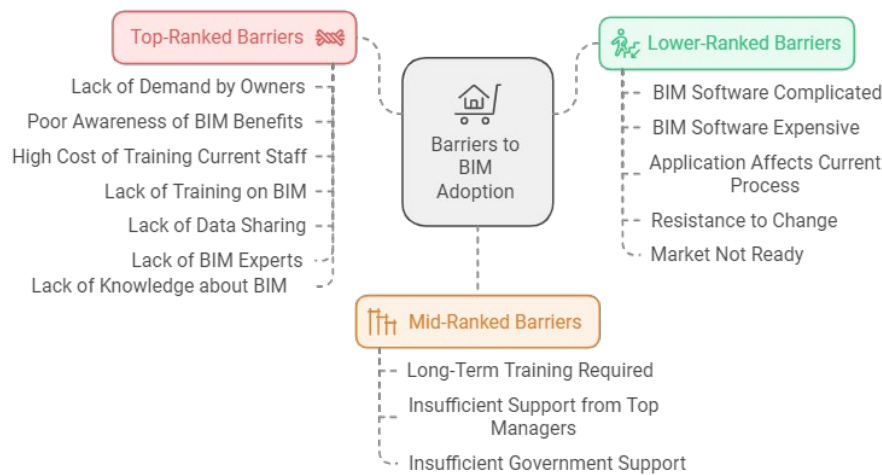


Figure 4.4.4.4: Barriers Ranking Government Perspective

- **Top-ranked barriers**, (Figure 4.4.29) Illustrate that for government organizations, the most pressing barriers to BIM adoption are demand, awareness of BIM benefits, and training costs. The lack of internal BIM experts and the availability of proper training programs are also significant concerns but rank slightly lower.
- **Mid-ranked barriers** such as managerial support, long-term training needs, and government-wide participation are considered moderate challenges but not immediate barriers to adoption.
- **Lower-ranked barriers** such as software costs, cultural resistance, and market readiness are perceived as less critical, indicating that government agencies feel ready to adopt BIM as long as the key barriers of demand, awareness, and training are addressed.

4.4.4.5 Comparison among Different Sectors.

Table 4.4.19: Barriers Comparison among Different Sectors

<i>Barrier Factors</i>	<i>Consultant</i>		<i>Contractor</i>		<i>Government</i>	
	<i>s - Rank</i>	<i>Trend</i>	<i>s - Rank</i>	<i>Trend</i>	<i>Rank</i>	<i>Trend</i>
<i>Poor Awareness of BIM Benefits</i>	2	Agree	5	Agree	2	Agree
<i>High Cost of Training Current Staff</i>	3	Agree	2	Agree	3	Agree
<i>Lack of Training on BIM</i>	4	Agree	3	Agree	4	Agree
<i>Lack of Data Sharing (Collaboration with Other Professionals)</i>	5	Agree	4	Agree	5	Agree
<i>Lack of Knowledge about BIM</i>	6	Agree	6	Agree	7	Agree
<i>Lack of BIM Experts Within the Firm</i>	7	Neutral	7	Neutral	6	Agree
<i>BIM software is Expensive</i>	13	Neutral	12	Neutral	12	Neutral
<i>The Application of BIM Will Affect the Current Process</i>	12	Neutral	13	Neutral	13	Neutral

(Table 4.4.20) shows barriers comparison among different sectors

1. Lack of Demand by Owners

- Weighted Mean: 4.230 (all sectors)
- Rank: 1 in all sectors
- General Trend: Agree

This is the most critical barrier across all three sectors. The lack of demand from project owners for BIM is seen as a major impediment to its widespread adoption. A high weighted mean (4.230) and unanimously agreeing trends indicate that organizations can justify the investment in BIM only if clients specifically request BIM. This barrier affects consultants, contractors, and the government equally, showing that external demand strongly influences BIM adoption.

2. Poor Awareness of BIM Benefits

- **Consultants & Government:** Weighted Mean: 4.225, Rank: 2, Trend: Agree

- **Contractors:** Weighted Mean: 4.047, Rank: 5, Trend: Agree

Both consultants and the government have identified the same barrier as the second most significant obstacle, underscoring the widespread impact of poor awareness of BIM's advantages on its adoption in these sectors. The difficulty in communicating BIM's long-term benefits to clients and stakeholders is a shared challenge.

Contractors rank this slightly lower (5th), indicating that awareness may not be as critical as other barriers, such as cost and training. However, the agreed trend in all sectors underscores the necessity of education and awareness campaigns. This insight equips professionals with the knowledge and understanding they need to navigate the challenges of BIM adoption.

3. High Cost of Training Current Staff

- **Consultants & Government:** Weighted Mean: 4.183, Rank: 3, Trend: Agree

- **Contractors:** Weighted Mean: 4.183, Rank: 2, Trend: Agree

The cost of training staff in BIM (financial burden) is seen as a significant obstacle in all sectors. Contractors, in particular, rank this as the 2nd most considerable barrier, likely because of the operational and technical challenges involved in transitioning staff to BIM workflows. Contractors may face immediate costs in training on-site personnel to become proficient in new technologies. Meanwhile, consultants and the

government still consider BIM training essential, but they view it as less urgent than other barriers, such as demand and awareness.

4. Lack of Training on BIM

- Weighted Mean: 4.168 (all sectors)
- Rank: 4 (all sectors)
- Trend: Agree

The lack of training on Building Information Modeling (BIM) is a significant issue across consultants, contractors, and government sectors. It has a weighted mean of 4.168 and ranks 4th across all sectors with an agree trend. This barrier highlights the challenge of finding high-quality training programs, even when firms are willing to invest in training. It also complements the high cost of training, indicating that the problem is not just financial but also logistical.

5. Lack of Data Sharing (Collaboration with Other Professionals)

- Weighted Mean: 4.068 (all sectors)
- **Consultants & Government:** Rank: 4
- **Contractors:** Rank: 5
- Trend: Agree

Difficulties in collaboration among professionals using BIM are recognized as a significant barrier, consistently ranking in the top 5 across sectors. The need for seamless data exchange between multiple stakeholders (architects, engineers, contractors, etc.) is critical for BIM success. However, many firms struggle with this due to technical challenges or interoperability issues between different systems.

6. Lack of Knowledge about BIM

- **Consultants, Contractors:** Weighted Mean: 4.047, Rank: 6 Trend: Agree

- **Government:** Weighted Mean: 4.047, Rank: 7, Trend: Agree

There is widespread acknowledgment across all sectors of a knowledge gap regarding understanding BIM. Even though the agree trend shows this is a recognized problem, it ranks slightly less critical than demand, training, and collaboration. The government ranks this barrier lower (7th), possibly because it tends to rely more on external expertise than on in-house teams.

7. Lack of BIM Experts Within the Firm

- **Consultants, Contractors:** Weighted Mean: 3.974, Rank: 7, Trend: Neutral

- **Government:** Weighted Mean: 4.047, Rank: 6, Trend: Agree

Consultants and contractors rated this as a moderate issue with a weighted mean of 3.974 and a neutral trend, seventh rank. On the other hand, the government sees this as a slightly more significant barrier, giving it a weighted mean of 4.047, a rank of 6th, and an agree trend. This indicates a greater need for qualified BIM personnel within government organizations, which may face challenges in hiring experts.

- **Top Barriers:** In all sectors, the most significant barriers are the lack of demand by owners, the high cost of training, the lack of training on BIM, and poor awareness of BIM benefits. These factors are crucial for driving adoption and are universally acknowledged as significant barriers, with consistent agreement trends.

- **Mid-Ranked Barriers:** Barriers such as the lack of BIM experts, long-term training needs, and insufficient support from managers and the government rank in the middle, with a neutral trend. These barriers are important but are not considered the most urgent compared to the top barriers.
- **Lower-Ranked Barriers:** barriers such as BIM software cost, resistance to cultural change, and concerns about market readiness rank the lowest across sectors, with neutral trends. These barriers are either seen as manageable or less critical to the success of BIM implementation, showing that firms are generally confident in their ability to handle these challenges
- Overall, the consistent rankings and trends across consultants, contractors, and the government show a high level of agreement on the critical barriers to BIM adoption, with demand, training, and awareness being the most significant barriers to address.

4.4.4.6 Type of Barriers Factors of BIM Adoption

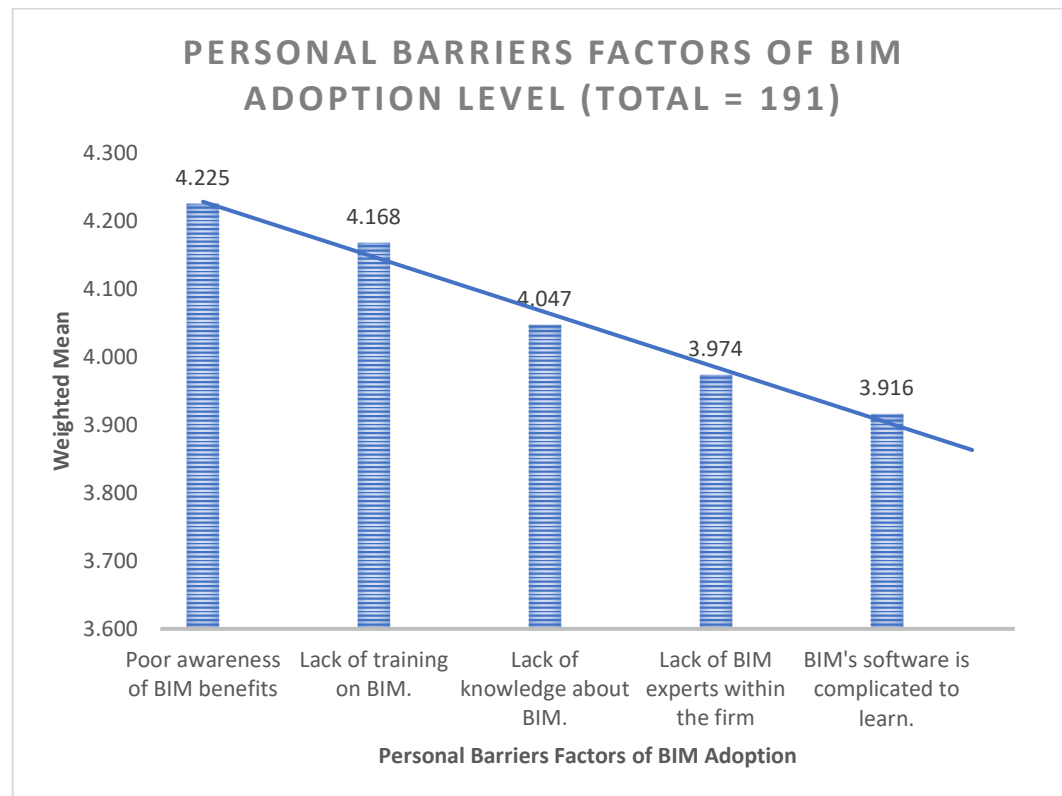


Figure 4.4.4.5: Personal Barriers Factors of BIM Adoption

Figure 4.4.30 shows the personal barriers factors of BIM adoption

1. **Poor awareness of BIM benefits** (Rank 1, Weighted Mean: 4.23, Trend: Agree)

Lack of awareness is a critical issue. When stakeholders, including architects, engineers, and contractors, are unaware of BIM's potential benefits, they may be less inclined to adopt it. This barrier significantly limits the use of BIM across projects, as its value is not fully understood.

2. **Lack of training on BIM** (Rank 2, Weighted Mean: 4.17, Trend: Agree):

Inadequate training severely impacts BIM implementation. Without sufficient training, staff may not feel confident using BIM tools, leading to poor utilization or incorrect implementation. This barrier hinders the full realization of BIM's advantages.

3. **Lack of knowledge about BIM** (Rank 3, Weighted Mean: 4.05, Trend: Agree)

This barrier highlights a knowledge gap, which can reduce the likelihood of successful BIM deployment. If professionals lack fundamental knowledge about BIM processes, integration across the project lifecycle may suffer, leading to inefficient workflows.

4. **Lack of BIM experts within the firm** (Rank 4, Weighted Mean: 3.97, Trend: Neutral):

The lack of skilled BIM experts within firms makes it difficult to lead and manage BIM projects effectively. Without in-house expertise, firms might rely on external resources, increasing project costs and slowing adoption.

5. **BIM's software is complicated to learn** (Rank 5, Weighted Mean: 3.92, Trend: Neutral):

While this barrier ranks lower, it still impacts adoption. Complex software learning curves can discourage users from engaging with BIM. Simplifying software and providing better user interfaces may reduce this barrier.

Personal barriers, especially a lack of awareness and training, significantly affect BIM adoption by limiting individual capabilities and understanding of the technology. These are the most critical barriers to address for successful adoption at the personal level.

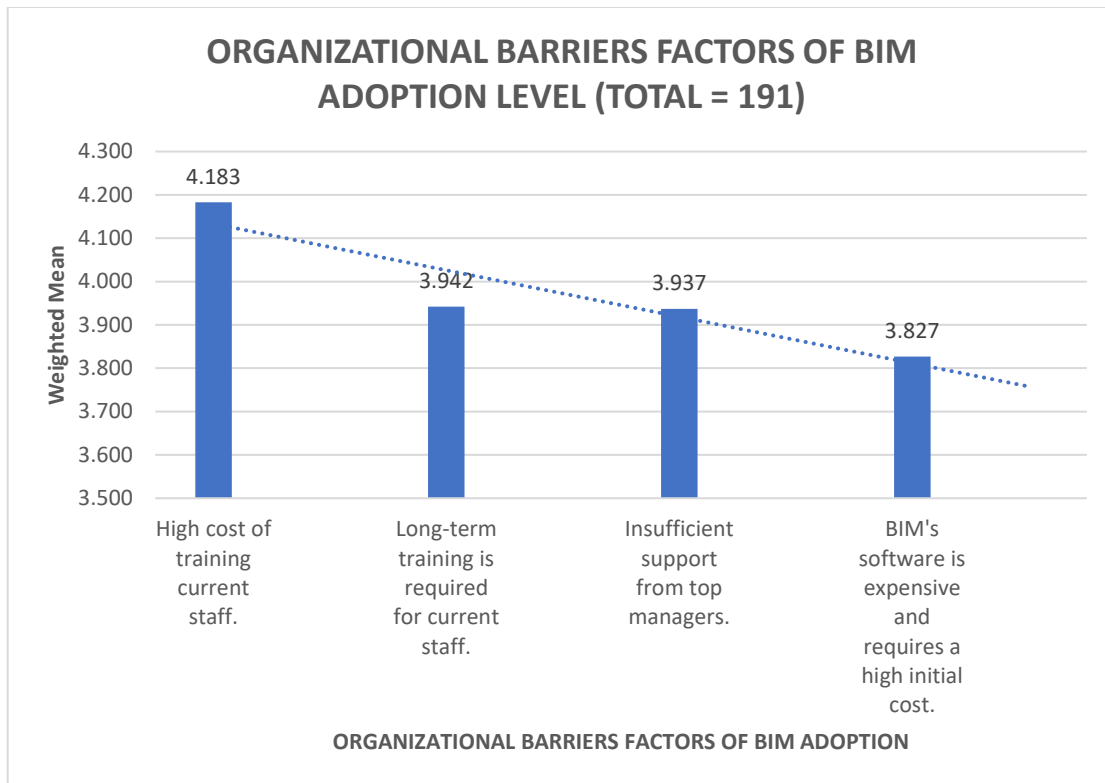


Figure 4.4.4.6: Organizational Barriers Factors of BIM Adoption

Figure 4.4.31 shows the organizational barriers factors of BIM adoption

1. **High cost of training current staff** (Rank 1, Weighted Mean: 4.18, Trend: Agree):

Training costs are a substantial financial burden on organizations. High costs may prevent firms from investing in upskilling their staff, slowing the rate of BIM adoption. It indicates that while firms recognize the importance of training, financial constraints limit their ability to implement BIM effectively.

2. **Long-term training is required for current staff** (Rank 2, Weighted Mean: 3.94, Trend: Neutral):

The long-term nature of BIM training is a challenge because it requires sustained effort and resources. Firms may hesitate to invest in lengthy

training programs, delaying the development of a skilled workforce capable of managing BIM projects.

3. **Insufficient support from top managers** (Rank 3, Weighted Mean: 3.94, Trend: Neutral):

A lack of managerial support slows down BIM implementation within organizations. Without backing from senior leadership, BIM projects may be underfunded or not prioritized, leading to poor organizational commitment to BIM adoption.

4. **BIM's software is expensive and requires a high initial cost** (Rank 4, Weighted Mean: 3.83, Trend: Neutral):

High software costs are a significant barrier, especially for smaller firms with limited budgets. The high upfront cost prevents investment in BIM, delaying its implementation. However, larger firms may have the financial resources to overcome this barrier more easily.

At the organizational level, financial barriers, particularly training and software costs, have the greatest impact on BIM adoption. The need for long-term training and the lack of top management support further hinders firms' ability to adopt BIM fully.

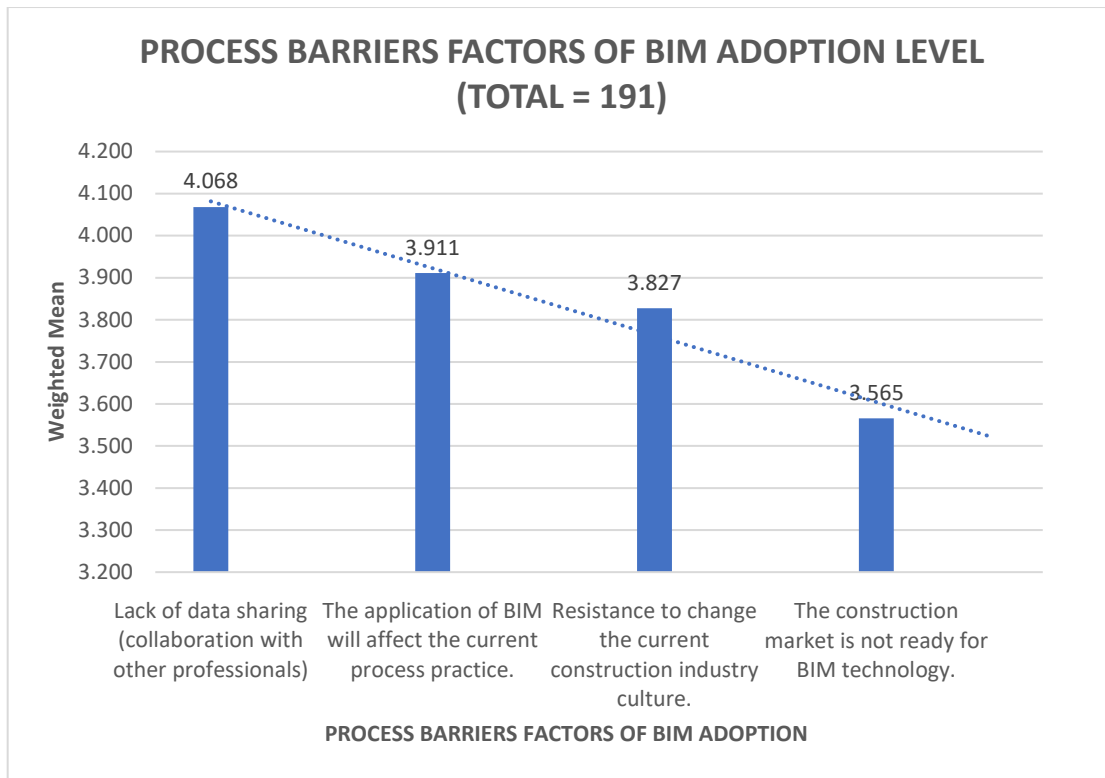


Figure 4.4.4.7: Process Barriers Factors of BIM Adoption

Figure 4.4.32 shows the process barriers factors of BIM adoption

1. **Lack of data sharing (collaboration with other professionals)** (Rank 1, Weighted Mean: 4.07, Trend: Agree):

BIM relies on collaborative processes to succeed, and a lack of data sharing among professionals significantly undermines its benefits. This barrier disrupts the flow of information, leading to inefficiencies and poor coordination between teams, which is crucial for BIM's integrated workflows.

2. **The application of BIM will affect the current process practice** (Rank 2, Weighted Mean: 3.91, Trend: Neutral):

Resistance to altering established workflows can hinder the full integration of BIM. If firms are disinclined to adapt their processes to

accommodate BIM, they may not realize their full potential, leading to partial or inefficient implementations.

3. **Resistance to change the current construction industry culture** (Rank 3, Weighted Mean: 3.83, Trend: Neutral):

Cultural resistance to change is a significant barrier within the construction industry. Despite its proven benefits, traditional practices and a reluctance to adopt new technologies mean BIM adoption is often slow.

4. **The construction market is not ready for BIM technology** (Rank 4, Weighted Mean: 3.57, Trend: Neutral):

If the market is not fully prepared for BIM, it creates an environment where even forward-thinking firms may face difficulties due to a lack of infrastructure, skills, or industry-wide standards. This slows down overall adoption rates despite potential interest from individual firms.

Overcoming these process barriers, particularly the lack of collaboration and resistance to change, is crucial to fully realizing BIM's potential. It will require significant shifts in firm practices and the broader culture of the construction industry.

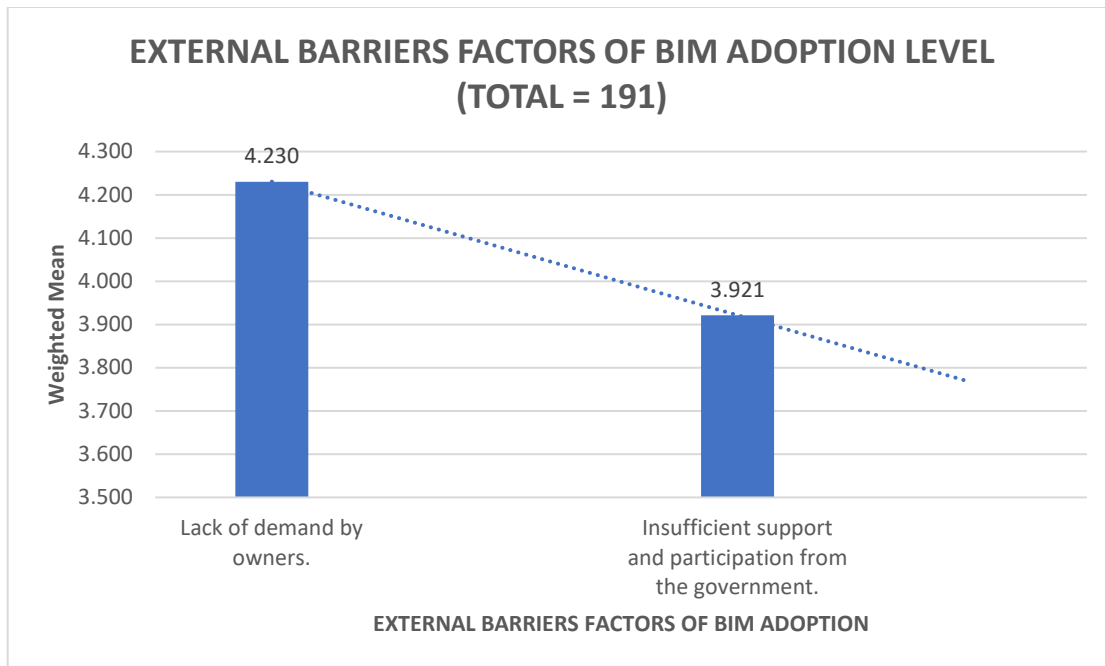


Figure 4.4.4.8: External Barriers Factors of BIM Adoption

Figure 4.4.33 shows the External barriers factors of BIM adoption

1. **Lack of demand by owners** (Rank 1, Weighted Mean: 4.23, Trend: Agree)

This is the most significant external barrier, as project owners play a crucial role in driving BIM adoption. If owners do not demand BIM, it creates a lack of incentive for firms to invest in the technology. Overcoming this barrier requires educating owners about BIM's benefits.

2. **Insufficient support and participation from the government** (Rank 2, weighted mean: 3.92, trend: agree):

The lack of government support, including regulations, policies, and incentives, slows BIM adoption. Governments have a pivotal role in setting industry standards and offering incentives, such as tax breaks or subsidies that encourage firms to adopt BIM.

External barriers, particularly the lack of demand from project owners and insufficient government support, significantly limit BIM adoption. These factors are critical because they influence industry-wide adoption rather than individual firm-level decisions.

4.4.4.6.1 Overall Impact of Barriers at Each Level

- **Personal Barriers:** These are the most critical barriers, as they directly affect the knowledge, awareness, and capabilities of individuals. Without addressing personal barriers, the industry will struggle to train skilled professionals who can use BIM effectively.
- **Organizational Barriers:** These primarily concern financial and managerial constraints. Firms must invest in training and support from leadership to adopt BIM successfully, but the high costs and long-term commitments make this challenging.
- **Process Barriers:** These barriers relate to industry-wide practices and collaboration. Addressing the lack of data sharing and resistance to change is essential for integrating BIM into existing workflows.
- **External Barriers:** These are significant because they affect the broader industry. Without demand from owners and support from governments, BIM adoption will be slow and fragmented, even if individual firms are willing to invest in the technology.

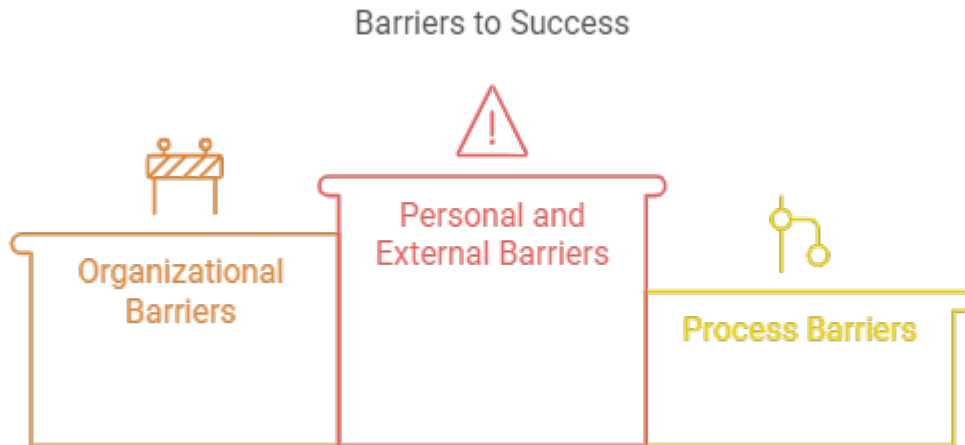


Figure 4.4.4.9: Barriers to Success

Each category of barriers plays a critical role in limiting BIM adoption. Personal and external barriers are seen as the most significant (Figure 4.4.34), followed by organizational and process barriers. To drive widespread BIM adoption, the industry must address these barriers holistically, focusing on training, reducing costs, promoting collaboration, and increasing demand from both owners and governments.

4.4.5 Section E: Measures to overcome BIM adoption and implementation challenges and assets the transformation needed (Adoption Factors).

Questionnaire: Question 1: 1. To what level can the following factors assist your company in overcoming BIM adoption and implementation challenges and improving BIM implementation capabilities?

Table 4.4.20: Factors Influencing BIM Adoption

<i>BIM Adoption Factors</i>	<i>Strongly Disagree</i>	<i>Disagree</i>	<i>Neutral</i>	<i>Agree</i>	<i>Strongly Agree</i>	<i>Weighted Mean</i>	<i>Ranking</i>	<i>The General Trend</i>
	<i>Freq.</i>	<i>Freq.</i>	<i>Freq.</i>	<i>Freq.</i>	<i>Freq.</i>			
	<i>%</i>	<i>%</i>	<i>%</i>	<i>%</i>	<i>%</i>			
<i>Government support through legislation</i>	1	5	28	56	101	4.314	1	Agree
	0.52	2.62	14.66	29.32	52.88			
<i>Full integration into academic programs</i>	1	4	27	70	89	4.267	2	Agree
	0.52	2.09	14.14	36.65	46.60			
<i>Availability of BIM software</i>	5	6	33	101	46	3.927	3	Neutral
	2.62	3.14	17.28	52.88	24.08			
<i>Participation in relevant professional organizations</i>	1	2	32	136	20	3.901	4	Neutral
	0.52	1.05	16.75	71.20	10.47			
<i>Avg. Weighted mean</i>						4.102		Agree

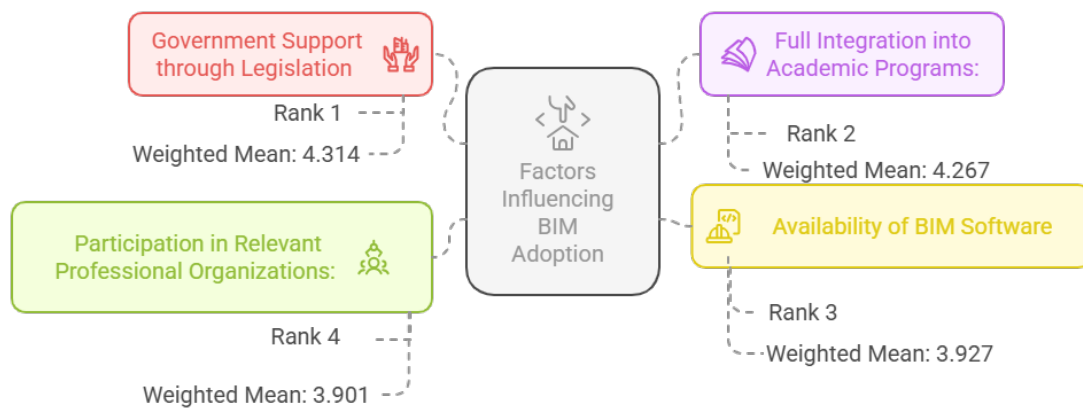


Figure 4.4.5.1: Factors Influencing BIM Adoption

The above (Table 4.4.20, Figure 4.4.35) shows the factors influencing BIM adoption, which need to overcome the BIM barriers.

1. Government Support through Legislation (Weighted Mean: 4.314, Rank: 1)

Government support through legislation stands out as the most critical factor driving BIM adoption, with a weighted mean of 4.314 and a first ranking indicating strong collective agreement among respondents. A significant majority, 52.88%, strongly agree, and 29.32% agree, underscoring the belief that government intervention is essential for the widespread implementation of BIM. The overall sentiment is very positive, with little disagreement (only 0.52% strongly disagree and 2.62% disagree). The general trend towards agreement reinforces the importance of government policies and regulations in setting standards, ensuring compliance, and promoting the consistent use of BIM across industries. This data highlights the crucial role of legislative frameworks in accelerating BIM adoption, addressing industry-wide challenges, and fostering uniformity in practice.

In summary, government intervention is viewed as the single most crucial factor for BIM adoption. The strong agreement indicates that respondents believe government policies, mandates, or incentives can significantly influence BIM implementation. Without this, adoption may face barriers such as lack of standardization, financial costs, or resistance to change.

2. Full Integration into Academic Programs: (Weighted Mean: 4.267, Rank: 2)

Full Integration into Academic Programs is ranked 2nd with a weighted mean of 4.267, reflecting strong support for incorporating BIM into education. A significant portion of respondents agree (36.65%) and strongly agree (46.60%) that integrating BIM into academic curricula is crucial for preparing future professionals. There is minimal opposition, with only 0.52% strongly disagreeing and 2.09% disagreeing, indicating that the vast majority recognize the importance of formal BIM education. The general trend shows broad agreement, affirming that integrating BIM into educational programs is viewed as necessary for ensuring the next generation of professionals are well-equipped to implement BIM effectively in the workforce. This highlights the need for academic institutions to align their training with industry requirements for long-term BIM success.

3. Availability of BIM Software: (Weighted Mean: 3.927, Rank: 3)

Availability of BIM Software ranks 3rd with a weighted mean of 3.927, indicating a somewhat more moderate level of agreement. A large percentage of respondents agree (52.88%) that software availability is

essential, though fewer strongly agree (24.08%), while a notable portion remains neutral (17.28%). This indicates that while respondents acknowledge the importance of access to BIM software, they do not see it as the primary barrier to adoption. The general trend is neutral, signaling that software availability may not be perceived as the primary driver of BIM adoption, although it is necessary. This indicates that while having access to the appropriate tools is crucial, they must also come with training, support, and other structural components to ensure effective implementation.

4. Participation in Relevant Professional Organizations: (Weighted Mean: 3.901, Rank: 4)

Participation in Relevant Professional Organizations ranks 4th with the lowest weighted mean of 3.901, indicating that while professional organizations are seen as helpful, they are not considered crucial for BIM adoption compared to other factors like government support or academic integration. Most respondents agree (71.20%), but only 10.47% strongly agree, and a significant 16.75% remain neutral, reflecting more reserved support for this factor. The general trend is neutral, indicating that while professional organizations are beneficial for networking and collaboration, they are not perceived as essential to driving BIM adoption. This highlights the idea that industry associations are supportive. Still, structural elements like legislation and education are seen as more important in promoting BIM practices on a large scale.

4.4.6 Section F: General Question (Willing to Adopt BIM)

Questionnaire: Question 1: If given the chance and support, do you think your organization is willing to change from a traditional/ manual approach to BIM?

4.4.6.1 Willing to Adopt BIM

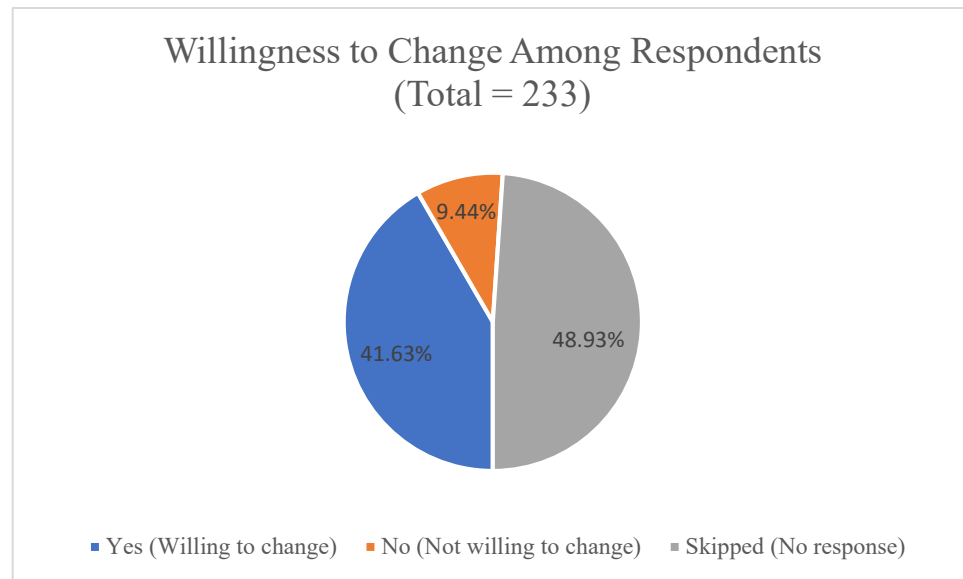


Figure 4.4.6.1: Willing to change from Traditional to BIM

○ **Refined Target Audience:**

The question of willingness to change is relevant to respondents who:

- Have fair knowledge or are well-informed about BIM but do not use BIM tools currently.
- They are not yet adopting BIM but are in a position to consider it. This potential for change is a key factor in our study.

○ **Exclusion:**

Respondents are currently using BIM tools since they've already adopted the technology.

Respondents are unaware of BIM since they lack sufficient understanding to provide a meaningful answer.

So, a total of (119 out of 233) (51.07%) respondents from the target respondents only

- **Yes (willing to change)—97 respondents:**

As shown in (Figure 4.4.36), about 28.7% of the total respondents (97 out of 233) indicated that they are willing to change. This indicates that a significant portion of the participants are open to adopting new processes, technologies, or methodologies in their organizations. This indicates a moderate level of preparedness and adaptability in the workforce for organizational changes. This group can be seen as early adopters, and their presence can positively impact the success of any transformation initiative.

- **No (not willing to change)—22 respondents:**

This group constitutes around 9.4% of the total respondents. These are individuals who are resistant to change, preferring to continue with current processes or methods. Although this is a smaller group, their resistance may stem from various factors, including fear of the unknown, discomfort with new technologies, and concerns about training and costs. If their barriers are not addressed, their resistance could impede organizational changes.

- **Skipped (no response)—114 respondents:**

A significant 48.9% of respondents did not answer this question. This large percentage indicates they are either already aware of and currently using BIM tools or have a lack of sufficient knowledge about BIM.

4.4.6.2 Willing to Adopt BIM by Education Level

Table 4.4.21: Willing to Adopt BIM by Education Level

<i>Willingness to Change</i>	<i>Diploma (Rank 3)</i>	<i>Bachelor's degree (Rank 1, Yes, willing to change)</i>	<i>Master's degree (Rank 2)</i>	<i>PhD degree (Rank 4)</i>	<i>Total</i>
Yes	6	62	27	2	97
Percentage %	5.04	52.10	22.69	1.68	81.51
No	0	16	6	0	22
Percentage %	0.00	13.45	5.04	0.00	18.49
Total	6	78	33	2	119
Percentage %	5.04	65.55	27.73	1.68	100.00

**Willingness to Change by
Education Level**

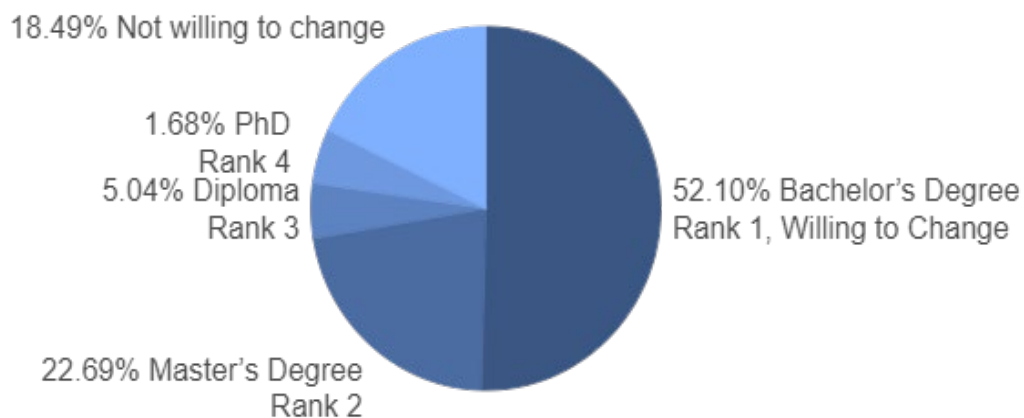


Figure 4.4.6.2: Willing to Change by Education Level

(Table 4.4.22), (Figure 4.4.37) shows willingness to change by education level, which shall be taking into consideration the need for improve the educational background.

- **Majority Willing to Change:** 81.51% of respondents are willing to change across all education levels. This strongly indicates openness to adopting new processes or technologies, such as BIM.
- **Small but Important Resistance:** A minority (18.49%) of respondents resist change, with the highest concentration of resistance among bachelor's degree holders.
- **Summary:** The willingness to change is highest among bachelor's and master's degree holders, who represent the majority of respondents. However, a notable portion of resistance exists, especially among bachelor's degree holders. Addressing the concerns of this group could be critical to driving successful organizational change. Meanwhile, the complete willingness of diploma and PhD holders makes them excellent candidates for early implementation efforts.

4.4.6.3 Willing to Adopt BIM by Business Type

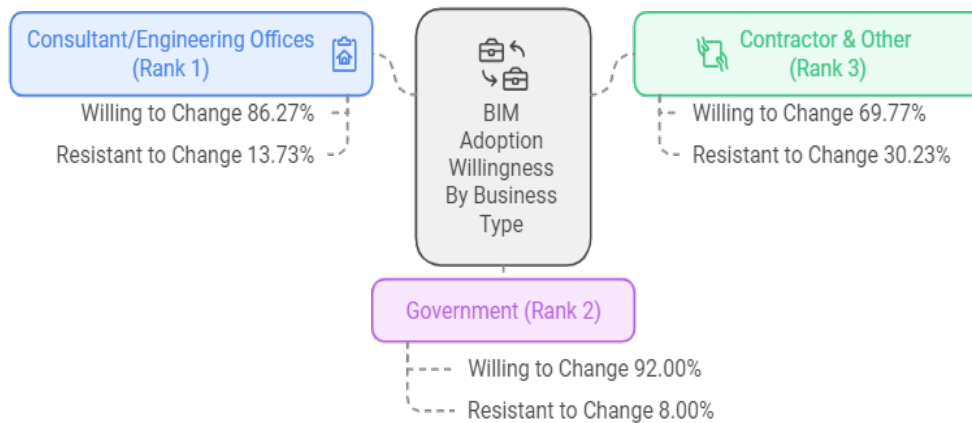


Figure 4.4.6.3: Willing to Adopt BIM by Business Type

- **Consultants/engineering offices** and **the government** are key drivers for BIM adoption as shown in (Figure 4.4.38). Their willingness and

influence in the design and regulatory phases positions them to spearhead BIM initiatives.

- **Contractors** need focused interventions to address costs, operational changes, and training concerns. Contractors could become essential players in implementing BIM on construction sites if these challenges are managed. Willing to Adopt BIM by Experience Level

Table 4.4.22: Willing to Adopt BIM by Experience Level

<i>Experience (Years)</i>	<i>Yes</i>	<i>No</i>	<i>Total</i>	<i>Yes %</i>	<i>No %</i>	<i>Total %</i>	<i>Rank (Yes)</i>
<i>Less than five years</i>	21	7	28	21.65%	31.82%	23.53%	2
<i>6-10 years</i>	26	6	32	26.80%	27.27%	26.89%	1
<i>11-15 years</i>	18	8	26	18.56%	36.36%	21.85%	3
<i>16-20 years</i>	14	1	15	14.43%	4.55%	12.61%	5
<i>More than 20 years</i>	18	0	18	18.56%	0.00%	15.13%	4

**Willingness to Change by
Experience Level**

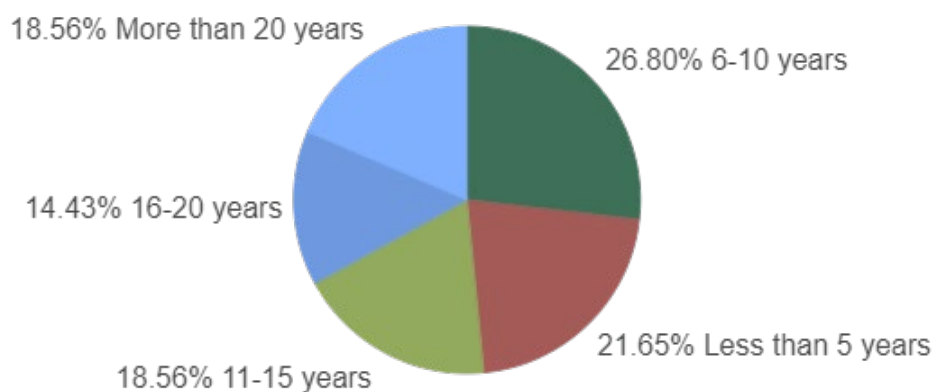


Figure 4.4.6.4: Willing to Adopt BIM by Experience Level

Summary: The data in (Table 4.4.24) & (Figure 4.4.39) indicate that professionals with 6–10 years of experience and those with more than 20 years of experience are the most open to adopting BIM. The 11–15-year

group presents the most significant challenge due to their high resistance. In contrast, professionals with less than five years of experience represent the next generation of professionals who are open to change but need support to overcome their hesitations. Organizations should focus on leveraging the most experienced and mid-career professionals' willingness to drive BIM adoption across teams.

4.5 Research Hypotheses testing

4.5.1 Level of Awareness of Building Information Modeling (BIM).

HB1. Null Hypothesis (H0): The construction industry in Bahrain indicates a **low level of awareness and usage** of Building Information Modeling (BIM), as most organizations lack knowledge about BIM.

Alternative Hypothesis (Ha): The construction industry in Bahrain indicates a **high level of awareness and usage** of Building Information Modeling (BIM), and most organizations have knowledge about BIM.

To assess the hypothesis, we first need to combine the higher categories of awareness (Table 4.4.9).

- Fair knowledge of BIM (18.5%)
- Well-informed about BIM but no usage (32.6%)
- Aware and currently using BIM tools (30.9%)

To assess low awareness, we focus on the following group:

- Not aware of BIM (18%)

Calculating the Total Awareness and Usage:

- Fair knowledge of BIM + Well-informed + Aware and using BIM = $18.5\% + 32.6\% + 30.9\% = 82\%$
- This means 82% of individuals are aware of BIM through basic knowledge, being well-informed, or actively using it.

Since 82% of the population is either aware of or currently using BIM, this exceeds the 50% threshold for high awareness and usage. BIM Therefore, reject the null hypothesis (H0) and accept the alternative hypothesis (Ha), concluding that the construction industry in Bahrain indicates a high level of awareness and usage of BIM, and most organizations have knowledge about BIM.

The results demonstrate that the Bahrain construction industry is knowledgeable about BIM, with a substantial portion of respondents being either well-informed or already using BIM tools.

4.5.2 Building Information Modeling (BIM) Software/Tool Usage Level.

HB2. Null Hypothesis (H0): There is no significant difference in the software usage listed in Bahrain (AutoCAD, Revit, Bentley, ArchiCAD, BIM 360, etc.).

Alternative Hypothesis (Ha): There is a significant difference in the software usage listed in Bahrain (AutoCAD, Revit, Bentley, ArchiCAD, BIM 360, etc.).

Since the data does not follow a normal distribution , non-parametric tests shall be used to evaluate the software usage and ratings. Non-parametric tests are ideal because they do not rely on assumptions about the data

distribution, such as normality. As mentioned in the methodology chapter, the Chi-Square Test is used to determine whether there is a significant difference between the observed frequencies of software usage and the expected frequencies (assuming equal usage across software tools).

The Friedman Test is the second non-parametric test that is suitable for evaluating the data because it deals with ordinal data (the ratings of the software tools) and repeated measures (the same participants rated multiple tools).

- Chi-Square Test:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Equation 4.5.2-1: Chi-Square Test

Where:

O_i = **Observed frequency** for a specific rating and software tool.

E_i = **Expected frequency** under the assumption that all tools would receive similar ratings.

Table 4.5.1: Total Chi-Square Contribution

<i>Software Tool</i>	<i>Total Chi-Square Contribution</i>
<i>AutoCAD</i>	73.20
<i>Revit Program</i>	73.23
<i>Navisworks</i>	17.26
<i>Bentley</i>	38.91
<i>Tekla</i>	33.43
<i>ArchiCAD</i>	30.61
<i>BIM 360</i>	26.99

- Calculations as per Table 4.5.1, The total **Chi-Square Statistic** is **295.66**.
- Since the p-value associated with this statistic is extremely small (based on 24 degrees of freedom), we reject the null hypothesis.

- Friedman Test:

Table 4.5.2: Descriptive Statistics for Software tools

<i>Descriptive Statistics</i>		
	N	Mean
<i>AutoCAD Architecture Program</i>	191	3.91
<i>Autodesk Revit Program</i>	191	3.78
<i>Autodesk Navisworks Program</i>	191	3.07
<i>Bentley Program</i>	191	3.31
<i>Tekla Program</i>	191	2.86
<i>ArchiCAD Program</i>	191	3.20
<i>BIM 360</i>	191	2.89

1. Assigning Ranks for Each Participant

Each participant's rating of the software tools is converted into ranks (Table 4.5.2). The tool with the highest rating receives the lowest rank (1), and the tool with the lowest rating receives the highest rank.

2. Calculating the Sum of Ranks for Each Software Tool

Once the ratings for all participants are ranked, the sum of ranks for each software tool is calculated by summing the ranks given to each tool across all participants (Table 4.5.3).

Table 4.5.3: Rank Sum for Software Tools

<i>Software Tool</i>	<i>Rank Sum</i>
<i>AutoCAD</i>	855.5
<i>Revit Program</i>	981.5
<i>Navisworks</i>	662.0
<i>Bentley</i>	834.5
<i>Tekla</i>	585.0
<i>ArchiCAD</i>	816.0
<i>BIM 360</i>	613.5

3. Calculating the Mean Ranks (Table 4.5.4)

Table 4.5.4: Rank Mean for Software Tools

<i>Ranks</i>	Mean Rank
<i>AutoCAD Architecture Program</i>	4.48
<i>Autodesk Revit Program</i>	5.14
<i>Autodesk Navisworks Program</i>	3.45
<i>Bentley Program</i>	4.37
<i>Tekla Program</i>	3.07
<i>ArchiCAD Program</i>	4.28
<i>BIM 360</i>	3.22

$$\chi_F^2 = \frac{12}{nk(k+1)} \sum R_j^2 - 3n(k+1)$$

Equation 4.5.2-2: Friedman Test

Where:

- n=191 (number of participants),

- $k=7$ (number of software tools),
- R_j is the rank sum for each software tool.

$$X^2 f = 188.62$$

Using the Friedman test statistic (188.62) with $k-1=6$ degrees of freedom, we get a p-value of:

$$p=5.03 \times 10^{-38}$$

Table 4.5.5: Rank and Mean Rank for Software Tools

<i>Rank</i>	<i>Software Tool</i>	<i>Mean Rank</i>
1	Revit Program	5.14
2	AutoCAD	4.48
3	Bentley	4.37
4	ArchiCAD	4.27
5	Navisworks	3.47
6	BIM 360	3.21
7	Tekla	3.06

(Table 4.5.5) illustrate the following:

- **Revit Program** has the highest mean rank (5.14), indicating that it was rated the most favorably by participants.
- **Tekla** has the lowest mean rank (3.06), indicating that it received the lowest ratings on average.

Since the **Friedman Test** statistic shows a significant difference ($\chi^2 F=188.62$, p-value $5.03 \times 10^{(-38)}$), we conclude that the differences in the rankings of the software tools are statistically significant.

- **Summary:** Both tests lead to the rejection of the null hypothesis, indicating significant differences in both the usage and ratings of the software tools.

4.5.3 Purpose of BIM Usage:

HB3. Null Hypothesis (H0): In Bahrain's construction industry, basic BIM functions like 2D Drawings, 3D Modeling/Presentation, Construction/As-Built Drawings, and Site Logistics are more frequently used than advanced BIM functions.

- **Alternative Hypothesis (Ha):** Advanced BIM functions (such as Clash Detection, 4D/5D modeling, etc.) are as frequently used or more frequently used than basic BIM functions.

Since the data does not follow a normal distribution, non-parametric tests shall be used to evaluate the BIM Function Adoption Level with respect the hypothesis above.

By testing HB3 according to the Total Frequency (Result as shown in the table below (Table 4.5.6)):

Table 4.5.6: BIM Function Adoption Hypothesis Test

<i>BIM Function Adoption</i>	<i>Total Frequently (Frequent + Very Frequent)</i>	<i>Conclusion</i>
<i>Basic BIM Functions</i>		
<i>2D Drawings</i>	73	Reject H ₁ , Accept H ₀ (frequent usage)
<i>3D Modeling/Presentation</i>	77	Reject H ₁ , Accept H ₀ (frequent usage)
<i>Construction / As-Built Drawings</i>	68	Reject H ₁ , Accept H ₀ (frequent usage)
<i>Visualization</i>	62	Reject H ₁ , Accept H ₀ (frequent usage)
<i>Site Logistics</i>	55	Reject H ₁ , Accept H ₀ (frequent usage)
<i>Advanced BIM Functions</i>		
<i>Planning and 4D Scheduling</i>	49	Reject H ₁ , Accept H ₀
<i>Budgeting and 5D Cost Estimation</i>	45	Reject H ₁ , Accept H ₀
<i>Engineering and 6D Sustainability Analysis</i>	46	Reject H ₁ , Accept H ₀
<i>7D Building Management</i>	45	Reject H ₁ , Accept H ₀
<i>Clash Detection</i>	50	Reject H ₁ , Accept H ₀
<i>Building Performance Analysis</i>	50	Reject H ₁ , Accept H ₀
<i>8D Safety Hazards Identification & Emergency</i>	46	Reject H ₁ , Accept H ₀

The **Null Hypothesis (H₀)** is **accepted** for all BIM functions. This means that basic BIM functions like 2D Drawings, 3D Modeling, and Visualization are more frequently used compared to advanced BIM functions like Clash Detection or 6D Sustainability.

4.5.4 Benefit Factors of BIM Adoption

Since the data does not follow a normal distribution, non-parametric tests will be used to evaluate the Benefit Factors of BIM Adoption with respect to the hypotheses outlined. A non-parametric one-sample test (Wilcoxon signed-rank test (Riina et al., 2023)) will be performed to test each hypothesis independently.

The test will evaluate whether the median value differs significantly from 3, which represents the neutral point on a Likert scale. If the p-value is less than 0.05, we reject the null hypothesis and accept the alternative hypothesis, indicating that the benefit factor is significant (Table 4.5.7).

Table 4.5.7: Benefit Factors of BIM Adoption Hypothesis Testing

<i>Benefit Factors of BIM Adoption</i>	<i>Hypothesis</i>	<i>p-value</i>	<i>Reject Null Hypothesis</i>
<i>HB4A. BIM is very beneficial when applied to the construction industry.</i>	-Null Hypothesis (H0): BIM does not provide any significant benefits when applied to the construction industry. -Alternative Hypothesis (Ha): BIM provides significant benefits when applied to the construction industry.	3.945E-30	Yes
<i>HB4B. BIM can promote early and accurate decision-making and reduce disputes between the parties involved.</i>	-Null Hypothesis (H0): BIM does not promote early and accurate decision-making or reduce disputes between the parties involved. - Alternative Hypothesis (Ha): BIM promotes early and accurate decision-making and reduces disputes between the parties involved.	3.112E-28	Yes
<i>HB4C. BIM can enhance project quality control, improve predictability, and</i>	- Null Hypothesis (H0): BIM does not improve project quality control or predictability.	1.047E-30	Yes

increase predictability.

Benefit Factors of BIM Adoption

HB4D. Reducing the project duration improves turnover, visualization, efficiency, and scheduling.

HB4E. BIM quantifies the Bill of quantity preparation automatically, which increases the level of accuracy.

HB4F. BIM can significantly boost productivity and work efficiency in the construction industry, resulting in significant time cost savings.

HB4G. BIM is a tool that assists the time and cost of design changes and eliminates and enhances design and resolution clashes.

HB4H. BIM can reduce delays in construction materials delivery, waste

-Alternative Hypothesis (Ha): BIM improves project quality control and predictability.

Hypothesis

p-value

Reject Null Hypothesis

-Null Hypothesis (H0): Reducing the project duration does not improve turnover, visualization, efficiency, or scheduling.

1.170E-29

Yes

-Alternative Hypothesis (Ha): Reducing the project duration improves turnover, visualization, efficiency, and scheduling.

-Null Hypothesis (H0): BIM does not improve the accuracy of Bill of Quantity preparation.

1.380E-29

Yes

-Alternative Hypothesis (Ha): BIM improves the accuracy of Bill of Quantity preparation by automatically quantifying it.

-Null Hypothesis (H0): BIM does not significantly boost productivity or work efficiency, nor does it result in significant time and cost savings

2.972E-31

Yes

-Alternative Hypothesis (Ha): BIM significantly boosts productivity and work efficiency, saving time and cost.

-Null Hypothesis (H0): BIM does not assist in managing the time and cost of design changes or resolving clashes.

7.954E-31

Yes

-Alternative Hypothesis (Ha): BIM assists in managing the time and cost of design changes and enhances the resolution of clashes.

-Null Hypothesis (H0): BIM does not reduce delays in construction materials delivery or waste.

2.127E-27

Yes

-Alternative Hypothesis (Ha): BIM reduces construction materials delivery and waste.

<i>Benefit Factors of BIM Adoption</i>	Hypothesis	p-value	Reject Null Hypothesis
<i>HB4I. BIM makes it easier to understand the ongoing project.</i>	-Null Hypothesis (H0): BIM does not make it easier to understand the ongoing project. -Alternative Hypothesis (Ha): BIM makes it easier to understand the ongoing project.	2.116E-31	Yes
<i>HB4J. BIM can improve multi-party communication and maintain synchronized communication.</i>	-Null Hypothesis (H0): BIM does not improve multi-party communication or maintain synchronized communication. -Alternative Hypothesis (Ha): BIM improves multi-party communication and maintains synchronized communication.	6.268E-30	Yes
<i>HB4K. BIM can monitor, track, and control project budgets.</i>	-Null Hypothesis (H0): BIM does not effectively monitor, track, or control project budgets. -Alternative Hypothesis (Ha): BIM effectively monitors, tracks, and controls project budgets.	6.349E-32	Yes
<i>HB4L. BIM can monitor and track progress during construction and avoid slippage</i>	-Null Hypothesis (H0): BIM does not effectively monitor or track progress during construction, nor does it help avoid slippage. -Alternative Hypothesis (Ha): BIM effectively monitors and tracks progress during construction and helps avoid slippage.	7.284E-28	Yes
<i>HB4M. BIM can significantly improve safety conditions at construction sites.</i>	-Null Hypothesis (H0): BIM does not significantly improve safety conditions at construction sites. -Alternative Hypothesis (Ha): BIM significantly improves safety conditions at construction sites.	3.536E-28	Yes
<i>HB4N. BIM fosters a culture of collaboration among project stakeholders, enhancing teamwork and</i>	-Null Hypothesis (H0): BIM does not foster a culture of collaboration among project stakeholders or enhance teamwork. -Alternative Hypothesis (Ha): BIM fosters collaboration among project stakeholders, enhancing teamwork	8.789E-27	Yes

<i>shared goals throughout the project life cycle.</i>	and shared goals throughout the project life cycle.		
<i>Benefit Factors of BIM Adoption</i>	Hypothesis	p-value	Reject Null Hypothesis
<i>HB4O. BIM improves project documentation.</i>	-Null Hypothesis (H0): BIM does not improve project documentation. -Alternative Hypothesis (Ha): BIM improves project documentation.	1.600E-29	Yes

The data in the above table strongly supports the alternative hypothesis, indicating that BIM adoption is beneficial in the various aspects tested ($p < 0.05$, null hypothesis rejected). These results indicate that BIM positively and significantly impacts the construction industry throughout the project lifecycle.

4.5.5 Challenges of BIM adoption and implementation

Since the data does not follow a normal distribution, non-parametric tests will be used to evaluate the barriers factor of BIM adoption with respect to the hypotheses outlined. A non-parametric one-sample test (Wilcoxon signed-rank test (Riina et al., 2023)) will be performed to test each hypothesis independently.

The test will evaluate whether the median value differs significantly from 3, which represents the neutral point on a Likert scale. If the p-value is less than 0.05, we reject the null hypothesis and accept the alternative hypothesis, indicating that the barrier factor is significant (Table 4.5.8).

Table 4.5.8: Barriers Factors of BIM Adoption Hypothesis Testing

Barriers Factors of BIM Adoption	Hypothesis	P-Value	Result
<i>HB5A. BIM's software is complicated to learn.</i>	- Null Hypothesis (H0): BIM's software is complicated to learn. - Alternative Hypothesis (Ha): Software is not complicated to learn.	2.95E-24	Reject H0
<i>HB5B. Lack of training on BIM.</i>	- Null Hypothesis (H0): Sufficient training on BIM is available. - Alternative Hypothesis (Ha): There is a lack of training available on BIM.	1.86E-17	Reject H0
<i>HB5C. Lack of BIM experts within the firm.</i>	- Null Hypothesis (H0): Firms do not experience a lack of BIM experts. - Alternative Hypothesis (Ha): Firms experience a lack of BIM experts.	2.14E-23	Reject H0
<i>HB5D. Poor awareness of BIM benefits</i>	- Null Hypothesis (H0): There is adequate awareness of BIM benefits in the construction industry. - Alternative Hypothesis (Ha): There is poor awareness of BIM benefits in the construction industry.	4.83E-24	Reject H0
<i>HB5E. Lack of knowledge about BIM.</i>	- Null Hypothesis (H0): Construction industry professionals have sufficient knowledge about BIM. - Alternative Hypothesis (Ha): Construction industry professionals lack knowledge about BIM.	8.92E-24	Reject H0
<i>HB5F. BIM's software is expensive and requires a high initial cost.</i>	- Null Hypothesis (H0): BIM's software is not expensive and does not require a high initial cost. - Alternative Hypothesis (Ha): BIM's software is expensive and requires a high initial cost.	3.09E-25	Reject H0
<i>HB5G. Long-term training is required for current staff.</i>	- Null Hypothesis (H0): Long-term training is not required for current staff to use BIM. - Alternative Hypothesis (Ha): Long-term training is required for current staff to use BIM.	2.68E-26	Reject H0
<i>HB5H. High cost of training current staff.</i>	- Null Hypothesis (H0): The cost of training current staff on BIM is not high. - Alternative Hypothesis (Ha): The cost of training current staff on BIM is high.	2.60E-25	Reject H0
<i>HB5I. Insufficient support from top managers.</i>	- Null Hypothesis (H0): There is sufficient support from top managers for BIM implementation.	1.83E-16	Reject H0

Barriers Factors of BIM Adoption	-Alternative Hypothesis (Ha): There is insufficient support from top managers for BIM implementation.		
	Hypothesis	P-Value	Result
<i>HB5J. The application of BIM will affect the current process practice.</i>	-Null Hypothesis (H0): The application of BIM will not affect the current process practice.	8.61E-15	Reject H0
	-Alternative Hypothesis (Ha): The application of BIM will affect the current process practice.		
<i>HB5K. The construction market is not ready for BIM technology.</i>	-Null Hypothesis (H0): The construction market is ready for BIM technology.	4.49E-09	Reject H0
	-Alternative Hypothesis (Ha): The construction market is not ready for BIM technology.		
<i>HB5L. Resistance to change the current construction industry culture.</i>	-Null Hypothesis (H0): There is no resistance to change in the current construction industry culture.	4.86E-22	Reject H0
	-Alternative Hypothesis (Ha): There is resistance to change in the current culture of the construction industry.		
<i>HB5M. Lack of data sharing (collaboration with other professionals).</i>	-Null Hypothesis (H0): There is sufficient data sharing and collaboration with other professionals in the construction industry.	1.27E-21	Reject H0
	-Alternative Hypothesis (Ha): There is a lack of data sharing and collaboration with other professionals in the construction industry.		
<i>HB5N. Insufficient support and participation from the government.</i>	-Null Hypothesis (H0): There is sufficient support and participation from the government in BIM adoption.	1.07E-25	Reject H0
	-Alternative Hypothesis (Ha): There is insufficient support and participation from the government in BIM adoption.		
<i>HB5O. Lack of demand by owners.</i>	-Null Hypothesis (H0): There is sufficient demand for BIM by project owners.	4.51E-21	Reject H0
	-Alternative Hypothesis (Ha): There is a lack of demand for BIM by project owners.		

The data in the above table strongly supports the alternative hypotheses, indicating that the identified barriers to BIM adoption are significant challenges in the construction industry ($p < 0.05$, null hypotheses rejected). These results indicate that barriers such as the lack of demand by owners, high software costs, insufficient training, and a shortage of BIM experts are critical obstacles that must be addressed. The findings also highlight that overcoming these barriers would enhance BIM implementation and maximize its positive impact on the construction industry throughout the project lifecycle.

4.5.6 Measures to Overcome BIM Adoption Challenges:

HB6. Null Hypothesis (H₀): Increasing government support, improving access to BIM software, integrating BIM into academic programs, and Participation in relevant professional organizations will significantly enhance the adoption of BIM in Bahrain's construction industry.

Alternative Hypothesis (H_a): Increasing government support, improving access to BIM software, integrating BIM into academic programs, and Participation in relevant professional organizations will not significantly enhance the adoption of BIM in Bahrain's construction industry.

Pearson Chi-Square Test: Since the p-value (0.428) < 0.05 , we accept the null hypothesis (H₀). This means that Increasing government support, improving access to BIM software, integrating BIM into academic programs, and Participation in relevant professional organizations will significantly enhance the adoption of BIM in Bahrain's construction industry.

4.5.7 General Question (Willing to Adopt BIM)

4.5.7.1 Willing to Adopt BIM by Education Level Hypothesis Testing

HB7. Higher Education Levels Are Associated with a Greater Willingness to Change

- **Null hypothesis (H0):** There is no significant difference in willingness to change between respondents with higher and lower education levels.

Alternative hypothesis (H1): Respondents with higher education levels are more likely to support change compared to those with lower education levels.

Table 4.5.9: Education Level vs. Willing to Adopt BIM

<i>Education Level</i>	<i>Yes</i>	<i>No</i>	<i>Total</i>
<i>Diploma</i>	6	0	6
<i>Bachelor's</i>	62	16	78
<i>Master's</i>	27	6	33
<i>PhD</i>	2	0	2
<i>Total</i>	97	22	119

Table 4.5.10: Willing to Adopt BIM by Education Level

<i>Test</i>	<i>Value</i>	<i>df</i>	<i>p-value (Asymptotic Significance)</i>
<i>Pearson Chi-Square</i>	2.029	3	0.566
<i>N of Valid Cases</i>	119		

Pearson Chi-Square Test: (Table 4.5.9) & (Table 4.5.10) Since the p-value ($0.566 > 0.05$), we fail to reject the null hypothesis (H_0). This means that education level does not have a statistically significant effect on willingness to change.

Chapter 5: Conclusion and Recommendations

5.1 Introduction

This chapter summarizes the research findings of Building Information Modeling (BIM) in the construction industry in Bahrain. The transformative opportunities of building information modeling (BIM) have been studied, focusing on the benefits and barriers to implementation. It successfully shed light on the current picture of BIM awareness and its uptake through a quantitative method. It provides a summary of the key findings and conclusions along with recommendations for stakeholders involved in the project as well as recommendations for further research related to BIM transformation in the Bahrain construction sector.

5.2 Summary of Main Findings

- **Level of Awareness:** The construction industry in Bahrain demonstrates a high level of awareness regarding BIM, with 82% of participants reporting either fair knowledge, being well-informed, or actively using BIM tools. However, with only 30.9% actively using BIM, there is a significant gap between knowledge and application. This gap underscores the issue faced by the construction industry in Bahrain, and only 18% of the respondents are unaware of BIM. In other words, there is a high level of awareness against low adoption levels. It's crucial to address the significant barriers to BIM implementation to bridge this gap and fully realize the potential of BIM in Bahrain's construction industry.

- **BIM Knowledge by Education Level:** There is a notable gap in BIM awareness among construction professionals, particularly among Bachelor's degree holders, where a significant majority (76.19%) are unaware of BIM. This indicates a potential deficiency in BIM education within undergraduate programs, highlighting the urgent need for curriculum enhancements that incorporate BIM training. Conversely, individuals with Master's degrees demonstrate greater engagement with BIM, with 33.33% actively using BIM tools. This trend indicates that higher educational attainment correlates with increased BIM knowledge. Similarly, PhD holders also exhibit strong BIM knowledge, reinforcing the idea that advanced academic levels contribute positively to understanding and utilizing BIM. Therefore, promoting BIM training and integration into higher education curricula could effectively enhance overall BIM knowledge within the construction industry.
- **BIM Knowledge by Profession:** Among different professions in the construction industry, there are significant disparities in BIM awareness and usage. Civil engineers exhibit the most considerable knowledge gap, with 61.90% unaware of BIM and only 31.94% actively utilizing BIM tools. This underscores the need for targeted training and education within this profession to foster greater adoption. Architects, however, demonstrate a relatively low unawareness rate (9.52%) and show that 22.22% actively engage with BIM tools. This indicates that there is significant potential for increased usage through more practical applications and project involvement, highlighting a promising avenue for growth in this profession. Project managers

reflect moderate awareness, with 19.44% actively using BIM tools; however, 19.74% are well-informed yet not utilizing BIM, indicating a pressing need for additional training to bridge this gap. In contrast, BIM specialists, who showcase the highest usage rate (15.28%), play a pivotal role in promoting BIM adoption within organizations. Their expertise and dedication are crucial in the comparative analysis that highlights the varying levels of BIM engagement across professions, indicating that tailored educational initiatives could significantly enhance BIM knowledge and application throughout the construction industry.

- **BIM Knowledge by Experience Level:** The adoption of Building Information Modeling (BIM) varies significantly across different experience levels within the construction industry. Among professionals with less than five years of experience, 31.94% actively use BIM tools, and a substantial portion (37.21%) possess fair knowledge of BIM. However, a noteworthy 33.33% remain unaware of BIM, highlighting the need for enhanced training early in their careers. For those with 6-10 years of experience, a significant 30.26% of well-informed individuals do not utilize BIM, indicating potential barriers to application that could be addressed through targeted support and resources. Similarly, professionals with 11-15 years of experience exhibit comparable trends, with 26.39% actively using BIM and 27.63% being well-informed but not applying it, further emphasizing the necessity for practical training initiatives. In contrast, professionals with 16-20 years of experience and more than 20 years of experience demonstrate lower engagement with BIM, indicating resistance to

adopting new technologies. This points to the urgent need for tailored training programs that assist senior professionals in transitioning from traditional methods to more modern, efficient practices. Addressing these disparities in BIM knowledge and application across experience levels is crucial for fostering a more technologically advanced construction industry.

- **BIM Knowledge by Sector:** The engagement with Building Information Modeling (BIM) tools varies significantly between the private and public sectors. In the private sector, 70.83% of respondents actively utilize BIM tools, demonstrating a higher level of engagement than their public sector counterparts. However, despite this high awareness, 72.37% of private sector professionals remain well-informed about BIM yet do not apply it in practice, indicating potential barriers to its implementation that could be addressed. Conversely, the public sector exhibits much lower engagement, with only 23.61% actively using BIM tools. This highlights a significant opportunity for improving the practical application of BIM in public projects, where enhanced coordination and efficiency could yield substantial benefits. Furthermore, the combined public and private sector shows the lowest adoption rate at 5.56%, with many respondents unaware of BIM. This indicates a general lack of focus on BIM practices across both sectors, emphasizing the need for strategic initiatives to promote its adoption and integration within the construction industry in Bahrain.
- **BIM Knowledge by Project Scale:** The adoption of Building Information Modeling (BIM) tools demonstrates significant variation based on project scale. For small projects, the adoption rate is low at

2.78%, with 21.43% of professionals unaware of BIM and 20.93% possessing only fair knowledge. This, due to cost and resource constraints, may hinder BIM implementation in smaller-scale projects. In medium-sized projects, adoption increases to 19.44%; however, a substantial 32.89% of respondents are well-informed about BIM but do not utilize it, indicating the presence of practical barriers that prevent application. Larger projects see a notable uptick in engagement, with 38.89% actively using BIM tools and only 9.52% unaware of BIM, indicating that the complexity and demands of larger projects often drive the need for advanced management solutions like BIM. Interestingly, the adoption rate for very large projects is 38.89%. However, this group faces a significant challenge, and 45.24% remain unaware of BIM, highlighting potential project scale gaps in BIM adoption. These findings underscore the need for targeted efforts to promote BIM in smaller, less complex projects while addressing awareness and resource constraints across all project scales.

- **Software Usage Level:** In Bahrain, Building Information Modeling (BIM) is primarily utilized for basic visualization and drawing production; however, its integration into broader construction processes remains limited. The reliance on traditional 2D and 3D content generation methods has hindered the advancement of BIM practices, with the maturity level categorized as Stage 1. This indicates that current BIM processes lack the necessary modeling capabilities for effective collaborative use among stakeholders. Furthermore, the existing BIM tools in Bahrain are not sufficiently integrative and do not significantly improve project outcomes. Despite some

advancements in awareness and the availability of BIM software, the industry continues to lag in maximizing efficiency and leveraging the full potential of BIM to enhance project delivery and management. This situation underscores the need for strategic initiatives to elevate BIM maturity and promote comprehensive integration within the construction sector. This is primarily attributed to a lack of training, limited client demand for higher-dimensional outputs (4D to 8D), and cost barriers related to software and training. Also, poor awareness of BIM benefits. Additionally, the construction industry's relatively traditional practices and absence of mandatory regulatory frameworks for full BIM lifecycle implementation contribute to the underutilization of advanced BIM dimensions.

- **Benefits of BIM Adoption and Implementation:** BIM offers numerous advantages, including improved efficiency, collaboration, and significant cost savings. The analysis of Building Information Modeling (BIM) benefits adoption highlights the varying priorities and needs across different sectors in the construction industry. Each sector demonstrates distinct focuses that reflect their specific roles within the construction process. For the government, productivity is the primary concern, emphasizing the importance of efficient project delivery, followed closely by project duration and quality control. This prioritization indicates the large-scale infrastructure projects they oversee, where timely completion and adherence to quality standards are essential for public accountability and resource management. The contractors prioritize their on-site execution responsibilities, emphasizing understanding ongoing projects as their top concern.

Productivity and budget control are also critical, reflecting the need for real-time project management to enhance efficiency and reduce costs during execution. Consultants and engineering firms place significant importance on budget control, which ranks as their top benefit from BIM adoption. This focus on financial management is crucial for effective project planning and design. Productivity also ranks highly among their priorities, alongside documentation, highlighting the need for streamlined processes in project delivery. In conclusion, this analysis underscores the necessity for tailored BIM implementation strategies that address the unique needs of each sector. By recognizing these priorities, stakeholders can work towards optimizing BIM adoption to improve collaboration, efficiency, and overall project outcomes in the construction industry.

- **Barriers Factors of BIM Adoption:** Despite the benefits of BIM, several obstacles hinder its adoption, including top barriers in all sectors. The most significant barriers are the lack of demand by owners, the high cost of training, the lack of training on BIM, and poor awareness of BIM benefits. These factors are crucial for driving adoption and are universally acknowledged as significant barriers, with consistent agreement trends. Also, mid-ranked barriers such as the lack of BIM experts, long-term training needs, and insufficient support from managers. These barriers are essential. Still, they are not considered the most urgent compared to the top barriers. Overall, the consistent rankings and trends across consultants, contractors, and the government show a high level of agreement on the critical barriers to

BIM adoption, with demand, training, and awareness being the most significant barriers to address.

- **Measures to overcome BIM adoption:** The analysis emphasizes that government support through legislation and comprehensive integration into academic programs are the most significant drivers for successful BIM adoption in Bahrain. Policy reform and education are essential pillars for overcoming the existing challenges and facilitating effective BIM implementation. By aligning policies and incorporating BIM into academic curricula, the construction sector can generate increased owner demand and greater awareness of BIM knowledge. This approach will naturally lead to a rise in BIM experts within the market, reducing the need for external training, as most skills and knowledge will be developed during the education. The market will be better prepared through government legislation fostering an environment conducive to adopting BIM as a standard practice. Additionally, while the availability of software tools and industry collaboration remains critical, they complement policy and education efforts. Redirecting internal resources toward developing in-house expertise will further reduce reliance on external consultants and support. The construction sector in Bahrain must prioritize policy reforms and educational initiatives to lay a solid foundation for BIM adoption. Through this strategy, the industry can enhance efficiency, reduce costs, and improve collaboration, ultimately positioning itself to leverage the full potential of BIM practices.

- **Willingness to Adopt:** Overall, there is a significant willingness to adopt BIM within the construction industry in Bahrain, with a total openness of **81.51%**, indicating a readiness for technological advancement across respondents.
- **Willing to Adopt BIM by Education Level:** Higher educational attainment correlates with increased willingness to adopt BIM, particularly among Bachelor's degree holders at 52.10% and Master's degree holders at 22.69%, highlighting the importance of educational initiatives to promote BIM understanding.
- **Willing to Adopt BIM by Business Type:** Consultants and government entities demonstrate the highest levels of willingness to adopt BIM, with 86.27% of consultants and 92.00% of government representatives recognizing and embracing the benefits of this technology.
- **Willing to Adopt BIM by Profession:** Civil engineers show the most significant willingness to adopt BIM at 34.45%, yet they also exhibit notable resistance, indicating a critical need for targeted training and support to facilitate this transition.
- **Willing to Adopt BIM by Experience Level:** Younger professionals with less than five years of experience show a willingness of 21.65%, while those with over 20 years of experience demonstrate complete openness at 100%, emphasizing the potential for change across all experience levels.
- **Willing to Adopt BIM by Organization Sector:** The public sector's high willingness to adopt BIM at 92.00% sets a positive precedent for

overall industry transformation, underscoring the necessity for public entities to lead by example in embracing technological innovations.

5.2.1 Achievement of Research Objectives

This research effectively addressed all five research objectives outlined at the outset of the study. The first objective (HB1), which was to identify construction project management challenges that BIM can resolve, was achieved through a literature review. Chapter 2 established that issues such as poor planning, unrealistic scheduling and budgeting, inadequate project scope determination, and lack of communication and coordination between stakeholders are major challenges in construction project management. Chapter 4 confirmed that respondents recognized these as critical challenges and viewed BIM as a practical solution, particularly due to its capabilities in 3D modeling, clash detection, scheduling integration, and improved collaboration (Sections 4.4.2.3 and 4.4.3).

The second objective (HB2), focusing on the benefits of BIM implementation, was fully met. As shown in Table 4.4.17, Section 4.4.3, professionals identified improved productivity, budget control, reducing project duration, improving quality control, and project documentation as top-ranked benefits. These perceptions were statistically validated through hypothesis testing in Table 4.5.7, confirming the significance of these benefits with strong p-values.

The third objective (HB3), which aimed to explore the barriers to BIM adoption, was comprehensively addressed in Sections 4.4.4 and 4.5.5. Respondents identified key challenges such as the lack of demand by

owners, high training costs, the lack of training on BIM, and poor awareness of BIM benefits. These were confirmed through hypothesis testing in Table 4.5.8, where barriers such as lack of demand by owners ($p = 4.51\text{E-}21$), lack of training ($p = 1.86\text{E-}17$), and high cost ($p = 2.60\text{E-}25$) showed statistically significant impact.

The fourth objective (HB4), which examined BIM awareness levels in Bahrain, was also achieved. Section 4.4.2.1 reports that 82% of respondents were aware of BIM. However, only 30.9% used it regularly (Section 4.4.2.2), revealing a significant gap between awareness and actual usage. Further breakdowns (Tables 4.4.10–4.4.11) show awareness disparities based on education, profession, experience, and project size. For example, 76.19% of participants with a bachelor's degree were unaware of BIM (Table 4.4.10), confirming the need for academic integration.

The fifth objective (HB5), which aimed to evaluate the willingness and ability of engineering firms in Bahrain to adopt BIM, was partially achieved. As reported in Section 4.4.6, 51.07% of respondents expressed a willingness to adopt BIM within their organizations. This indicates a moderate level of interest and readiness among industry professionals. However, hypothesis testing in Section 4.5.7.1 (Table 4.5.9) found no statistically significant association between willingness and education level ($p = 0.566$), suggesting that other factors, such as organizational structure, available resources, or project scale, may have a greater influence on adoption readiness. While the study successfully measured willingness, the analysis of barriers (Sections 4.4.4 and 4.5.5)

revealed significant limitations affecting firms' ability to implement BIM. These include high software and training costs, limited access to qualified personnel, lack of institutional support, and the absence of client-driven demand, particularly from government and private sector owners. As such, although there is clear interest in adopting BIM, these systemic constraints continue to hinder full-scale implementation. Therefore, this objective was considered partially achieved, as willingness alone does not guarantee capacity for adoption without addressing the underlying structural and resource-based challenges.

5.3 Conclusion:

This research aimed to investigate the transformation towards Building Information Modeling (BIM) in Bahrain's construction industry by evaluating awareness, usage, benefits, barriers, and measures to overcome the barriers. Using a quantitative approach, data were collected from 247 construction professionals in Bahrain through structured questionnaires, with interviews conducted with selected professionals to validate questionnaire responses. This study provides statistically validated insights into the current state of BIM in Bahrain.

The analysis indicates that in Bahrain's construction sector, there is considerable knowledge of Building Information Modelling (BIM) but very limited use. While 82% of professionals were familiar with BIM, only 30.9% use it, which indicates a significant gap between awareness and usage. a statistically significant disparity confirmed by descriptive analysis and hypothesis testing (Section 4.5.1). The analysis also revealed that the adoption of advanced BIM functionalities—such as 4D scheduling, 5D

cost estimation, and facility management—is still limited, with most users confined to 2D and 3D modeling (Table 4.4.16). The main challenges for low adoption are the lack of demand from project owners for government, consultants, and contractors to use BIM, high training costs, lack of access to BIM training, and lack of awareness of benefits. These findings are further supported by statistically significant barrier factors (Table 4.5.8).

The study also highlights a notable educational gap at the undergraduate level: 76.19% of bachelor's degree holders were unfamiliar with BIM, underscoring the need to integrate BIM into academic curricula. In contrast, the private sector exhibits more proactive behavior toward BIM adoption compared to the public sector. Nonetheless, barriers are present in both sectors, suggesting that a coordinated strategy is essential to facilitate BIM implementation across the industry.

The analysis also revealed disparities in BIM practice based on profession and experience. For example, civil engineers appear to have the greatest need for training and capacity-building initiatives. In terms of adoption trends, younger professionals and senior experts exhibit distinct patterns that require tailored support. Although BIM is more frequently used in large and complex projects, its uptake in small to medium-sized projects remains constrained by cost and resource limitations. Notably, medium-scale projects showed the highest acceptance level (89.47%), suggesting they could serve as practical models for broader BIM implementation in Bahrain.

Despite the challenges, 81.51% of respondents expressed a willingness to adopt BIM in their work environments, indicating a strong readiness for a

technology-driven transformation. Consulting firms and government agencies demonstrated particularly high levels of commitment to adopting BIM tools and practices.

With the implementation of policy reforms and integration in educational programs, the urge to develop the construction sector will only result in strengthening the BIM framework adopted by Bahrain, which addresses core project management challenges. These initiatives will enhance collaboration, resource utilization, scheduling, risk mitigation, and monitoring capabilities. This will create a pool of professionals trained in BIM who are able to leverage its benefits. Ultimately, this new workforce will ensure more efficient project delivery, leading to better stakeholder satisfaction while minimizing errors and delays. This will enable Bahrain's construction sector to face future challenges more efficiently and innovatively.

5.3.1 Study Limitations and Their Impact on Conclusions

Although offering significant insights on BIM adoption in Bahrain, this study is constrained by various limitations that may affect the interpretation of its findings. The restricted sample size and dependence on self-reported data may fail to encompass the complete range of experiences within the wider construction industry. The study also failed to analyze the financial and temporal costs associated with BIM adoption, which are critical elements affecting decision-making, particularly in resource-limited contexts. These limits indicate that, although the conclusions are accurate within the specified scope, they should be regarded as a preliminary step towards a more comprehensive understanding of BIM practices in Bahrain.

Future studies may build upon these findings through more comprehensive financial studies and an expanded stakeholder demographic.

5.4 Recommendations:

The following recommendations are proposed based on the findings of the research:

1. Strengthen Government Support through Policy and Legislation
2. Integrate BIM Training into Educational Curricula
3. Facilitate Access to BIM Software and Tools
4. Promote Participation in Professional Organizations and Industry Networks
5. Develop Targeted Training Programs for Professionals
6. Provide financial and technical support to encourage BIM adoption in smaller-scale projects where cost constraints limit usage.
7. Encouraging internal resource development over external dependency will foster organizational self-sufficiency and reduce long-term costs.
8. Monitor and Evaluate BIM Adoption Progress Implementing monitoring frameworks will help adjust strategies and ensure alignment with industry needs.

The practical implications of the recommendations presented in this study are significant for Bahrain's construction sector. Government authorities, such as the Council for Regulating the Practice of Engineering Professions (CRPEP) and municipalities, can play a critical role by incorporating BIM requirements into public and private project procurement standards and building codes. Engineering curricula can be revised by academic

institutions, such as universities, to include practical BIM training that is consistent with industry software. Construction companies are encouraged to establish internal BIM units for coordination and to invest in continuous staff development programs. If executed collaboratively, these measures can expedite the adoption of BIM and considerably enhance project performance in Bahrain in terms of cost, time, and quality.

5.5 Recommendations for Future Studies

This study provides a foundational understanding of BIM awareness, usage, benefits, and barriers within Bahrain's construction sector. Future research can build on these findings by applying more advanced statistical models, expanding the sample to include a wider range of stakeholders such as project owners, regulators, and clients, and conducting comparative studies across GCC countries. Additionally, the validated questionnaire from this study can be adapted in other contexts or used in longitudinal research to track changes in BIM adoption over time.

Future research could focus on the following areas to further understand BIM's impact and facilitate its adoption:

1. Conduct studies to evaluate the long-term economic benefits of BIM implementation, specifically focusing on return on investment (ROI) and cost-effectiveness across project types.
2. Assess the long-term vs. short-term benefits of BIM adoption on project outcomes and delivery performance, including cost, time, and quality
3. Assess the Long-Term Impact of BIM on project performance

4. Assess the potential of BIM for environmental impact tracking and sustainable material management.
5. Assess the impact of BIM on project tracking, predictive analytics, and decision-making, including its role in real-time decision-making support.
6. Study and identify the gap between academic BIM education and industry requirements, and propose improvements in training and curriculum.
7. Study the role of BIM in mitigating project risks, such as design conflicts, scope changes, delays, and safety hazards.
8. Conduct longitudinal or sector-specific studies to examine BIM maturity progression and implementation success factors over time.

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APPENDICES

7.1 Appendix A: Research Questionnaire

Questionnaire Survey

Dear Sir/Madam: -

This research has the potential to significantly influence the future of the construction industry in Bahrain. I am preparing a research project to investigate and study the Transformation to Building Information Modeling in the Construction Industry in Bahrain: Benefits & Barriers. This research will be conducted using a statistical software package (SPSS), a widely used data analysis and interpretation tool. This will fulfill the requirements for a master's degree in engineering management at the University of Bahrain. This questionnaire aims to (1) study the level of awareness of Building Information Modeling (BIM) in Bahrain among Engineering firms, (2) investigate the benefits of BIM implementation in Engineering firms in Bahrain, (3) investigate the barriers to implementing BIM in engineering firms in Bahrain, (4) willingness and ability of the engineering firms in Bahrain to use BIM. This is a pilot study to check the readability and clarity of the main questionnaire. You are kindly requested to spare part of your valuable time to answer all the attached questions carefully and substantively based on your experiences. Please rest assured that all data collected from this questionnaire will be treated with the highest level of confidentiality. Your responses will be anonymized and aggregated for analysis, ensuring that no personal information is shared. Your collaboration on this research project is of utmost importance, and your insights will significantly contribute to our findings. I truly value your participation and look forward to your contributions. For more information or clarifications, please email me at salehbdour@gmail.com.

Thank you,

Researcher: Saleh Arafat Albdour (+973) 36804050

Please read these notes before filling out the questionnaire:

• **Ideal participants in this questionnaire:**

Engineers, architects, engineering managers, or any others who (were) playing the roles of contractor, consultant, or government in the contracting process from the public, semi-public, and private sectors in Bahrain building construction projects.

• **Introduction:**

This research questionnaire was developed to identify the main factors in the transformation to Building information modeling in building construction projects in Bahrain's private & public sectors. The questionnaire includes two parts: (1) & (2). Part (1) focuses on demographic information (experiences and education levels), while Part (2) includes the level of awareness of BIM and usage, benefits and barriers to BIM, and the willingness and ability to apply BIM in engineering firms in Bahrain. You are requested to choose the frequency of occurrence and specify the factors from your perspective.

• **Important terminologies:**

Note: (All the definitions have been taken from the literature review of this thesis)

“**BIM**” Building Information Modeling is a process that involves generating and managing digital representations of the physical and functional characteristics of locations—supported by various tools and technologies.

“**Frequency**” refers to the likelihood of occurrence of the factors listed and how they impact the transformation of building information modeling in construction projects in Bahrain.

✓ **Frequency of occurrence:** As per the table, two criteria are used to evaluate the factors.

✓ **First Frequency:**

- 1- Never: (Never occur).
- 2- Rarely: (Rarely occur).
- 3- Occasionally: (occur from time to time).
- 4- Frequently: (mainly occur).
- 5- Very Frequently: (occurs all the time).

✓ **Second Frequency:**

- 1- Strongly Disagree
- 2- Disagree
- 3- Neutral
- 4- Agree
- 5- Strongly Agree.

PART 1- Section A: Respondent's Experiences

1. What is your Education Level? (Mandatory question)

- ☐ Diploma
- ☐ Bachelor's degree
- ☐ Master's degree
- ☐ PhD degree

2. What type of business are you engaged in for your current job? (Mandatory question)

- ☐ Consultant/ Engineering Offices
- ☐ Government
- ☐ Contractor & Other

3. What is your role within your organization? (Mandatory question)

- ☐ Civil Engineer
- ☐ Architect
- ☐ Project Managers
- ☐ Surveyor Engineer
- ☐ Electrical Engineer
- ☐ Mechanical Engineer
- ☐ Facility Engineer
- ☐ BIM Specialist

4. How many years of experience do you have? (Mandatory question)

- ☐ Less than five years
- ☐ 6-10 years
- ☐ 11-15 years
- ☐ 16-20 years
- ☐ More than 20 years

5. In which sector does your organization operate? (Mandatory question)

- ☐ Public Sector
- ☐ Private Sector
- ☐ Public & Private Sector (Both)

6. What is the scale of the ongoing project/s that your organization is currently engaged in? (Mandatory question)

- ☐ Small (Less than 500,000 BD)
- ☐ Medium (Above 500,000 BD –1,000,000 BD)

- ☐ Large (Above 1,000,000 BD –2,000,000 BD)
- ☐ Very Large (Above 2,000,000 BD)

PART 2- Section A: Level of awareness of Building information modeling (BIM) & Usage.

Please mark [☒] factors in the table according to their frequency of occurrence.

Whereas Frequency is shown above the table:

➤ Current States of the Awareness and Usage of BIM

1. What is your level of knowledge of BIM?

<i>Level of Knowledge of BIM</i>	
1. Not aware of BIM <u>(If selected, please do not proceed further.)</u> .	☐
2. Fair knowledge of BIM.	☐
3. Well-informed about BIM but no usage.	☐
4. Aware and currently using BIM tools <u>(If selected, please don't answer the last question)</u> .	☐

2. What is your organization's usage level of the following BIM Software/Tool?

1= Never 2= Rarely 3= Occasionally 4= Frequently 5= Very Frequently

<i>BIM Software</i>	<i>Usage Level</i>				
	1	2	3	4	5
1. AutoCAD Architecture Program	☐	☐	☐	☐	☐
2. Autodesk Revit Program	☐	☐	☐	☐	☐
3. Autodesk Navisworks Program	☐	☐	☐	☐	☐
4. Bentley Program	☐	☐	☐	☐	☐
5. Tekla Program	☐	☐	☐	☐	☐
6. ArchiCAD Program	☐	☐	☐	☐	☐
7. BIM 360	☐	☐	☐	☐	☐

3. For what purpose do you use BIM Application Software in your Organization?

1= Never 2= Rarely 3= Occasionally 4= Frequently 5= Very Frequently

<i>BIM Functions Adoption</i>	<i>Usage Level</i>				
	1	2	3	4	5
<i>1. 2D (Dimensions) Drawings</i>	☐	☐	☐	☐	☐
<i>2. 3D Modelling/ Presentation</i>	☐	☐	☐	☐	☐
<i>3. Construction / As-Built Drawings</i>	☐	☐	☐	☐	☐
<i>4. Planning and 4D scheduling</i>	☐	☐	☐	☐	☐
<i>5. Budgeting and 5D Cost Estimation</i>	☐	☐	☐	☐	☐
<i>6. Engineering and 6D Sustainability Analysis</i>	☐	☐	☐	☐	☐
<i>7. 7D Building management</i>	☐	☐	☐	☐	☐
<i>8. Clash Detection</i>	☐	☐	☐	☐	☐
<i>9. Visualization</i>	☐	☐	☐	☐	☐
<i>10. Site Logistics</i>	☐	☐	☐	☐	☐
<i>11. Building performance analysis</i>	☐	☐	☐	☐	☐
<i>12. 8D Safety hazards identification and emergency management</i>	☐	☐	☐	☐	☐

Section B: Benefits of BIM adoption and implementation

Please mark [☐] factors in the table according to their frequency of occurrence.

Whereas Frequency:

1= Strongly Disagree 2= Disagree 3= Neutral 4=Agree 5= Strongly Agree

1. Evaluate the following benefits of implementing BIM (Mandatory question)

<i>Benefit Factors of BIM Adoption</i>	<i>BIM Benefit Level</i>				
	1	2	3	4	5
1. BIM is very beneficial when applied to the construction industry.	☐	☐	☐	☐	☐
2. BIM can significantly boost productivity and work efficiency in the construction industry, resulting in significant time & cost savings.	☐	☐	☐	☐	☐
3. BIM is a tool that assists the time and cost of design changes and eliminates and enhances design and resolution clashes.	☐	☐	☐	☐	☐
4. Reducing the project duration improves turnover, visualization, efficiency, and scheduling.	☐	☐	☐	☐	☐
5. BIM quantifies the Bill of quantity preparation automatically, which increases the level of accuracy.	☐	☐	☐	☐	☐
6. BIM can monitor and track progress during construction and avoid slippage	☐	☐	☐	☐	☐
7. BIM can reduce delays in construction materials delivery, waste	☐	☐	☐	☐	☐
8. BIM can monitor, track, and control project budgets.	☐	☐	☐	☐	☐
9. BIM can improve multi-party communication and maintain synchronized communication.	☐	☐	☐	☐	☐
10. BIM fosters a culture of collaboration among project stakeholders, enhancing teamwork and shared goals throughout the project life cycle.	☐	☐	☐	☐	☐
11. BIM can promote early and accurate decision-making & reduce disputes between the parties involved.	☐	☐	☐	☐	☐
12. BIM can enhance project quality control, improve predictability, and increase predictability.	☐	☐	☐	☐	☐

13. BIM can significantly improve safety conditions at construction sites.	☐	☐	☐	☐	☐
14. BIM improves project documentation.	☐	☐	☐	☐	☐
15. BIM makes it easier to understand the ongoing project.	☐	☐	☐	☐	☐
16. BIM capable of overseeing, tracking, and managing project budgets.	☐	☐	☐	☐	☐

Section C: Challenges of BIM adoption and implementation

Please mark [☐] factors in the table according to their frequency of occurrence.

Whereas Frequency:

1= Strongly Disagree 2= Disagree 3= Neutral 4=Agree 5= Strongly Agree

1. What challenges does your firm face in adopting and implementing BIM?
(Mandatory question)

Barriers Factors of BIM Adoption	BIM Challenges Level				
	1	2	3	4	5
HB5P. BIM's software is expensive and requires a high initial cost.	☐	☐	☐	☐	☐
HB5Q. BIM's software is complicated to learn.	☐	☐	☐	☐	☐
HB5R. Lack of BIM experts within the firm	☐	☐	☐	☐	☐
HB5S. Lack of training on BIM.	☐	☐	☐	☐	☐
HB5T. Long-term training is required for current staff.	☐	☐	☐	☐	☐
HB5U. High cost of training current staff.	☐	☐	☐	☐	☐
HB5V. Lack of knowledge about BIM.	☐	☐	☐	☐	☐
HB5W. Lack of demand by owners.	☐	☐	☐	☐	☐
HB5X. Resistance to change the current construction industry culture.	☐	☐	☐	☐	☐
HB5Y. The application of BIM will affect the current process practice.	☐	☐	☐	☐	☐
HB5Z. The construction market is not ready for BIM technology.	☐	☐	☐	☐	☐

<i>HB5AA. Lack of data sharing (collaboration with other professionals)</i>	☐	☐	☐	☐	☐
<i>HB5BB. Insufficient support from top managers.</i>	☐	☐	☐	☐	☐
<i>HB5CC. Poor awareness of BIM benefits</i>	☐	☐	☐	☐	☐
<i>HB5DD. Insufficient support and participation from the government.</i>	☐	☐	☐	☐	☐

Section D: Measures to overcome BIM adoption and implementation challenges and assets the transformation needed.

Please mark [☐] factors in the table according to their frequency of occurrence.

Whereas Frequency:

1= Strongly Disagree 2= Disagree 3= Neutral 4=Agree 5= Strongly Agree

1. To what level can the following factors assist your company in overcoming BIM adoption and implementation challenges and improving BIM implementation capabilities? (Mandatory question)

<i>Adoption Factors</i>	<i>Levels of Overcome the Challenges of BIM Adoption.</i>				
	1	2	3	4	5
<i>1. Participation in relevant professional organizations</i>	☐	☐	☐	☐	☐
<i>2. Full integration into academic programs</i>	☐	☐	☐	☐	☐
<i>3. Availability of BIM software</i>	☐	☐	☐	☐	☐
<i>4. Government support through legislation</i>	☐	☐	☐	☐	☐

2. If given the chance and support, do you think your organization is willing to change from a traditional/ manual approach to BIM?

☐ Yes

☐ No

Thank you for taking the time to complete this survey.

الملخص

تتدفق نمذجة معلومات البناء (ببم) إلى عالم صناعة البناء والتشييد، حيث تُعد أداة حيوية تعزز إدارة مشاريع البناء من خلال قدراتها متعددة الأبعاد. وعلى الرغم من قيمتها العالمية، لا تزال ببم غير مُستغلة بشكل كافٍ في البحرين، مما يُحدث فجوة بين أفضل الممارسات الدولية والتطبيق المحلي. تبحث هذه الدراسة في أسباب تأخر تبني ببم في البحرين، كما تستكشف السبل الممكنة لسد هذه الفجوة. وتركز الدراسة على اعتماد نمذجة معلومات البناء داخل صناعة البناء في البحرين، مع تسليط الضوء على الفوائد والعوائق والعوامل المؤثرة في تنفيذها.

وباستخدام منهج كمي، جُمعت البيانات من 247 متخصصًا في قطاع البناء في البحرين من خلال استبيانات منظمة، وتم إجراء مقابلات مع عدد من المهنيين لتأكيد نتائج الاستبيان. كشفت النتائج عن مستوى عالٍ من الوعي ببم (82%) بين المهنيين، ومع ذلك، هناك فجوة ملحوظة بين المعرفة والاستخدام الفعلي، حيث يستخدم 30.9% فقط أدوات ببم بشكل نشط. كما أظهرت النتائج أن الخصائص الأساسية لببم مثل إنتاج الرسومات ثنائي الأبعاد والنمذجة ثلاثية الأبعاد يتم تبنيها بشكل شائع، في حين أن دمج الميزات المتقدمة مثل كشف التعارضات، وإعداد الميزانيات، وتقدير التكاليف، وإدارة المرافق لا يزال محدودًا (أي أن استخدام ببم في البحرين يقتصر على الرسومات ثنائية وثلاثية الأبعاد).

ومع ذلك، هناك رغبة قوية في تبني ببم، حيث أبدى 81.51% من المشاركين استعدادهم لتنفيذه، وخصوصًا بين المكاتب الاستشارية والجهات الحكومية. وتُظهر الدراسة أن المستوى التعليمي وحجم المشروع يؤثران في تفاوت المعرفة باستخدام ببم؛ فعلى سبيل المثال، يُظهر المهنيون الحاصلون على درجات أكاديمية عليا مثل الماجستير والدكتوراه مشاركة أكبر مقارنة بحاملي درجة البكالوريوس. كما تُظهر المشاريع الكبيرة معدلات اعتماد أعلى، حيث يستخدم 38.89% أدوات ببم بنشاط، في حين أن 9.52% فقط غير مدركين له، مما يشير إلى أن متطلبات المشاريع الكبرى غالبًا ما تدفع الحاجة إلى حلول متقدمة مثل ببم.

وتُظهر الدراسة عدة فوائد رئيسية لاعتماد ببم، بما في ذلك تحسين الإنتاجية، وتعزيز كفاءة العمل، وتحسين مراقبة الميزانية، وتقليل مدة تنفيذ المشروع، وتحسين التوثيق. لكنها في الوقت ذاته تُبرز عوائق كبيرة أمام التنفيذ، مثل ضعف الطلب من قبل مالكي المشاريع، وارتفاع تكاليف التدريب، ومحدودية الوصول إلى برامج التدريب، وانخفاض الوعي بفوائد ببم.

وتخلص الدراسة إلى أن التشريعات الحكومية والتكامل الأكاديمي يمثلان عنصرين أساسيين لنجاح تبني بيم في البحرين، وأنهما المفتاح لتجاوز التحديات وتيسير تنفيذ بيم بشكل فعال. فمواءمة السياسات ودمج بيم في المناهج الدراسية يمكن أن يزيدا من طلب المالكين ووعيهم، مما يؤدي إلى تنمية عدد الخبراء المحليين. كما أن إعادة توجيه الموارد الداخلية لبناء الكفاءات الذاتية يمكن أن يقلل من الاعتماد على الاستشاريين الخارجيين، ويعزز ممارسات بيم المستدامة والفعالة في قطاع البناء.

جامعة البحرين
كلية الهندسة
قسم الهندسة الميكانيكية



دراسة التحول إلى نمذجة معلومات البناء في صناعة البناء
والتشييد في البحرين: الفوائد والعوائق

أطروحة مقدمة كجزء من متطلبات الحصول على درجة الماجستير في الإدارة الهندسية

إعداد

صالح عرفات صالح البدور

الرقم الجامعي : 20152809

إشراف د. يوسف محمد المالكي

أستاذ مساعد

جامعة البحرين

مملكة البحرين

يونيو 2025