

CAPITAL UNIVERSITY OF SCIENCE AND  
TECHNOLOGY, ISLAMABAD



Identification and Assessment of  
Building Information Modeling  
(BIM) Adoption Issues Using  
Modified Model of Unified  
Theory of Acceptance and Use of  
Technology (UTAUT) for  
Construction Sector of Pakistan

by

Tamoor Tanveer

A thesis submitted in partial fulfillment for the  
degree of Master of Science

in the

Faculty of Engineering

Department of Mechanical Engineering

2025

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*In humble reverence and unwavering devotion, I dedicate the entirety of this thesis to Allah Almighty, seeking His divine guidance as I embark on this scholarly journey*



## CERTIFICATE OF APPROVAL

**Identification and Assessment of Building Information Modeling  
(BIM) Adoption Issues Using Modified Model of Unified Theory of  
Acceptance and Use of Technology (UTAUT) for Construction Sector  
of Pakistan**

by

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## *Acknowledgement*

I am dedicating this thesis to Allah Almighty, whose boundless mercy and infinite wisdom have guided me through every step of this journey. His grace has been my strength, and His blessings have made this achievement possible. I also extend my heartfelt reverence to Prophet Muhammad (PBUH), the Divine Servant Leader, whose teachings have profoundly influenced my life and instilled in me the values of perseverance, integrity, and compassion.

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**Tamoor Tanveer**

## *Abstract*

Building Information Modeling (BIM) is still not widely used in construction sector of Pakistan. The purpose of this study is to determine the factors affecting the nation's adoption of BIM solutions. A modified version of the unified theory of acceptance and use of technology (UTAUT) framework is used in the study to accomplish this goal. The dependent variable in this study is behavioral intention, which stands for a person's intention to embrace and use technology. According to the model, a number of variables may have an effect on behavioral intention, including perceived cost, attitude, social influence, facilitating conditions, performance expectancy, effort expectancy, and generation gap.

By employing a survey-based research approach, this study gathers information from 294 respondents who either utilize BIM now or plan to do so soon. A survey of the literature led to the development of eight hypotheses. Descriptive statistics, reliability analysis, regression analysis, Pearson correlation analysis, and confirmatory factor analysis (CFA) using SPSS and AMOS software were among the statistical methods used in the study to examine these assumptions.

The findings show that behavioral intention to adopt BIM is significantly impacted by both performance expectation and effort expectancy, however modestly. Contrary to predictions, perceived cost has a beneficial effect, but social influence and enabling circumstances have a greater impact. Interestingly, attitude turns out to be the most important predictor, highlighting how important it is in influencing adoption choices. In turn, behavioral intention has a major role in driving the adoption of BIM, highlighting its significance as a crucial factor in the Pakistani context.

The results indicate that BIM adoption is influenced by multiple factors. Performance expectancy, effort expectancy, and social influence underscore the significance of perceived usefulness, ease of use, and societal support. Facilitating conditions and a positive attitude further promote adoption, while behavioral intention remains the strongest driving force. However, the rejected hypotheses reveal some unexpected findings. Perceived cost, rather than acting as a barrier, positively

influences behavioral intention, suggesting a more complex relationship that warrants further investigation. Similarly, the generation gap unexpectedly fosters BIM adoption, indicating that generational differences may encourage, rather than hinder, adoption. Ultimately, all hypotheses except hypothesis (H<sub>5</sub>) and hypothesis (H<sub>7</sub>) were supported by the data analysis.

**Keywords:** Building Information Modeling (BIM), UTAUT model, Behavioral intention, Performance expectancy, Effort expectancy, Social influence, Facilitating conditions, Perceived cost, Attitude, Generation gap, Confirmatory factor analysis (CFA), SPSS/AMOS

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# Abbreviations

|                |  |
|----------------|--|
| <b>AEC</b>     | Architecture, Engineering, and Construction      |
| <b>AMOS</b>    | Analysis of Moment Structures                    |
| <b>BI</b>      | Behavioral Intention                             |
| <b>BIM</b>     | Building Information Modeling                    |
| <b>CFA</b>     | Confirmatory Factor Analysis                     |
| <b>CFI</b>     | Comparative Fit Index                            |
| <b>CM</b>      | Construction Management                          |
| <b>CMIN/DF</b> | Chi-square to degrees of freedom ratio           |
| <b>CTAMTPB</b> | Combined TAM and Theory of Planned Behavior      |
| <b>EE</b>      | Effort Expectancy                                |
| <b>FC</b>      | Facilitating Condition                           |
| <b>ICT</b>     | Information and Communication Technology         |
| <b>IDT</b>     | Innovation Diffusion Theory                      |
| <b>IFI</b>     | Incremental Fit Index                            |
| <b>IPD</b>     | Integrated Project Delivery                      |
| <b>LOD</b>     | Level of Development                             |
| <b>MEP</b>     | Mechanical, Electrical, Plumbing                 |
| <b>MM</b>      | Motivational Model                               |
| <b>MPCU</b>    | Model of PC Utilization                          |
| <b>NBIMS</b>   | National Building Information Modeling Standards |
| <b>NFI</b>     | Normed Fit Index                                 |
| <b>PC</b>      | Perceived Cost                                   |
| <b>PE</b>      | Performance Expectancy                           |
| <b>RE</b>      | Reverse Engineering                              |

|               |  |
|---------------|--|
| <b>RMSEA</b>  | Root Mean Square Error of Approximation            |
| <b>RUCAPS</b> | Really Universal Computer-Aided Production System  |
| <b>SCT</b>    | Social Cognitive Theory                            |
| <b>SI</b>     | Social Influence                                   |
| <b>SPSS</b>   | Statistical Package for the Social Sciences        |
| <b>TAM</b>    | Technology Acceptance Model                        |
| <b>TAM2</b>   | Revised Technology Acceptance Model                |
| <b>TLI</b>    | Tucker Lewis Index                                 |
| <b>TPB</b>    | Theory of Planned Behavior                         |
| <b>TRA</b>    | Theory of Reasoned Action                          |
| <b>UTAUT</b>  | Unified Theory of Acceptance and Use of Technology |

# Chapter 1

## Introduction

Building Information Modeling (BIM) is a technology application as well as a methodology. This procedure is intended to produce and oversee information at every stage of a building project. Timelines, structural connections, material inventories, construction material quantities and qualities, geometric details, and cost projections are all included in BIM. BIM is essentially a complete 3D digital foundation for efficient building project management.

### 1.1 Background

In 1975 Chuck Eastman [1] offered the theoretical framework for a more comprehensive and useful role for computer use in architecture with his "Building Description System". R. Aish and N. Bredella [2], a software developer, helped create the Really Universal Computer-Aided Production System (RUCAPS) in the 1980s. Furthermore, in 1982 [3], Graphisoft developed ArchiCAD software which was initially based on "virtual structure" later it was developed in "virtual structure model". This system was among the first to use the "building modeling" approach. For almost 20 years, this modeling technique had been used under several titles, such as intelligent object, virtual building, and product model. By means of a complete model that can be efficiently used throughout several phases of a project, including planning, design, construction, and facility management, BIM

presents a clear benefit over conventional computer-aided design (CAD) models. For efficient and successful design and construction management, BIM is becoming more and more popular among architects and project managers [4].

The national building information modeling (NBIMS) organization in the United states of America (USA) defines BIM as a digital representation of a facility's functional attributes [5]. Depending on its particular uses and how people use it, different organizations and people have different definitions of BIM (building information modeling). Because of this, the majority of definitions of BIM cover the vast array of advantages it provides. According to the national institute of building sciences, BIM is the technique of utilizing cutting-edge digital technology to produce a computational depiction of a facility's operational and tangible attributes as well as the project and life-cycle data associated with it. For facility owners or operators, this digital library is an essential resource that makes it easier to use and maintain the facility effectively during its whole life cycle [6].

Building Information Modeling (BIM) in Pakistan's construction industry remained relatively low in contrast to other developed nations [7]. While international markets have steadily integrated BIM into all project phases to enhance efficiency and life cycle management, Pakistan is still in the early stages of BIM adoption, with a rate of around 30% and even lower in provinces like Sindh. The key obstacles include high adoption cost, limited awareness among construction professionals, a shortage of skilled personals, and weak regulatory formworks. However, the growing interest in BIM among professionals, particularly in urban centers like Karachi and on internationally funded projects highlights the potential for meaningful progress.

Traditionally, the "B" in BIM refers to "building," but it is more accurately understood as the "act to build," making it applicable to a broad range of construction projects, including infrastructure. The "I," stands for "information," the core value of BIM emphasizing the need for accurate, accessible, and shared data throughout the project lifecycle. Effective information management is essential for sustainability and project success. The "M" represents model, reflecting the digital representation of a project's physical and functional aspects [8]. These models

incorporate various disciplines architecture, structural, and MEP and follow level of development (LOD) like (LOD 100, LOD 200, and LOD 300) to define their detail and accuracy across different project stages. Within BIM, level of development (LOD) defines the content, reliability, and level of detail within model elements at different project stages. level of development (LOD) helps specify minimum requirements for geometry and information, ensuring the model's suitability for various users like analysis or cost estimation, ultimately supporting better PM decisions [9].

## 1.2 Traditional Process Versus BIM Process

As fig 1.1, shows that during the construction phase, numerous issues and mistakes arise as a result of deficiencies in the design phase. Moreover, industry has a lot of problems with coordination, standards, and communication. The effective transfer of design information is a crucial component in solving these interoperability challenges, and this is where building information modeling (BIM) is essential for this. BIM uses a model as a centralized database, allowing for easy sharing and retrieval of information as needed, in contrast to traditional techniques, which involve project participants exchanging papers and drawings with each update [10]. BIM offers a modern, digital, and collaborative framework for design and construction processes, representing a significant shift from the traditionally fragmented and predominantly 2D based practices common in Pakistan [11]. Construction professionals in the country acknowledge the notable benefits of BIM, including enhanced design quality, improved control over projects time lines and budgets, and increased client's satisfaction through early detection of design conflicts and better coordination. Nonetheless, the transition to BIM is not without challenges; it demands more efforts from designers and presents issues related to software interoperability. Despite these advantages, BIM implementation in Pakistan remains limited, primarily due to a shortage of trained professionals, insufficient awareness, high adaptation cost, and resistance to changing established rational work flows. As a result conventional methods continue to dominate the construction industry.

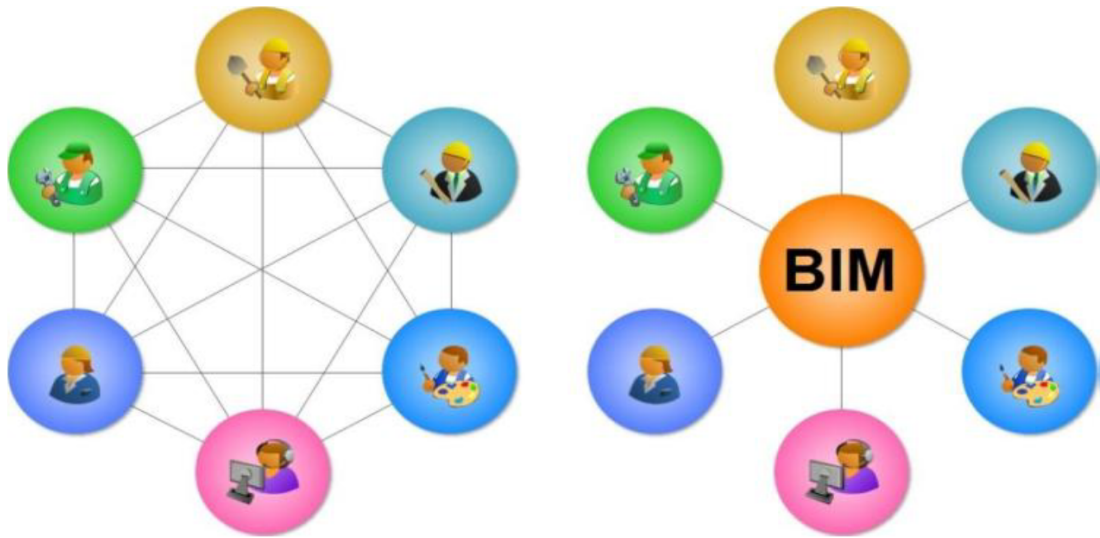


FIGURE 1.1: Traditional Process versus BIM Process [10].

### 1.3 Problem Statement

The construction sector is distinguished by its complex and dynamic design, which frequently involves complicated schedules, various stakeholders (engineers, clients, contractors, project managers) and a large number of interrelated operations. The incorporation of BIM in the construction sector has received considerable attention for its ability to improve efficiency, cooperation, and overall project results.

Although, various studies [12, 13], have been conducted on the challenges hindering building information modeling (BIM) adoption in construction sector of Pakistan, issues such as high cost, limited awareness, skill shortage, and weak institutional support still remain less focused, the current study discusses the BIM adoption issues in different manners, by using unified theory of acceptance and use of technology (UTAUT) model.

The primary challenge lies in identifying the obstacles and constraints impeding the wider deployment of BIM technology in Pakistan. This research examines the various issues related to BIM adoption within the construction sector of Pakistan. It employs the modify version of the UTAUT (unified theory of acceptance and use of technology) model, incorporating additional factors specific to the context of BIM adoption.

The results of this study aim to assist construction professionals, project managers, and stakeholders (engineers, clients, contractors, project managers) in making informed decisions, optimizing resource management, and proactively addressing potential risks. Ultimately, the goal is to enhance project outcomes, reduce delays, and improve the overall success of construction projects.

## 1.4 Research Questions

Considering on the above discussions, four main issues are discussed in this study.

### Research Question 1

To what extent do performance expectancy and effort expectancy affect individuals' behavioral intention to adopt building information modeling (BIM) in the construction sector of Pakistan?

### Research Question 2

To what extent do social influence and facilitating conditions impact individuals' behavioral intention to use BIM and their actual usage and learning behavior?

### Research Question 3

How do perceived cost and individual's attitude influence behavioral intention to adopt building information modeling (BIM) technology?

### Research Question 4

How does the generation gap and behavioral intention influence user behavior towards the adoption of BIM technology?

## 1.5 Research Objective

The study has following specific objectives that are considered in this research work:

**Research Objective 1**

To examine the influence of performance and effort expectancy on individuals' behavioral intention to adopt building information modeling (BIM) within the construction sector of Pakistan.

**Research Objective 2**

To assess the impact of social influence and facilitating conditions on individuals' behavioral intention, actual usage, and learning behavior in the context of BIM adoption.

**Research Objective 3**

To investigate the effect of perceived cost and attitude on behavioral intention toward adopting BIM technology.

**Research Objective 4**

To analyze the relationship between the generation gap and behavioral intention, how these factors influence user behavior in the adoption of BIM technology.

This study aims to gain a better knowledge of the issues associated with BIM adoption and provide useful insights for formulating strategies to overcome hurdles and ensure effective implementation. The findings are designed to give actionable insights to stakeholders such as industry experts, legislators, and researchers, hence encouraging widespread BIM use and driving innovation and efficiency for the construction sector.

## **1.6 Significance of the Study**

The significance of this study arises from the potential benefits that BIM adoption might provide for Pakistan's building sector. Building information modeling (BIM) is a technology invention that has gained global recognition for improving the quality, efficiency, and sustainability of building projects.

However, BIM adoption in Pakistan has been slow, and in order to encourage its broader usage, a number of obstacles and challenges must be removed. By identifying these challenges and proposing possible solutions, this research can provide Key insights and actionable recommendations for policymakers, construction professionals, and other stakeholders in AEC industry for the construction sector of Pakistan. Moreover, as Pakistan is a developing country with a growing construction industry, the adoption of BIM can also have positive economic impacts by creating new job opportunities and enhancing productivity of the construction activity. Therefore, addressing the challenges associated with BIM adoption in Pakistan can have significant benefits for the country's construction industry, economy, and overall development.

BIM adoption in Pakistan stands at just 11%, with its use primarily limited to creating 2D and 3D drawings. This represents a narrow application of BIM's capabilities, highlighting the need for broader and more comprehensive utilization of the technology [14]. The advanced dimensions of BIM, including 4D (construction sequencing through Gantt charts and timelines), 5D (cost management and construction cost estimation), 6D (detailed information for facility management and operations), 7D (sustainability aspects of a project), and 8D (site safety and risk analysis), are not currently utilized in Pakistan's AEC industry. There are different reasons of not implementing this advance technology in construction sector of Pakistan such as the high cost of BIM related software, lack of experienced BIM professionals, inadequate information sharing practices to stakeholders, high cost of adoption and regularity and security concerns.

## 1.7 Supporting Theories

The unified theory of acceptance and use of technology (UTAUT) and its extended versions have been extensively employed to analyze technology adoption behavior across diverse contexts. Eight well-known theories are included in the traditional UTAUT model, which was created by Venkatsah et al. and emphasizes four major factors that affect technology use: performance expectancy, effort expectancy, so-

cial impact, and facilitating conditions. Using context-specific variables, updated UTAUT models have expanded on this basis to increase explanatory power.

### 1.7.1 Classical UTAUT (Unified Theory of Acceptance and Use of Technology)

The UTAUT (unified theory of acceptance and use of technology) model was first introduced by Venkatesh et al. [15], to integrate eight distinct models, which includes the theory of planned behavior (TPB), the technology acceptance model (TAM), the motivational model (MM), the model of pc utilization (MPCU), the theory of reasoned action (TRA), the innovation diffusion theory (IDT), the social cognitive theory (SCT), and a combined version of the TAM and TPB (CTAMTPB). The UTAUT (unified theory of acceptance and use of technology) holds that an individual's actual usage of technology is determined by their behavioral intention [16].

Four main factors SI (social influence), PE (performance expectancy), EE (effort expectancy), and FC (facilitating conditions) have a direct impact on this goal. Additionally, the impacts of these variables are lessened by significant contextual and demographic factors such as gender, age, experience and voluntary usage. According to the UTAUT model, performance expectancy is the conviction that a technology improves job performance and is a reliable indicator of usage intention. Perceived ease of use is referred to as effort expectancy; however users' experience reduces its impact. Social influence, which is more pronounced in settings where technology use is required, is the idea that other people expect one to utilize it. The idea that infrastructure and organizational support make technology use possible is known as "facilitating conditions," and it influences actual use but not intention.

This study uses the UTAUT (unified theory of acceptance and use of technology) to analyze the underutilization of inter-organizational ICT (information and communication technology) in building projects [17]. It defines PE (performance expectancy), EE (effort expectancy), SI (social influence), and FC (facilitating

conditions) as the four main elements driving the adoption of ICT. While effort expectation refers to knowledge and skills, where adoption is impacted by procedural clarity and simplicity of use, performance expectancy is influenced by perceived advantages and drawbacks and mitigated by time constraint. ICT usage is driven by social influence, which comes from contractual requirements and stakeholder expectations, while enabling conditions, which operate as both facilitators and obstacles, depend on ICT alignment with work practices and the availability of technical resources. The study highlights the need to view ICT adoption in a social and organizational context, acknowledging users as social actors who are impacted by group norms rather than acting as lone decision-makers. Assuring that ICT solutions are in line with industry-specific requirements and working circumstances, the research recommends improving acceptance by honing implementation tactics through the use of social influence, organizational support, and customized training programs.

### **1.7.2 Modified UTAUT (Unified Theory of Acceptance and Use of Technology)**

This Study [18], examined the factors that shape individuals' intentions to adopt green banking and how these intentions influence their actual usage behavior, using a modified version of the unified theory of acceptance and technology (UTAUT). The adopted model included six key predictors performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitating conditions (FC), environmental responsibility (ENR), and environmental concerns (ENC) - which were proposed to impact behavioral intention (BI), while facilitating conditions (FC), environmental responsibility (ENR), and environmental concerns (ENC) were also accepted to directly affect usage behavior (UB). The analysis showed that performance expectancy (PE), effort expectancy (EE), facilitating conditions (FC), environmental responsibility (ENR), and environmental concerns (ENC) significantly contributed to user's intention to engage in green banking, where as social influence (SI) did not have a notable influence. Among the influencing factor, facilitating conditions (FC) and performance expectancy (PE) were identified as

the strongest contributors to adoption intention, with environmental responsibility (ENR) and environmental concerns (ENC) playing a moderate role. Additionally, the study found that facilitating conditions (FC), environmental responsibility (ENR), environmental concerns (ENC), and behavioral intention (BI), had a direct and positive impact on actual usage. Behavioral intention (BI), also served as significant mediator between the initial predictor and usage behavior. In summary, the modified UTAUT model proved effective in explaining green banking adoption in Pakistan, accounting for 58.8% of the variance in intention and 47.6% in actual usage behavior.

Another study [19], adopted the modified UTAUT (unified theory of acceptance and use of technology) framework to examine how faculty members in communication and media studies (CMS) departments across Pakistan perceive and implement artificial intelligence (AI) in their instructional practices. Through qualitative interviews aligned with the primary construct of UTAUT, the research aimed to identify the key drivers of AI acceptance among educators. The investigation considered components such as performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitating conditions (FC), hedonic motivation (HM), attitude towards use (ATT), and behavioral intention (BI) which collectively contribute to usage behavior (UB). The results showed that instructors largely believe AI could enhance their efficiency and job performance, indicating strong PE. Many found AI tools user friendly, signaling positive EE though age was seen to influence this perception. Participants also played a significant interest in learning and applying AI in their teaching, reflecting positive attitudes and intentions (ATT and BI). While some were initially hesitant, personal engagement with AI tools led to enjoyment, revealing the influence of HM. Peer interactions and professional networks were found to encourage adoption, pointing to the role of SI. Nonetheless, the study highlighted major obstacles: insufficient institutional support and lack of resources and training, which weakened FC. As a result, actual implementation of AI remained limited, often confined to administrative uses rather than teaching. Ultimately, study demonstrated the usefulness of modified UTAUT in analyzing AI adoption, while emphasizing the essential role of supportive condition in translating intent into real world application.

## 1.8 Organization of the Study

The current study is divided into five chapters. A brief overview of each chapter is presented below;

- The basic introduction, problem statement, research questions, research objectives, significance of the study and relevant studies are provided in Chapter 1.
- The detailed literature is covered in Chapter 2, considering the literature is reviewed on introduction of BIM, benefits of BIM, analysis of BIM adoption worldwide and Pakistan, previous studies applying UTAUT in different technologies, factors influencing BIM adoption, BIM technology adoption issues in Pakistan and research Gap.
- Chapter 3 explains the research methodology.
- Chapter 4 covered an analysis of the questionnaire data gathered in the previous chapter. Various statistical methods and testing techniques are employed to interpret the data. All types of test results are critically discussed, followed by a summary of decisions on hypothesis acceptance or rejection. The results are organized in a clear, structured manner, providing an overview of the outcomes and their relevance to the field in focus.
- Chapter 5 outline the study's conclusions, evaluate its limitations and propose directions for future research.

# Chapter 2

## Literature Review

The literature related to the research topic is addressed through a structured approach. In first step, the literature is reviewed on introduction to building information modeling (BIM), benefits of BIM, worldwide BIM adoption and situation of BIM in Pakistan. The second step covers the literature related technology adoption theories and previous studies applying unified theory of acceptance and use of technology (UTAUT) in different technologies. In third step, a review of the literature is conducted to determine the factors impacting BIM adoption, the challenges associated with its implementation in Pakistan, and the application of the UTAUT framework in BIM adoption within the construction sector of Pakistan. Lastly, the research gap is highlighted based on reviewed literature.

### 2.1 Building Information Modeling (BIM)

Building Information Modeling (BIM) is a "model-based technology connected to a database containing project information." It digitally stores comprehensive details about a building, such as the quantities and properties of its components, throughout the project lifecycle. By combining structured and integrated data from various disciplines, BIM creates a digital representation of an asset, embracing all aspects of the project lifecycle, including as planning, design, construction, and operations [20].

BIM refers to the technology and process utilized to develop a comprehensive virtual representation of a building. This digital model includes exact geometry, spatial connections, geographical information, quantities, and the attributes of the architectural components essential for construction, fabrication, and procurement processes. Unlike traditional design methods, computer-aided design (CAD) introduces a modern approach to modeling physical objects, including building elements. In this technique, building components are represented as objects that integrate both their actual shape and different properties, a notion commonly referred to as object-oriented computer-aided design [21].

BIM originated in the late 1970s at Georgia Institute of Technology and quickly gained traction. Its growth was driven by construction teams recognizing the benefits of integrating project processes through BIM. In 2002, the term “BIM (building information modeling)” was used to describe virtual representation for facility management, design, and construction [22]. In 1986, Graphisoft pioneered virtual building technology by releasing its software, which facilitates the creation of 3D models. This marked a significant advancement in computer-aided design (CAD) technology at that time. The term building information modeling (BIM) became widely recognized after Autodesk introduced in its own BIM software [23].

Internet search as shown in Fig 2.1, reveals that building information modeling (BIM) is perceived differently by professionals, ranging from a software program to a process for managing building data or a comprehensive approach integrating design, construction, and maintenance. While its full potential in the construction sector remains untapped, BIM continues to evolve with advancing technology.

For architects and designers, it enables 3D visualization, design exploration, and clash detection. Engineers use it to integrate disciplines and improve design quality, while contractors rely on it for task sequencing and conflict resolution, enhancing efficiency and communication. Post-construction, facility managers utilize BIM for asset management, and owners benefit from project visualization, enabling informed decisions on materials, costs, and planning. BIM ultimately enhances collaboration, efficiency, and decision-making across all stages of the construction life-cycle [10].

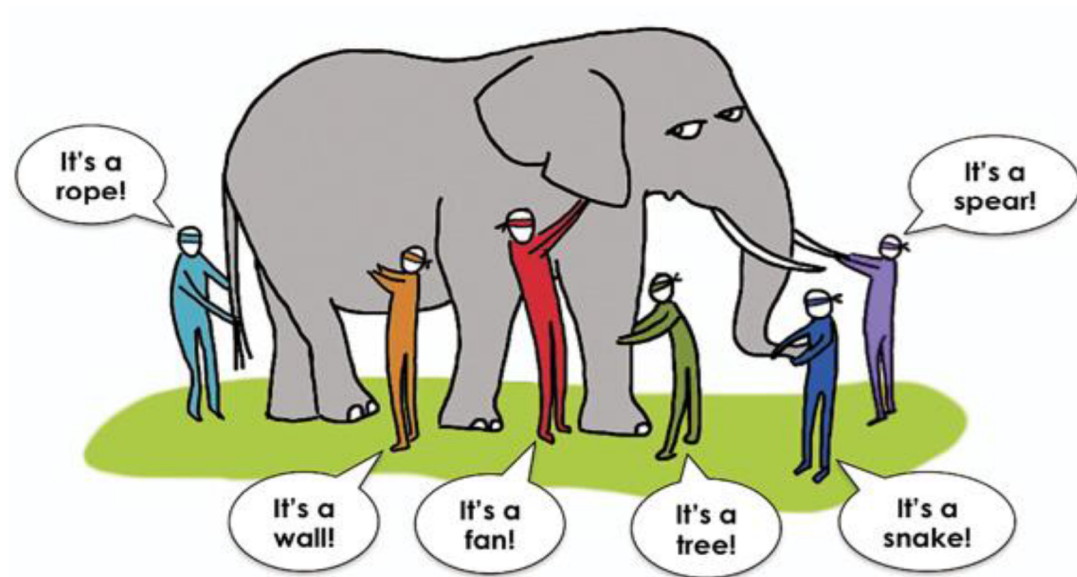


FIGURE 2.1: BIM can hold varying meanings for different professionals [10].

The importance of BIM stems largely from its ability to increase collaboration avoids mistakes; minimize time and cost and boosting overall efficiency and quality in construction projects. However, to achieve these benefits, it is crucial for all stakeholders (engineers, clients, contractors, project managers) to adopt BIM practices and actively participate in the collaborative process. BIM facilitates effective stakeholder (engineers, clients, contractors, project managers) collaboration, coordination, and communication in building projects in several ways.

The levels of information in BIM are categorized into eight dimensions as shown in figure 2.2, each serving a specific purpose [24]. The 3D model provides a detailed representation of a building's structure, enabling stakeholders to visualize and address structural issues collaboratively. Adding time, 4D BIM incorporates scheduling to depict project progress, detect conflicts, and analyze the impact of changes. The 5D dimension focuses on cost estimation, allowing precise budgeting and analysis of scope or material changes. 6D BIM supports facility management by analyzing energy use and providing data on maintenance, configuration, and decommissioning. The 7D dimension emphasizes sustainability, defining required data for environmental analysis, while 8D BIM targets site safety and risk management, incorporating health and safety information to identify and address potential issues proactively. Together, these dimensions enhance collaboration, efficiency, and project outcomes across the building lifecycle [25].

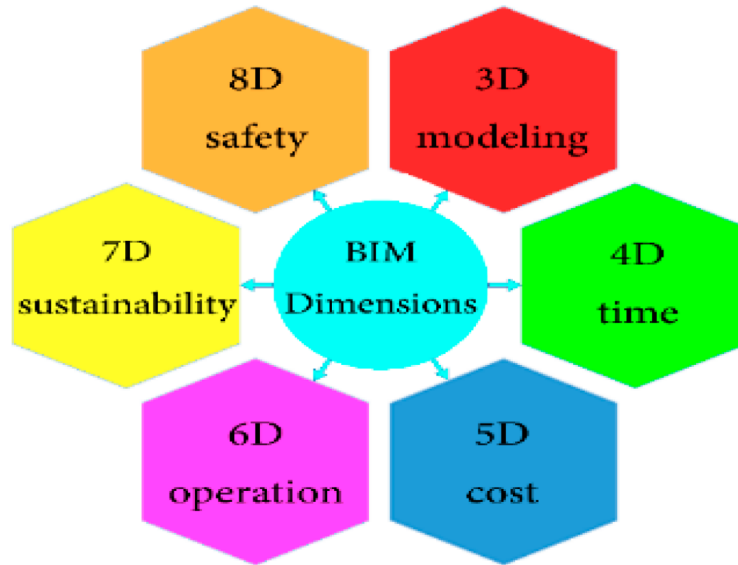


FIGURE 2.2: Overview of BIM Dimensions: From 3D Modeling to Safety [24].

### 2.1.1 Building Information Modeling Aspects

IPD (integrated project delivery) is a cooperative approach that unites project managers, designers, engineers, and systems to increase project efficiency and value. It focuses on team collaboration, prioritizing overall project success over individual goals. Building Information Modeling plays key role by allowing a unified model to the team to analyze, visualize and communicate complex project data effectively. This integration improves productivity, streamlines project management, and enables team to track progress, make decisions, and resolve issues effectively. IPD integrates project management, while BIM provides the technological platform to support this.

Effective communication is essential, and project managers often enhance their skills through higher education. Over the past decade, initiatives like SMART originally known as the IAI (international alliance for interoperability) have aimed to optimized interoperability between construction software, with the IFC (industry foundation classes) standardizing data to ensure consistent communication across tools throughout a project's lifecycle [23].

BIM possesses different traits that may be effectively applied for successful project management. It is a powerful tool that helps in resolving geometrical design incon-

sistencies in construction projects. It enables the integration of plans from various disciplines, allows for the identification of conflicts, and facilitates aesthetic problem modification. BIM also aids in analyzing energy consumption, developing better alternatives, and performing studies for sound, light, and mechanical systems. BIM also helps in estimations for time, cost, and allow managers to visualize project at any moment and understand various project phases. It also simulates various options for executives and project managers to accurately predict outcomes. BIM can be used to coordinate design, analysis, and construction operations across various stages of a project by ensuring project integrity. Quantity takeoffs in BIM models can help project teams to analyze their choices and understand all available options. BIM models often consist of objects, breaking them down into smaller objects, and resulting in a clear scope of projects. Collaboration and team building are crucial aspects for BIM success in construction projects. By combining efforts from different disciplines, BIM promotes team development and direct communication. This integrated model enables project managers, architects, engineers, and contractors to collaborate and communicate more efficiently by reducing conflict among various stakeholders [26].

## **2.2 BIM Adoption in Construction as Innovation**

The worldwide AEC industries are progressively adopting BIM technologies. However, developing nations like Pakistan are still lagging. BIM implementation increases efficiency and provides numerous advantages like more efficient information reuse, quicker design processes, and customer satisfaction [27]. A No. of factors need to be considered for effective transition from BIM level 1 to level 2 maturities, which include raising clients and other potential stakeholder (engineers, clients, contractors, project managers) understanding about the advantages of BIM. Education and training are also necessary for prospective BIM team members. Integrating BIM into undergraduate and graduate courses might be an effective way to include it into architectural, building, and construction education [28].

The initial ten years of the 21st century have seen a substantial rise in the demand for eco-friendly structures, primarily driven by escalating energy expenses and increasing environmental apprehensions. Optimal decisions concerning the sustainable architecture of a building are most effectively undertaken while planning and design process.

BIM enables the integration of various data into a single cohesive model, presenting an opportunity to integrate sustainability measures are implemented early in design process. BIM proves instrumental in conducting intricate analyses of building performance by ensuring a well-optimized design. Designers can leverage from these findings by generating essential documentation for official certification and facilitating successful implementation of BIM [29].

Considering the situation of endeavors seeking Leadership in Energy and Environmental Design (LEED<sup>®</sup>) certification, a widely recognized and implemented system for green building assessment in the United States, numerous LEED<sup>®</sup> credits necessitate the submission of drawings to obtain eligibility for credit. While traditional Computer-Aided Design (CAD) software can be employed to generate these drawings; nevertheless, BIM software proves more adaptive at producing them efficiently within the building information model framework. Notably, BIM software offers an additional advantage of parametric change technology by streamlining the coordination of alterations and ensuring consistency throughout. This excludes the need for manual intervention in updating drawings or links.

BIM adoption in India [30] found a high potential for acceptance, according to the reported literature. BIM's modest adoption in Indian construction firms demonstrates its potential for sharing information and integrating it across trades, leading to easier and better decisions.

The following Table 2.1 compares the effectiveness of BIM with Auto-CAD in Indian construction industry. The findings of the comparison between AutoCAD and BIM use show that BIM enhances the precision and quality of engineering designs for precast, fabrication, and erection processes while drastically lowering the resources needed for drawing verification.

TABLE 2.1: Comparison of efficiency between CAD and BIM [30].

| <b>The Efficiency Difference Between CAD and BIM Applications<br/>for Particular Project in Different Phases</b> |                        |                        |                        |                         |
|--|------------------------|------------------------|------------------------|-------------------------|
| <b>Task</b>  | <b>CAD<br/>(Hours)</b> | <b>BIM<br/>(Hours)</b> | <b>Hours<br/>Saved</b> | <b>Time<br/>Savings</b> |
| Schematic  | 190                    | 90                     | 100                    | 53%                     |
| Design Development   | 436                    | 220                    | 216                    | 50%                     |
| Construction Documents   | 1023                   | 815                    | 208                    | 20%                     |
| Checking and Coordination  | 175                    | 16                     | 159                    | 91%                     |
| <b>Totals</b>  | <b>1824</b>            | <b>1141</b>            | <b>683</b>             |                         |

A case study of Vietnam pinpoints 39 important worldwide elements that affect the BIM adoption for projects construction and have a significant impact on construction labor productivity. These 39 factors are divided into five primary groups; those primary variables include "perceived organizational benefits of BIM," "technology quality," "experience and skills," "perceived usefulness," and "speed of BIM tools." Although BIM has been utilized since the early 2000s in the Vietnamese AEC sector, adoption is still limited [31].

The critical success factors (CSFs) play an important part for implementing BIM in developing nations where the construction sector is still in the initial phases of technology adoption. The statistical study shows three most important elements are the availability of talented personnel, good leadership, and access to information and technology. The data is subjected to factors analyses and the findings show that sixteen CSFs' underlying components are connected to people, industries, projects, policies, and resources. CSFs' are critical to the effective adoption of BIM in enterprises particularly those with limited resources [32].

Government regulations and mandates can either directly or indirectly encourage the development of new technologies; therefore, they can serve as a driving factor in the BIM adoption for both the business sectors and the academic community. Government employees, academicians from universities, professionals from busin-

ess, and college students are all involved in BIM implementation. BIM technology interconnects these relevant parties. The promotion of BIM technology may be sped up with government accountability acting as the catalyst. Governments are able to assist the development of new technologies because to their public service resources. It is advised that the government should exert more influence so that business and academia can work together collaboratively. Aligning BIM technology with work elements is emphasized by focusing on factors like information sharing, standard procedures, and educating for senior managers. Project manager and field engineers' interest and willingness are deemed more critical than project-specific factors for project selection. In selecting BIM services, the study recommends prioritizing outcomes and goals over input costs with emphasis on BIM adoption value, company strategy, client requirements, and current BIM technology [33].

For BIM software applications, technical factors like interoperability and ease of use are considered along with non-technical factors such as known successful BIM cases and economic impact. The identified CSFs are proposed as metrics for evaluating and managing BIM adoption within an organization, offering a foundation for future BIM evaluation models [34].

## 2.3 Benefits of BIM Adoption

In the 21st century, technological advancements, primarily driven by progress in computer science, have continually enhanced various fields; this includes the construction industry. Over the past decade, there has been a notable shift in design tools within the AEC industry, transitioning from traditional 2D modeling to more sophisticated 3D modeling approaches. One of the most significant advancements in this regard is BIM, which has developed as a robust suite of design management tools highly regarded by professionals in the AEC sector. BIM offers substantial benefits across the entire lifecycle of a building, with particular emphasis on improving design processes, as well as enhancing construction and facility management practices [35].

BIM not only enhances technological capabilities but also transforms the design and construction processes. It facilitates better decision-making and accelerates project timelines by reducing complexity and integrating various disciplines, such as documentation and design. BIM enables the seamless integration of plans, sections, details, graphics, and data achieving a level of coordination that is unachievable with traditional 2D methods [36]. As a result, the time required for design can be significantly reduced by approximately half, and at a proportionate cost reduction. This "half time at half cost" scenario not only leads to cost savings but also expedites entry into the construction market, providing early access to potential benefits. Consequently, employing BIM can yield savings in design costs and capitalize on earlier opportunities to engage with the construction market. During the operational phase, building information modeling (BIM) generates accessible, simultaneous information concerning project performance and its economic aspects. BIM produces a digital record of transformations and advancements occurring throughout the operational phase. According to an Autodesk analysis, BIM speeds the adaption of conventional building models to match site-specific constraints, which is especially useful for businesses like retail that build comparable structures in several locations. Based on the survey findings, the majority of BIM users see it as a tool for reducing the demand for human resources throughout the operational phase.

Initially, the utilization of BIM 3D technology proved immensely beneficial during the design phase, serving as the primary tool for coordinating technology and construction drawings. This facilitated the construction management (CM) team in reducing time spent on revisions and corrections. Furthermore, it allowed for the early identification of critical points and areas from both structural and technological perspectives, enabling timely preparation of critical tasks. The generation of work package quantities from the BIM model helped minimize errors typically associated with human nature in material and product ordering, ensuring timely procurement. The economic advantages derived from the system's utilization, coupled with savings achieved through selected solutions and accurate bill of quantities, outweighed the additional management costs associated with employing the BIM methodology by no less than tenfold [37].

Effective adoption and integration of BIM can mitigate the complexities and challenges associated with project management. BIM facilitate interoperability among many business sectors, improves existing communication channels, and offers a collaborative environment. Also, if it is successfully implemented, performance and productivity might be enhanced for the duration of the project [38].

## 2.4 BIM Tools Used in Construction Industry

The construction sector makes extensive use of BIM tools to enhance the planning, execution, and maintenance of infrastructure and building projects [39]. BIM software, such as Autodesk Revit, Graphisoft, Archicade, Trimble, and Navisworks, as well as BIM applications, such as design and modeling, clash detection, quantity takeoff, construction scheduling, and facility management, are examples of common BIM tools. These tools assist the construction sector in enhancing collaboration, lowering costs, and improving project outcomes [40].

Using a three-story residential structure as a case study [41], the study investigates the uptake and efficacy of BIM technologies for project management in the Bangladeshi construction sector. The primary tool for producing intricate 3D architectural, structural, and MEP models enhanced with construction and material data was Autodesk Revit 2018. Autodesk Robot Structural Analysis was used for structural analysis, while Autodesk Navisworks 2018 and Revit were used for conflict identification, which found more than 100 clashes. By integrating the Revit model in Navisworks with MS Project schedules, 4D scheduling was made possible, allowing for time-based construction visualization. Revit produced quantity take-offs for 5D cost estimation, which were then further processed in Excel. By handling RFIs and assisting with design clarity, Autodesk Design Review 2018 aided in the execution phase. When compared to conventional 2D approaches, the study finds that BIM tools greatly enhance visualization, collision detection, scheduling, cost calculation, and structural analysis, eventually lowering uncertainties, flaws, costs, and time. Table 2.2, present a list of most commonly used BIM tools in the AEC industry.

TABLE 2.2: BIM Software Tools for AEC Industry.

| Related Software      | Primary Function   | Manufacturer                                    |
|-----------------------|--|---|
| Autodesk Revit        | Create a 3D models with intelligent objects, producing documentation, and facilitating collaboration across disciplines [42].                                    | Autodesk  |
| Autodesk Navisworks   | Helps identify and resolve overlaps or conflicts between different building elements before construction begins [43].  | Autodesk  |
| Bentley MicroStation  | It offers a wide range of features for design, documentation, and construction management [44].  | Bentley Systems                                 |
| ArchiCAD              | Known for its user-friendly interface and object-oriented workflow. ArchiCAD excels at architectural design and generating high-quality documentation [45].      | Graphisoft                                      |
| Vectorworks Architect | A versatile BIM software for landscape architects, and interior designers [46].  | Vectorworks, Inc., part of the Nemetschek Group |
| Tekla BIMsight        | Specially designed for BIM collaboration and coordination for teams to review, analyze, and markup BIM models from different software [47].                      | Trimble Connect                                 |
| Solibri Model Checker | Focused on quality assurance and code compliance checking within BIM models, resolving issues related to building codes, accessibility, and sustainability [48]. | Solibri, Inc.                                   |

Table 2.2: (Continued).

| Related Software | Primary Function  | Manufacturer  |
|------------------|---|---------------|
| Edificius        | A user-friendly BIM solution tool for architectural and structural design, with focus on energy efficiency and sustainable building practices [49]. | ACCA Software |
| Allplan Bimplus  | A BIM software solution for architects and designers, with a focus on ease of use and collaboration [50].   | Allplan GmbH  |

## 2.5 Analysis of BIM Adoption Worldwide

Building information modeling (BIM) technology has received worldwide popularity, with the United States leading the way in its application. Various countries, particularly in North America, Europe, Oceania, and Asia, have established BIM programs, goals, and standards. The United Kingdom, for example, the requirement for BIM usage in government projects was enforced starting in 2016 [51].

In Asia, countries like Singapore and Hong Kong have developed BIM committees and guidelines. China incorporated BIM in its national plan in 2012. The general trend reveals that North America, Europe, Oceania, and Asia are fast approaching BIM maturity, whereas the Middle East/Africa and South America are still in the early phases of implementation. The technology diffusion model categorizes BIM users worldwide, with more developed nations using a wider range of BIM services [52].

### 2.5.1 BIM Study Country by Country

In Australia [52], there has been significant adoption of Building information modeling (BIM) among design professionals, reaching 61% implementation at extremely high level, with a 77% projected increase by 2016. The National BIM

Initiative (NBI) has issued a comprehensive report in two volumes: Volume 1 outlines the strategy for BIM adoption, while Volume 2 details the implementation plan, including detailed costing and time span. The National BIM Guide and BIM Management Plan have received widespread recognition and support, serving as frameworks for building projects and educational programs. It is proposed that the industry work with the Australian government to pursue policies that would accelerate BIM adoption and promote the expansion of the construction sector.

Although there is no formal BIM plan in Austria, the Austrian Standards Institute is essential in pushing BIM adoption. It is a non-profit service organization that manages BIM standards through Working Group 011.09 of the Austrian Standards Committee 001 "Building Construction." The most recent standards, published in July 2015, are outlined in two documents: ÖNORM A 6241-1, which addresses Computer Aided Design (CAD) data structures and BIM at Level 2, and ÖNORM A 6241-2, which focuses on BIM at Level 3. Austrian standards provide all users with a free German-language file aligned with these criteria, which they can use to develop the data model [52].

Belgian building research institute [53], as a focal point for the digital revolution brought about by BIM in Belgium's AEC industry. Despite the promise of BIM, the BBRI has emphasized the lack of national standards and its limited application in the sector. To address this, initiatives are underway to teach construction professionals about BIM via information sessions and seminars. Although BIM is gaining popularity, it is often perceived merely as a software tool or a substitute for 3D modeling. BIM's projected productivity gains have yet to be fully realized in Belgium. However, organizations like the ADEB-VBA's BIM workgroup are actively advocating for its adoption, including the development of BIM guide.

BIM implementation within the Brazilian AEC industry, primarily guided by the private sector [54]. Several Brazilian organizations have formed study and working groups to investigate and encourage BIM adoption via events, seminars, and projects. Despite these efforts, the notion of BIM remains relatively restricted in the Brazilian market. Notable projects include the BIM Interdisciplinary Group and the Brazil BIM Network, these initiatives, sponsored by the Brazilian Federa-

eral Agency responsible for coordinating the development of Higher Education Personnel; organize seminars, courses, and conferences to promote BIM practices. Additionally, Brazil launched its first standard, NBR 15965-1 (construction information classification system), through the BIM standard committee.

Both Chile and Canada [55], are actively advancing the BIM adoption to modernize their construction industries. In Chile, the government, inspired by the UK, has introduced a national BIM plan through the National Economic Development Agency (Corfo). This initiative seeks to establish BIM requirements for public projects by 2020 and private projects by 2025, aiming to achieve a 20% reduction in both project cost and construction timeline. The plan is supported by various ministries and industry stakeholders to enhance sustainability, boost productivity, and foster industrial capacity. Similarly, Canada has taken significant strides in BIM adoption, led by the Institute for BIM in Canada (IBC), which has developed a Canadian Roadmap for Lifecycle BIM backed by a National BIM mandate. Through collaboration with the UK BIM Task Group, the Canadian BIM Council (Can-BIM) has developed a protocol to enhance standards through strategic partnerships. Furthermore, the building SMART Canada Education Committee promotes BIM education, securing government funding for the creation of a Canadian Practice Manual for BIM. Both Canada and the UK are utilizing BIM to foster sustainability, enhance project management, and tackle socio-economic issues within their respective construction industries.

China's 12th National Five-Year Plan [56], designed by the Ministry of Housing and Urban-Rural growth, focuses on industrialization, informatization, urbanization, and agricultural modernization, with BIM technology at the forefront of the country's construction sector growth. The China BIM Union, also known as the China industry technology innovation strategic alliance, was instrumental in the formulation of the "Unified Standard for BIM Application" in 2013, as well as related standards for practice-oriented BIM software and data exchange. China's BIM activities are now focused on improving data interchange and interoperability between projects in order to increase industrial efficiency.

The Czech Republic [57], BIM awareness and usage are increasing, thanks in large

part to the Czech BIM Council's efforts. This forward-thinking group works to integrate BIM processes in a variety of industries, including building, design, education, standards, and law. Their endeavors include conducting BIM DAY events since 2013 and creating the Czech BIM Guide. However, traditional 2D design documentation continues to dominate due to a lack of defined BIM laws and uneven implementation. Furthermore, the expensive cost of BIM software remains a major impediment to wider use. Despite these limitations, 87% of individuals knowledgeable with BIM believe it is the future of the building industry.

Denmark has been a pioneer in adopting Building Information Modeling (BIM), introducing legislation in 2007 and strengthening it with ICT regulations in 2013 for projects exceeding DKK5 million [58]. Since 2008, the government has expanded regulations to include public sector renovation projects and state-funded social housing in an effort to address productivity stagnation in construction.

By June 2011 in Denmark, the required use of BIM has been expanded to include municipal and regional projects costing more than €2.7 million, as well as central government projects with lesser budgets. Organizations like BIPS, which has lobbied for BIM since 2003, as well as programs like Denmark Building SMART and Digital Convergence (Dikon), have helped to define standards and construct uniform IT frameworks. Furthermore, universities such as Alborg University, Aarhus School of Architecture, and Technical University of Denmark provide programs focusing on interoperability and 3D modeling, demonstrating Denmark's dedication to BIM adoption and improving design and construction process.

The Dubai municipality required the adoption of BIM in November 2013, for specific architectural and MEP (mechanical, electrical, plumbing) works in the Emirates, including buildings exceeding 40 storey's or 27,871m<sup>2</sup> and governmental initiatives include hospitals, universities, and schools. An updated circular in July, 2015 expanded the mandate to include architecture and MEP in governmental projects with buildings above 20 floors, with additional requirements for structural models for those exceeding 40 floors. Abdalla [59], highlights the municipality's call for local construction firms to contribute data for a national research and development databank to promote BIM implementation, while Mehran [60], high-

lights challenges like the lack of established BIM standards and protocols in the UAE and Dubai, and limited client understanding of BIM's practical implications. Group like the Emirates BIM Group have been created to help newcomers use BIM software. With large-scale infrastructure projects such as the Dubai Metro extension and World Expo 2020 approaching, significant progress in BIM implementation is expected in the Emirates.

In France and Germany [55], the adoption of BIM in France is being propelled by government initiatives aimed at modernizing the AEC industry. The France set a goal for the complete integration of BIM into all public sector projects by 2017, with a particular focus on the housing sector, aiming for the construction of 500,000 homes by that year. As part of its construction stimulus plan, France has allocated €20 million over three years to promote digital tools within the industry, aligning with broader European initiatives. The creation of the Digital Transition Plan for construction is overseeing the French roadmap, which includes educational programs and support measures to foster BIM adoption.

Meanwhile, Germany's BIM mandate, prompted by budgetary constraints in public sector projects, is supported by Plan build 4.0, a collaborative initiative to democratize digital design and construction technologies. BIM implementation, starting with Performance Level 1, will become mandatory for all new projects by 2020. The German Institute for Standardization (DIN) and the association of German Engineers (VDI) are leading standardization activities aimed at developing legally enforceable BIM standards. Furthermore, both organizations need the inclusion of BIM in academic courses to guarantee that future professionals are prepared with the necessary abilities for the business.

In September 2014 [61], Hong Kong's Construction Industry Council (CIC) developed a Working Group under the Committee on Environment and Technology, chaired by the Hong Kong Housing Authority, to meet rising demand for Building Information Modeling. The group developed the BIM strategic implementation Roadmap, aiming for complete BIM adoption across all projects by 2014. The plan, which has the support of significant developers and the Real Estate Developers, comprises collaboration, incentive, standard, legal frameworks, education,

and risk management techniques. The HKIBIM BIM Standard provides rules for uniform project execution, and educational institutions have offered BIM courses to help local AEC businesses compete worldwide.

In Italy, adoption of BIM lacks a mandatory requirement for public works; however, one of the emerging economic regions of Italy, Lombardia has started advocating for BIM as the preferred method for building. Notable efforts include Saint-Gobain's creation of Italy's first BIM library, which is intended to boost BIM use in public construction and infrastructure projects by increasing efficiency, profitability, and lowering mistakes and costs. The Institute for BIM Italy (iBIMi) promotes open BIM, emphasizing its cultural, educational, and practical aspects. Furthermore, organizations such as OICE have actively promoted BIM adoption, exemplified by their International Forum on BIM held in Rome in April 2016 [62]. Furthermore, the Italian Standards Body (UNI) has just released sections 1, 4, and 5 of the National UNI 11337 standards, which specify methods for digital information management in building projects. Government-funded programs, like as the INNO Vance project, have played an important role in increasing BIM usage in Italy. These activities evolved in the creation of a national database encompassing technical, scientific, and economic data relevant to the AEC sector, with the objective of improving energy efficiency, strengthening project performance, and decreasing costs through greater BIM use [63].

In Netherlands, the BIR was established in 2012 under the Directorate-General for public works and water management a BIM initiative has been implemented to increase the quality, consistency, and international competitiveness of the Dutch construction sector. This was complemented by BIM Loket, a national platform promoting open BIM standards, which facilitated widespread BIM adoption in Dutch architecture by 2015. Major projects, such as the SAA road reconstruction program, showcase the Netherlands' commitment to BIM. Conversely, in New Zealand, BIM adoption remains voluntary, with only 45% of projects utilizing it as of 2015, according to BAC. The BAC, established in 2014, focuses on raising awareness, providing handbooks like the New Zealand BIM Handbook, and bridging industry knowledge gaps to promote wider adoption and demonstrate BIM's

value to clients and stakeholders [55].

Norway's construction sector in 2013, building information modeling (BIM) became pivotal for industry recovery. The Norwegian government responded by implementing a national BIM mandate in 2016, aiming to enhance error reduction, coordination, energy efficiency, and overall operational efficiencies. Collaborative efforts among major public sector clients resulted in specific requirements for open standards adoption by all project participants by July 2016. Additionally, the Norwegian homebuilders association (NHA) actively promoted BIM and industry foundation classes (IFC) adoption, issuing a BIM Manual in 2011 to assist in residential project planning. Norway's BIM guidelines, initially developed as the BIM Manual, have since gained widespread acceptance among stakeholders in the country [64]. While Portugal currently lacks a mandate for Building Information Modeling (BIM), but steps are being taken to establish standards for its implementation, signaling a gradual shift in the construction industry's mindset. Recommendations urge the government to consider a mandate to bolster the region's service competitiveness. A suggested roadmap envisions a technologically sophisticated and highly integrated construction sector in the 2020s, driven by innovative enterprises and supported by a competent workforce [65].

Costa [66] anticipated that growing awareness of BIM (building information modeling) will pave the way for the creation of a national digital construction plan. Although no formal mandate exists, Portugal's public sector demonstrates significant ICT integration, highlighted by the mandatory use of e-Procurement. Organizations such as the Technical Committee for BIM Standardization (CT 197 – BIM) are actively promoting Building Information Modeling adoption within the construction industry. CT 197 – BIM has developed Portugal's first strategic framework for construction 4.0, outlining short, medium, and long-term objectives.

In Qatar, building information modeling (BIM) has progressed significantly, fueled by mega projects aligned with the country's National Vision 2030, including the Doha Metro System and FIFA World Cup 2022 stadiums. Projects in Qatar and Scotland have used BIM approaches that are consistent with the protocols of the USA and UK. Qatar's "Q-BIM" association promotes BIM standards through

mentorship, networking, and lobbying. In Scotland, the government enforced BIM Level 2 compliance by April 2017, as detailed in the Scottish BIM Implementation Plan, which was developed in partnership with the Scottish Futures Trust. This strategy, divided into five parts, intends to increase efficiency by mandating BIM Level 2 for projects that surpass the OJEU level. In addition, Scotland provided tools such as the building information modeling (BIM) Level 2 advantages Tool and the BIM Compass to assist the AEC industry in evaluating BIM advantages and preparedness [55].

In Singapore, the building and construction authority (BCA) launched a BIM roadmap with the goal of universal adoption in the construction industry by 2015, aligning with the government's goal of increasing industry productivity. To incentivize early adoption, a \$6-million BIM fund was introduced in 2010, covering various costs and encouraging universities to offer BIM courses [64]. Spain announced a plan in 2015 to increase BIM use in public sector projects, with the goal of implementing it by March 2018 and requiring its usage in infrastructure projects by July 2019. This plan includes task groups and a Technical Committee in charge of managing BIM integration, supporting open BIM standards, and creating a consistent academic training framework [67].

In Sweden, the non-profit entity BIM Alliance Sweden promotes open standards and published guidelines to advance BIM adoption, while in Switzerland, the Digital Construction Switzerland Syndicate advocates for digitalization in the construction industry, conducting research and fostering collaboration for digital transformation. The syndicate's efforts in Zurich, including the establishment of a dedicated BIM forum, reflect Switzerland's pioneering initiatives in collaborative digital Modeling within the construction sector [68].

The UK Government's Construction Strategy aimed to reduce public sector asset costs by mandating the Level 2 collaborative implementation of Building Information Modeling (BIM) for centrally funded public projects by April 2016. This initiative was supported by the establishment of the BIM Task Group. Efforts from various entities like the British Standards Institute (BSI), the Construction Industry Council (CIC), and the UK BIM Task Group led to significant results,

with a reported 54% adoption rate among construction professionals in 2016. Educational support for the BIM Mandate expanded, with organizations offering accreditation courses and universities providing post-graduate programs in BIM management. Currently, the UK is initiating a Level 3 BIM program [55].

BIM adoption in North America, with usage among construction professionals increasing significantly from 28% in 2007 to 71% in 2012 [69]. In the United States, BIM is widely utilized, particularly by significant government agencies like the General Services Administration (GSA) and the United States Army Corps of Engineers (USACE), who need BIM outputs for large-scale projects. Programs such as the GSA's National 3D-4D-BIM initiative, as well as mandates from a variety of agencies, highlight the country's leadership in BIM adoption. The National BIM Standard-United States (NBIMS-US) supports this approach by providing consensus-based standards and best practices for the built environment. Globally, key BIM proponents, such as building SMART chapters, have convinced more than 60% of governments to adopt rules or guides to support BIM implementation [70]. In Oceania [51], a survey by positioned region fourth in terms of BIM implementation depth, proficiency level, and years of usage, following North America, Europe, and Asia. Meanwhile, reports by McGraw Hill (2015) highlight China expects a 200% rise in the No. of architects using higher levels of BIM over the next two years. Singapore has launched a second BIM roadmap to promote public sector productivity. Since April 2016, UK has required BIM for all new centrally financed public sector projects, backed up by detailed frameworks and rules that have encouraged similar programs worldwide. As a result, the UK has emerged as a leader in BIM adoption, with broad implementation in recent years. The Brexit decision, however, complicates the EU BIM Task Group's consultation process and may have an impact on BIM knowledge and practices in member states.

## 2.6 Situation of BIM Adoption in Pakistan

In Pakistan, the construction sector is one of the most crucial industries, playing a considerable role in economic growth and acting as the greatest source of emplo-

ymment in the country. The sector is growing across multiple disciplines, including as energy, architecture and planning, industrial development, and transportation, making it a vital driver of the nation's economic prosperity. However, like other nations, Pakistan's construction sector struggles to keep projects within budget and on time [71]. Due to numerous project delays and budget overruns, Pakistan's construction sector makes it difficult to meet the government's goal of progressive growth. The internationalization of Pakistani construction contracting businesses (CCFs), which is impacted by company size and expertise, is a significant problem. While bigger organizations pursue worldwide development to counterbalance local market saturation, smaller enterprises face challenges owing to inadequate assets, such as inadequate managerial knowledge and international reputation [72].

The current status of BIM adoption in Pakistan is insufficient, only 27% of businesses in the construction industry use BIM are actively involved in its deployment to some extent. The majority, comprising 73% of organizations, are not involved in BIM implementation in any capacity, indicating a pressing need for technology transfer to construction stakeholders [73]. Traditional coordination between employers and employees, including designers, contractors, and suppliers, is deemed ineffective. Particularly, consultants and contractors lack efficient channels for progress monitoring to evaluate project performance throughout its lifecycle. A vast majority of industry experts in Pakistan's construction sector claim poor (39.2%) or moderate (25.5%) awareness of BIM, with 21.6% expressing no awareness and only 2% indicating extremely high awareness. It is also indicated varying levels of knowledge regarding BIM, with 20% claiming to have no knowledge and the remainder considering them to have minimal, moderate, or expert-level understanding of BIM concepts. Notably, while only 27% of organizations are currently involved in BIM adoption, there is widespread optimism among construction professionals regarding BIM's future, with 96% expressing support for its implementation in the Pakistani market [74].

### 2.6.1 Issues in BIM Adoption in Pakistan

The study [75], examines the obstacles preventing the construction industry of

Pakistan from adopting BIM (building information modeling), and identifies major challenges like inadequate training and skills, a lack of knowledge among project stakeholders (engineers, clients, contractors, project managers), and unsuitable government policies. Despite 63% awareness in Pakistan [14], actual usage is just 11% mostly basis 3D modeling, organizational resistance and poor communication further hinder progress, alongside global issues like non-uniform standards and software incompatibility. The study also highlights the need for targeted intervention to promote BIM implementation, ultimately aiming to improve cost savings, reduce rework, and enhance clash detection in construction projects within Pakistan.

Moreover, several factors contribute to the slow adoption BIM in Pakistan's Construction sector. These include the relatively recent introduction of BIM in industry, financial constraints related to acquiring necessary hardware and software, and the absence of established standards and protocols across parties. Furthermore, insufficient government involvement, low consumer demand and a shortage of trained BIM professionals contributing in high human resource costs, further hinders BIM adoption. Additionally, the complex setup process and the significant costs associated with its implementation present major barriers [76].

## 2.7 Factors Influencing BIM Adoption

BIM has the potential to become a standard technological innovation for construction projects. However, various factors may influence the BIM adoption process, depending on the specifics. This article [31], provides an overview of BIM applications in Vietnam's AEC industry, with a focus on how BIM may improve the efficacy and efficiency of project management. Despite improvements, Vietnam's labor productivity still falls short of that of its neighbors, which is why BIM is being prioritized to raise construction productivity and project results. Although there has been some adoption of BIM, especially in state-funded projects, it is still somewhat restricted. However, understanding of the benefits of the BIM is expanding, and the government hopes for broad use by 2021.

Vietnam's implemented BIM projects are expected to improve decision-making, dispute resolution, project performance, and quality enhancement. Building on previous international research, this study intends to precisely investigate factors influencing BIM adoption within construction projects in Vietnam. The elements that influence BIM adoption in building project execution were divided into five categories: technology, management, human, project, and external. To rank these parameters, the study employed the Relative Importance Index (RII) and descriptive statistics. The findings revealed that the top five most important factors influencing BIM adoption are Perceived usefulness, BIM tool efficiency, BIM's organizational benefits, technological quality, and degree of experience and abilities.

The study [77], identified 4 factors of UTAUT (Unified Theory of Acceptance and Use of Technology) model, that influence the adoption of technology in AEC industry: Facilitating condition (the degree to which a user believes that organizational and technical infrastructure exist to support the use of technology), social influence (the degree to which a user perceives that important others believe they should use the technology), performance expectancy (the degree to which a users believes the technology will improve their performance), and effort expectancy (the degree of ease associated with using the technology).

These factors influence behavioral intention to use a technology and actual technology usage, as do moderators such as age, gender, experience, and voluntariness. New concepts including price value, habit, and hedonic motivation have been added to this model in subsequent studies. It is necessary to comprehend these factors in order to explain why people select to accept and use technology, especially in organizational setups.

In another study [78], the adoption of mobile banking is tremendously influenced by different variables. One important motivator is a user's perception that mobile banking needs improvement in its performance by providing easy payments, quick replies and efficient services. Adoption rates are also impacted by how simple people trust mobile banking is to use and understand. Social influence also has a significant impact; a user's choice is shaped by the advice an options a friend, family, and superiors. Importantly, favorable condition-the availability of tools,

information, and support system are necessary to promote adoption. Beyond these factors, use adoption is directly impacted by privacy, concerns and confidence in the service's dependability and security. Additionally, the attraction of low cost and the promise of convenience are powerful motivators. Therefore, the key to promoting broader acceptance of mobile banking services is mix of perceived benefits, simplicity of use, social validation, and safe, practical, and reasonable price access.

The goal of the study is to investigate the critical success factors (CSFs) for adopting BIM in developing nations and its use in the construction sector is still relatively new [32]. The study's core goals are to: (1) identify CSFs and assess their influence on BIM adoption, and (2) investigate the essential characteristics of these CSFs in developing nations with poor BIM adoption. The relative importance of 16 CSFs for BIM adoption was determined using collected data. The findings show that the top three criteria driving BIM adoption are (1) the accessibility of competent personnel, (2) good leadership, and (3) the availability of information and technology. This study further explores the growing interest in creative project management within the AEC industry, particularly with BIM. BIM offers benefits such as improved coordination and cost savings, but also presents challenges, including insufficient experience and interoperability.

The study identifies Critical Success Factors (CSFs) for BIM adoption, focusing on the importance of technology infrastructure, skilled personnel, and strong leadership. It emphasizes the need for tailored strategies, particularly for large organizations facing resistance to change. The study also highlights that policy and industry support are lacking, with resources and human factors playing a pivotal role in the successful BIM adoption. Although based on opinions from Turkish businesses, the findings provide valuable insights for construction managers and BIM consultants. Future research is recommended to further investigate BIM interest among younger generations and explore CSF interactions in more depth.

According to the survey, BIM is essential to changing the global AEC (Architecture, Engineering, and Construction) industry by increasing stakeholder engagement and enhancing project results using sophisticated digital modeling and

simulation approaches. While developed economies have showcased impressive results with BIM adoption, there's a pressing need to assess its awareness and adoption factors in the Nigerian AEC Industry [79].

A survey conducted among Nigerian building construction firms reveals significant factors and challenges to BIM adoption. Key drivers include the availability of trained professionals, software accessibility, client interest, and industry stakeholders' awareness. Conversely, barriers include social, reluctance to acceptance, legal constraints, and the high cost of software. These findings align with previous research and pave the way for further exploration and development in BIM adoption within Nigeria. Recommendations include integrating BIM training into educational programs, raising awareness through professional and governmental initiatives, and fostering a supportive environment for BIM adoption. The report underlines the importance of continued research in developing a complete framework for BIM adoption in Nigeria's construction sector.

Government construction strategy (GCS) is an effort of the UK government is attempting to increase the effectiveness of the construction industry in addressing the global financial crisis. The government, which makes up a sizeable portion of the industry's yearly turnover, supports the GCS's suggested steps in an effort to promote sustainability and economic recovery. The requirement that all project and asset information be BIM compliant by 2016 and the required usage of fully collaborative three-dimensional building information modeling (BIM) are important components of this plan. Notwithstanding the known advantages of BIM, not much study has been done to assess the significance of its many drivers [80]. BIM is widely regarded as a significant advancement in the representation of buildings, providing organized data that is beneficial throughout the duration of a project. Although there is evidence of the adoption of BIM, there hasn't been any critical examination of how its standards will affect the sector.

The research attempts to fill the knowledge gap about the elements that lead to building information modeling (BIM) adoption by identifying and ranking these drivers through a comprehensive literature analysis. It seeks to provide insight into the relative importance of these drivers for both active and non-users of BIM,

providing valuable insights for effective BIM deployment. The study prioritizes eighteen key drivers from existing literature and introduces two new drivers: "inventory generation for complex products" and "sales promotion to clients." It highlights how organizational experience and BIM adoption influence the significance of these drivers, showing that government mandates are the primary motivator for non-BIM users. However, post-implementation, operational factors such as "clash detection" and "cost savings through reduced rework" gain prominence. The study underscores the need for customized approaches based on organizational experience, as perceptions of BIM drivers significantly shift after implementation.

The government has provided endorsement for the construction industry's effective use of BIM, acknowledging it as a revolutionary technical advancement with significant potential [33]. The study uses a survey to learn what stakeholders anticipate from government support of BIM implementation and offers recommendations for how governments may encourage the use of this technology. It shows the significance of government policies in influencing industrial and technical breakthroughs and underscores the need of effectively adopting innovation, such as BIM, for economic success. The creation and implementation of complex technological systems, such as BIM, are considered to require government backing, with policies being crucial in promoting innovation processes.

To effectively support BIM implementation, the paper underscores the vital role of government intervention through enforcement of laws and mandates that promote the adoption of innovative technology. Government employees, academics, business professionals, and students are just a few of the stakeholders involved in the BIM implementation process. With government supervision, these stakeholders may all be connected through BIM technology. Survey takers from various categories anticipate government policies to support BIM adoption. A few major areas where government action may have a big influence on BIM adoption are recognized as being fiscal assistance, national standards, and professional training. Governments may encourage the development of new technologies by utilizing resources allocated to public services, which will eventually result in the AEC sector developing and industrializing more quickly.

## 2.8 Overview of the Theories to Determine the Adoption of Technology

The social sciences have placed a great deal of emphasis on the reasoning behind people's adoption or rejection of a given technology, marketing, and information systems (IS). Researchers have spent the last thirty years trying to identify, forecast, and clarify the variables that affect both individual and organizational adoption of technology [81].

Some theories of behavior shift their emphasis from the person to the behavior itself or the interactions that exist between individuals, their social and physical contexts, and the behavior itself. Many theories and models of technology acceptance have been developed in an effort to better understand the elements influencing users' adoption decisions and behaviors. This study looks at a number of models, including the motivational model (MM), the unified theory of acceptance and use of technology (UTAUT), the theory of reasoned action (TRA), the theory of planned behavior (TPB), the technology acceptance model (TAM) and its extended version (TAM2), the innovation diffusion theory (IDT), the social cognitive theory (SCT), and a hybrid model that combines the TAM and the theory of planned behavior (CTAMTPB).

### 2.8.1 Theory of Reasoned Action (TRA)

Theoretical framework of reasoned action (TRA), first introduced by Fishbein and Ajzen in 1975 and further developed in 1980 [82], provides a basis for comprehending human behavior. According to the theory of TRA, people usually think about the effects of their choices before acting on them. Subjective norms (SN), attitude (A), and behavioral intention (BI) are its three main components (Fig 2.3).

Behavioral intention (BI) is a person's intention or goal for future actions; it comes before behavior. It is influenced by how a person approaches particular actions. Past experiences have an impact on attitude (A), which is a person's assessment of

a behavior, whether it is good or bad. A person's sense of what society expects of them in terms of behavior is reflected in their subjective norms (SN). Though TRA has received a lot of study interest, especially in fields like information systems (IS), it has several significant drawbacks. Its inability to predict behavior in the absence of purpose is a result of its assumption that personal beliefs are dependent on an individual's intentions. Furthermore, because of unforeseeable circumstances and the passage of time, TRA struggles to forecast future behavior and lacks clarity when defining the ideas that underlie attitudes. Finally, it has a restricted range in terms of behavioral intention [83]

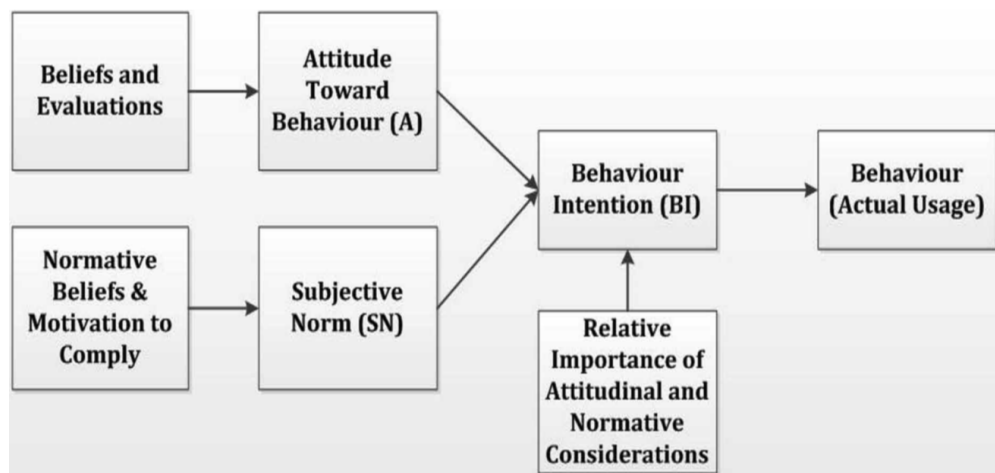


FIGURE 2.3: Theory of Reasoned Action [81].

## 2.8.2 Theory of Planned Behavior (TPB)

The TPB (theory of planned behavior) addresses the limitations of the TRA (theory of reasoned action), especially with regard to behavior prediction in situations in which people have partial volitional control [84]. If behavioral intention does not fully match the behavioral criteria or if intention changes prior to execution, then volitional control refers to the predictability of a voluntary act based on behavioral intention. In order to take into consideration circumstances where people wish to take an activity but lack confidence, TPB expands on TRA by introducing the concept of Perceived Behavioral Control (PBC). The feeling of internal and external factors that might facilitate or hinder an action, as well as the perceived ease or difficulty of carrying out that activity, is known as perceived behavioral

control, or PBC. Similar to the Theory of Reasoned Action (TRA), the Theory of Planned Behavior (TPB) suggests that three factors—personal behavior change (PBC), subjective norms (SN), and attitude (AT)—have an impact on behavioral intention (BI). TPB also investigates how these factors are modified by human views, which are classified into three types: behavioral beliefs, normative beliefs, and control beliefs [85].

TPB has been modified to improve its performance and used in a number of study domains, including online banking and the workplace. TPB nevertheless carries many drawbacks, such as its incapacity to take into account elements like self-identity, moral responsibility, and habit, as well as the absence of a clear prediction relationship between BI and behavior. Furthermore, TPB's prediction accuracy is limited by its inability to describe the process by which individuals undertake behavior, and its generalization across many contexts necessitates measurement changes. Prediction accuracy may be further impacted by include in the PBC model any unknown or hidden elements.

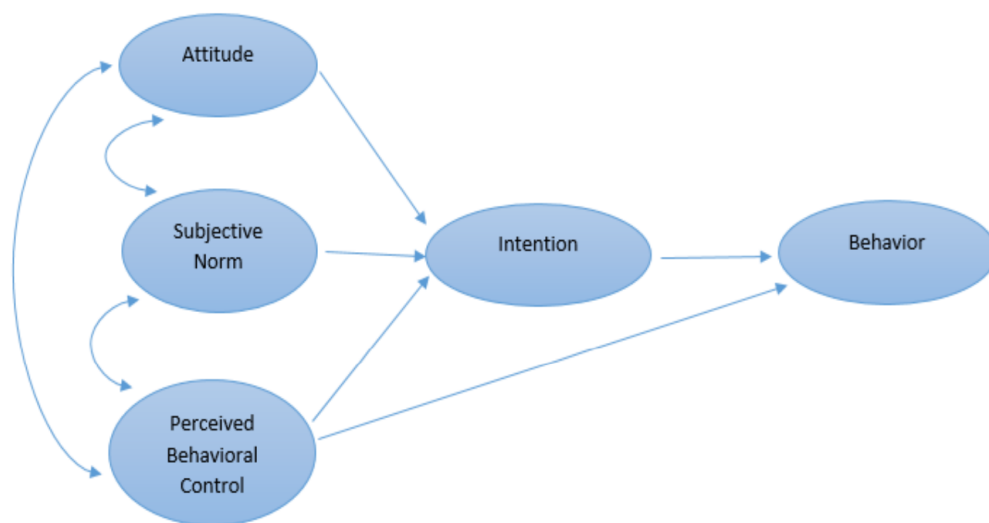


FIGURE 2.4: Theory of Planned Behavior (TPB) [84].

### 2.8.3 Technology Acceptance Model (TAM)

The TAM, proposed by Davis in 1989 [86], provides a framework for determining individuals' adoption of technology in the IT area. Perceived usefulness (PU) and perceived ease of use (PEOU) are the two main variables of technology acceptance

model (TAM), a variant of the theory of reasoned action (TRA), which predicts people's attitudes and behavioral intentions toward the adoption of technology. A framework for examining how individuals in the IT sector embrace and use technology is offered by the technology acceptance model (TAM) (Fig 2.5).

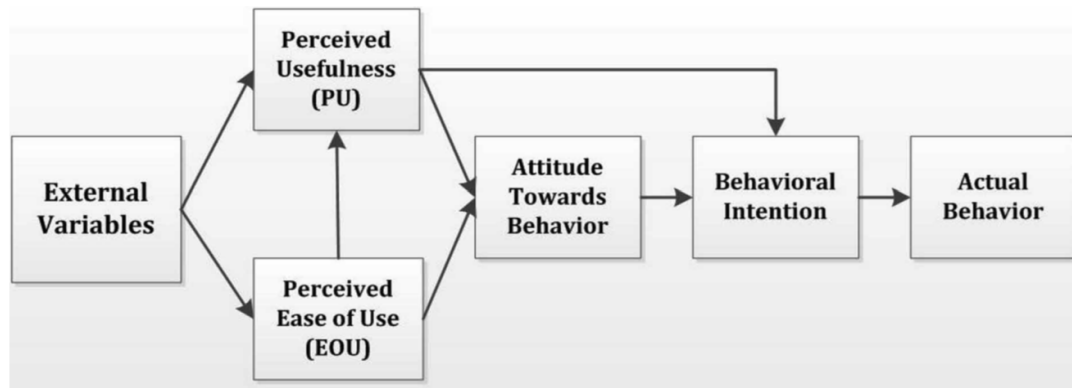


FIGURE 2.5: Technology Acceptance Model (TAM) [87].

Perceived utility (PU) and perceived ease of use (PEOU) are the two key characteristics it identifies. These traits are used by TAM, an application of the theory of reasoned action (TRA), to forecast people's attitudes and intentions about the adoption of new technologies. TAM, in contrast to TRA, does not include social norms because of theoretical ambiguities and practical difficulties. Key components identified by TAM include external variables (PU/PEOU), attitude (A), behavioral intention (BI), PU, and PEOU. External variables impact BI, and PU/PEOU moderates their effects. Introduction, validation, extension, and elaboration are the stages in TAM's evolution that lead to its use in e-government, e-commerce, and e-learning, among other settings. Nevertheless, TAM has drawbacks, such as its dependence on self-reported usage, absence of accurate usage metrics, incapacity to fully explain findings, and disregard for social, personal, and cultural effects. Furthermore, TAM accounts for only 60% of the variance in behavioral intention that remains unexplained. Despite its limitations, it continues to be widely employed due to its flexibility and effectiveness in explaining technology adoption in specific contexts.

Another research [88] discusses the TAM and its variations, which traditionally focus on voluntary technology adoption. However, the authors argue that these models may not fully apply in environments where technology use is mandated,

such as in organizations. To investigate the linkages described in the technology acceptance model (TAM) in an obligatory usage setting, they conducted a field research in the banking industry. When compared to voluntary adoption situations, the results show differences in the relationships among attitudes, behavioral intentions, perceived utility, and ease of use. Specifically, ease of use emerged as the primary determinant of behavioral intention in mandatory settings, contrasting with prior research where perceived usefulness was more prominent.

The study highlights the need of taking attitudes and perceptions of usefulness into account when implementing required technology in order to avoid undesirable negative effects such as sabotage or decreased work satisfaction.

The authors suggest implementing mechanisms like training programs and user groups to foster positive attitudes and enhance perceived usefulness, especially when transitioning from familiar systems.

#### **2.8.4 Revised Technology Acceptance Model (TAM 2)**

TAM2 was created as a result of the TAM's advancement and contains additional constructs dealing with social impact and cognitive processes [77]. SN (subjective norms), VOL (voluntariness), EXP (experience), and IMG (image) are examples of social impact elements that are included in TAM2. IMG describes how utilizing an invention affects a person's social status, whereas SN shows how other people's opinions affect a person's choice to use a technology (Fig 2.6).

VOL represents belief that the adoption choice is optional, which effects influence of SN. EXP evaluates system familiarity and has an inverse relationship with SN's influence. Job relevance (JR), output quality (OQ), result demonstrability (RD), and perceived ease of use (PEOU) are cognitive processing elements in TAM2.

The tangibility of innovative results is measured by result demonstrability (RD). Research that validated TAM2 in several areas, including as e-learning and internet usage, showed that it had more explanatory power than TAM and that SN had a major influence on BI in TAM2 [89].

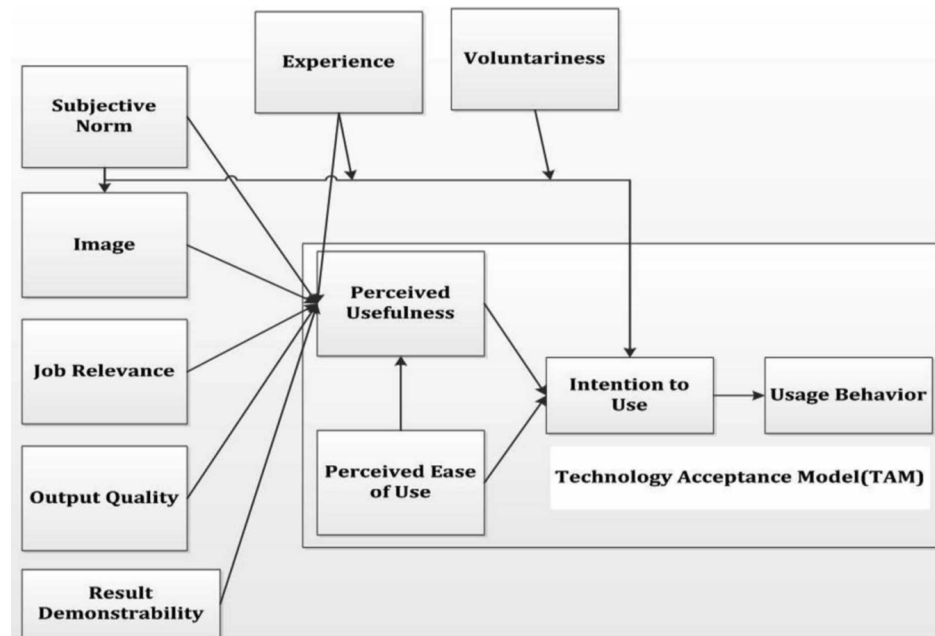


FIGURE 2.6: Revised Technology Acceptance Model (TAM-2) [77].

### 2.8.5 The Motivational Model (MM)

Motivation theory aims to explain the elements that motivate people to pursue certain objectives or results. While it is significant in many parts of society, it is especially important in business and management (Fig 2.7) [90]. This is because motivated people perform better, and enhanced efficiency frequently leads to more revenue. The study evaluates how perceived utility and enjoyment affect intentions to use computers at work. Previous research has thoroughly connected perceived utility to usage intentions. However, the function of pleasure remains underexplored [91]. The research conducts two studies to investigate these effects, finding that both perceived usefulness and enjoyment significantly influence intentions to use computers. It also investigates how intentions function as a mediator in the link between actual usage behavior and reported effectiveness and satisfaction. It also explores the interaction between perceived usefulness and enjoyment, suggesting an additive rather than interactive effect. Moreover, the study hypothesizes that PEU and output quality positively affects both PU and enjoyment, with task importance moderating these effects on usefulness but not on enjoyment. These findings provide insights into designing computer programs to enhance both their usefulness and enjoyment, thus increasing user acceptability in the workplace.

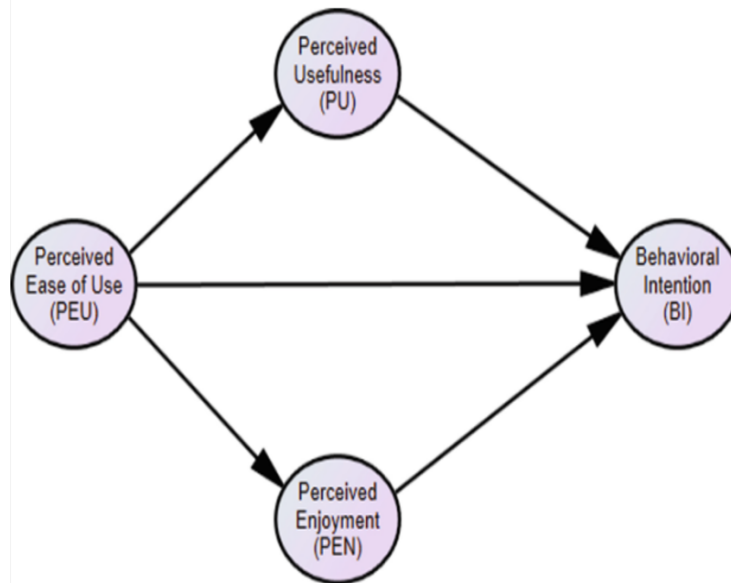


FIGURE 2.7: Motivational Model [91].

### 2.8.6 The Diffusion of Innovation Theory (DOI)

Rogers (1995) developed the DOI (diffusion of innovation) theory [92], which has impacted later acceptance models and provides a fundamental framework for comprehending technological adoption behavior. There are five steps in the dissemination process: adoption choice, knowledge, attitude, execution, and confirmation.

Before implementing an innovation, people must first learn about it, acquire data, make a decision, and then double-check their choice. Rogers (1995) classified innovation characteristics into five categories: trialability (TRI), complexity (COLX), observation (OBS), compatibility (COMP), and relative advantages (RA). These variables affect how innovations are received in relation to current solutions, how well they align with requirements and values, how hard they are to understand and apply, how simple they are to test, and how easily their advantages can be seen [93].

Additionally, the diffusion process (Fig 2.7) relies heavily on innovators; the participants in this process may be divided into five groups: early majority, late majority, innovators, laggards, and early adopters. Diverse groups play diverse roles in the adoption process: inventors set the pace, early adopters serve as role models for adoption, and later groups progressively embrace innovations over time.

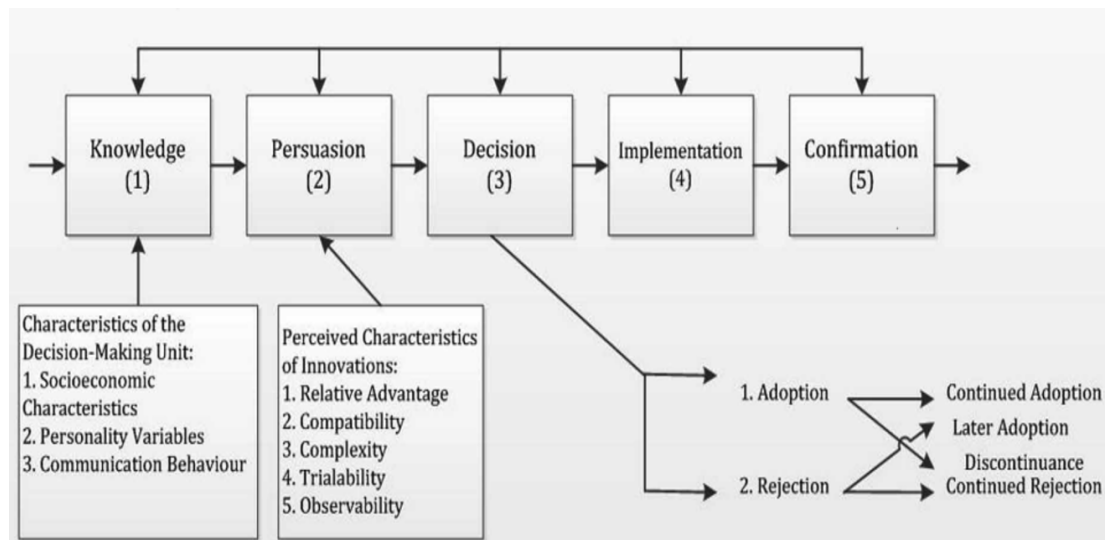


FIGURE 2.8: The Diffusion of Innovation Theory (DOI) [81].

### 2.8.7 The Social Cognitive Theory (SCT)

The SCT (social cognitive theory), proposed by Bandura in 1986 [81], distinguishes itself from the DOI (diffusion of innovation) theory by focusing on the significance of individual behaviors and reactions throughout the innovation process. SCT emphasizes the reciprocal relationship that exists between an individual's actions and their surroundings, highlighting the significance of identification, cognition, and vicarious learning. Three types of elements are involved in reciprocal determinism, a central idea of SCT: behavioral, personal, and environmental (Fig 2.9).

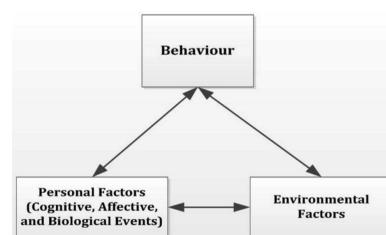


FIGURE 2.9: Social Cognitive Theory (SCT) [81].

SCT places more emphasis on social cognition and emphasizes how individuals perceive and respond to their environment, in contrast to DOI's concentration on social learning. Three elements are vital to the social diffusion of innovation, according to Bandura's triadic model within SCT: acquiring the innovation's associated knowledge and skills, putting it into practice, and the social network supporting the innovation's spread and support.

## 2.8.8 Unified Theory of Acceptance and Use of Technology (UTAUT)

The goal of the study [15], intended to develop a cohesive framework known as the UTAUT (unified theory of acceptance and use of technology) by combining numerous theories on information technology adoption (Fig 2.10). Researchers used longitudinal data from four different businesses to analyze and compare eight well-known models. UTAUT was developed by recognizing conceptual and empirical parallels amongst the current models. It includes three direct predictors of intention to use PE (performance expectancy), EE (effort expectancy), and SI (social influence), as well as two direct constructs of usage behavior, BI (behavior intention) and FC (facilitating conditions).

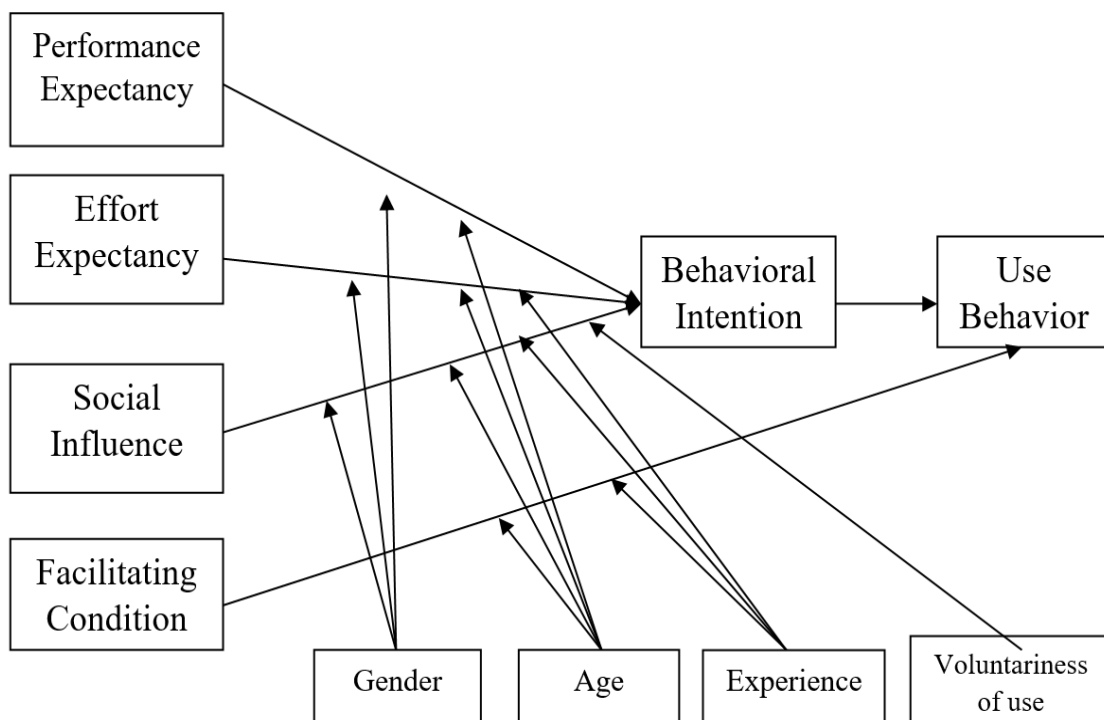


FIGURE 2.10: Unified Theory of Acceptance and Use of Technology (UTAUT) [15, 16].

Following an empirical evaluation and validation of the model using data from six organizations, it was shown to be able to account for 70% of the variance in usage intention. UTAUT combines important components from the original models and their moderators to provide a concise but thorough framework.

Significant moderating factors including age, gender, experience, and voluntariness were found in the research. Limitations were identified, highlighting the need for additional validation and the establishment of measuring scales, especially with regard to the operationalization of fundamental components.

Theoretical consequences include a more sophisticated knowledge of how intention and behavior determinants change over time, with age and gender appearing as important moderating factors. UTAUT highlights the changing nature of people's perceptions of technology and emphasizes the significance of contextual analysis in technology deployment techniques.

## **2.9 Comprehensive Assessment of Unified Theory of Acceptance and Use of Technology (UTAUT)**

UTAUT provides robust framework for analyzing patterns in technology adoption and usage (Fig 2.10). This model was introduced by Venkatesh et al. [15] to integrates eight distinct models, which includes the Theory of Planned Behavior (TPB), the technology acceptance model (TAM), the motivational model (MM), the model of pc utilization (MPCU), the theory of reasoned action (TRA), the innovation diffusion theory (IDT), the social cognitive theory (SCT), and a combined version of the TAM and TPB (CTAMTPB). All of aforementioned models were put to the test by Venkatesh, who combined them to create the more sophisticated UTAUT model, which was subsequently employed by many studies. The UTAUT highlights four key factors that affect individuals' intentions and behaviors toward using technology: PE, EE, SI, and FC. Additionally, UTAUT recognizes that four moderators' gender, age, experience, and voluntariness of use can influence the connections between these factors and the actual use of technology, a person's willingness to embrace technology is influenced by their opinions about its practicality, usability, social influence, and accessibility of contextual support, which are further impacted by situational and demographic factors [15].

The degree to which an individual believes that implementing a system would enhance their job performance is known as their performance expectation [15]. This idea is based on several theoretical models, such as the social cognitive theory (SCT), the model of pc utilization (MPCU), the motivational model (MM), the combined TAM and theory of planned behavior (CTAMTPB), the technology acceptance model (TAM), TAM2, and the innovation diffusion theory (IDT) [78]. A number of variables, including perceived utility, outside motivation, work fit, relative advantage, and anticipated outcomes, affect performance expectations. Research indicates that performance expectation plays a crucial role in influencing people's motivation to use technology, and it remains essential in situations when adoption is compulsory as well as optional [77].

Effort expectancy refers to "the level of ease involved in using a system" [15]. This idea, based on the principles of ease of use and complexity from models such as the technology acceptance model (TAM), the model of pc utilization (MPCU), and innovation diffusion theory (IDT), has commonalities in its definitions and measurement criteria. However, research show that its effect decreases as users get more familiarity with the technology over time [16].

Social influence refers to an individual's belief that influential people support their adoption of a new system. This concept is consistent with similar constructs such as subjective norms, social factors, and image, which are described in models such as the theory of reasoned action (TRA), TAM2, the theory of planned behavior (TPB), the combined TAM and TPB (CTAMTPB), the model of pc utilization (MPCU), and innovation diffusion theory (IDT). These frameworks concentrate on how people's behaviors are impacted by their perceptions of others' evaluations. Social impact is particularly essential in circumstances where technology use is mandated. In cases where technology use is obligatory, individuals may engage with technology primarily to fulfill compliance requirements rather than out of personal inclination. This could elucidate the variable impact observed for this construct across subsequent studies aimed at validating the model [16].

Facilitating Conditions are the extent to which individuals believe that the necessary technological and organizational support mechanisms are in place to enable

them to use a system efficiently. As outlined in frameworks like the theory of planned behavior (TPB), the combined TAM and theory of planned behavior (CTAMTPB), the model of PC utilization (MPCU), and innovation diffusion theory (IDT), this construct integrates elements of compatibility, perceived behavioral control (PBC), and facilitating conditions (FC). Although favorable factors have an immediate beneficial effect on desire to adopt a system, this effect fades beyond first adoption period. Consequently, the model indicates that enabling circumstances have direct and substantial influence on actual usage behavior [15].

The UTAUT emphasizes how the predictors of the technology adoption are moderated by age, gender experience, and voluntariness of usage. While gender influences connections including PE, EE, and SI, age influences all four variables. While voluntariness affects the relationship between SI and BI, experience moderates relationships with EE, SI, and enabling variables. By combining knowledge from several theories and reaching higher prediction accuracy, UTAUT improves our knowledge of technology adoption by accounting for 70% of the variation in usage intention. Furthermore, the model stresses the intricate relationship between factors influencing technology adoption and personal traits such as age and experience [15].

### **2.9.1 Application of UTAUT Model for Various Technological Adoptions**

The study aims to assess the appropriateness of the UTAUT model within the particular context of internet banking [94]. A survey instrument was constructed, referencing previous studies in the domains of online banking and technological adoption. The primary aim was twofold: firstly, to ascertain the applicability of the UTAUT framework in predicting adoption intention [15]. The study examined how three independent variables from the UTAUT framework PE, EE, and SI impact BI, while also accounting for the moderating roles of age, gender, and experience.

The world wide web (WWW), whose user base has grown exponentially since the early 1990s, has had a significant influence on organizations' and people' worldwide

online activities. Additionally, the paper stated that there are around 1,086 million internet users globally, with a 202.9 percent predicted yearly growth rate, with the Middle East having the highest percentage at 490.1 percent. The banking sector has made notable use of WWW technology to provide online banking services, which has increased client transactions and resulted in considerable cost reductions for banks. Research on the variables influencing client uptake, particularly in developing countries, is necessary given that despite the ease that internet banking offers, adoption of this technology is hindered. This research contributes to our knowledge of how individuals embrace technology, especially when it comes to online banking. The results point to the need for more research on cultural distinctions and models of technology adoption. The study also verifies an Arabic instrument, offering a foundation for further research in the area [94].

This study [95], investigates the uptake and application of open access in Tanzanian public universities, guided by UTAUT model. It identifies key predictors of researchers' behavioral intentions, including attitude, awareness, EE, and PE. Factors influencing actual use include age, awareness, BI, enabling conditions, and SI. Age plays an important role, directly impacting adoption by moderating effort expectancy and enabling conditions.

The study also expands the original UTAUT model by introducing attitude, Internet self-efficacy, and moderators such as position and awareness. The findings emphasize the importance of addressing these variables when planning and implementing open access initiatives. Recommendations include raising awareness within the academic community, ensuring robust ICT infrastructure, and establishing supportive legislation to promote broader adoption. Validation of this research model at other institutions in Tanzania and beyond is also advised to strengthen its applicability.

A unique study uses the UTAUT to examine the elements that influence Malaysians' adoption of internet banking [96]. With a significant increase in global internet users (444.8%) from 2000 to 2010, Malaysia emerged as one of the top 10 nations in internet usage by 2009, following the Malaysian Central Bank's launch of online banking services in 2000. The study aims to identify demographic differences bet-

ween adopters and non-adopters and determine key factors driving online banking adoption. While demographic factors such as gender, marital status, ethnicity, and education showed no significant impact, age and income revealed discrepancies potentially influenced by sampling limitations. The study concludes that Malaysians' behavioral intention (BI) to use online banking is not heavily influenced by demographic traits, supporting the applicability of the UTAUT model to this context. Findings suggest financial institutions should focus on building trust to enhance client satisfaction and attract new users. Online banking is highlighted as a means to improve convenience and efficiency while offering environmental benefits such as reduced paper usage and air pollution. However, limitations like small sample sizes and geographic constraints (focused on Kuala Lumpur) necessitate larger, more diverse studies across other Malaysian states. Future research is recommended to investigate generational differences, particularly between Generation X and Y, to better understand online banking adoption trends.

In developing nations like Kuwait, e-government programs are in early stages, requiring both public acceptance and government support for success. This study [97], using modified UTAUT model, found major drivers of e-government adoption, including peer influence, PE, EE, and enabling circumstances. These findings are congruent with those from industrialized nations, highlighting their broader importance. Although the study only included student participants, it successfully proved the potential to predict e-government adoption using these criteria, as well as moderating variables such as internet experience and academic course type.

The study establishes a solid platform for future research on e-government uptake in developing nations, recommending the inclusion of diverse participants and additional factors like trust and cultural influences. To promote widespread adoption, services must be user-friendly and tailored to individual needs, with clear benefits such as cost and time savings, reduced bureaucracy, and improved accessibility. Comprehensive awareness efforts and equitable access to technology, especially in underprivileged areas, are critical. Community-level initiatives providing internet and computer access can ensure inclusivity and foster adoption among all societal groups.

## 2.10 Application of UTAUT for BIM Adoption

The literature study illustrates how researchers have been breaking down and altering research approaches in accordance with the needs. Here are some examples of how the UTAUT have been applied to the adoption of BIM.

The aim of this study is to broaden the scope of the UTAUT model for better understand, how people see using building information modeling (BIM) [98]. The improved UTAUT model takes Experience and Voluntariness into account as moderators and adds Attitude as an independent variable through a survey of 84 industry stakeholders. The data indicate that performance expectations have no direct influence on behavioral intention, suggesting that BIM is seen as an inadequate addition to current work procedures. This highlights the importance of reinventing strategies, regulations, and incentive programs to increase BIM use locally and worldwide. Furthermore, a poll of 70 large construction businesses in the United Kingdom revealed pessimism about the government's capacity to meet its BIM adoption objectives. Several reasons hindered BIM adoption, including poor awareness, insufficient training, industry fragmentation, reluctance to change existing processes, unclear roles and responsibilities, and software compatibility issues.

The study began with a thorough examination of the literature, which demonstrated that the UTAUT model provides a solid and extensible theoretical platform for investigating people's perceptions of BIM. To make the model fit the goals of the research; some of its flaws were fixed. In particular, the literature's limitations and recommendations were taken into consideration while adopting the UTAUT paradigm. As shown in figure 2.11, initially, as an independent variable influencing user behavior, attitude was added. Second, by removing age and gender from the model, moderators were changed to better fit the BIM environment and the parameters of the study. Age was omitted from the model because the experience moderator controls for this factor in regard to BIM usage. Similarly, the gender moderator was eliminated since it was judged unnecessary, especially given the study's small sample size and the specialized character of BIM as an information

technology that has not been broadly embraced. Each of these components were validated using an interview based technique.

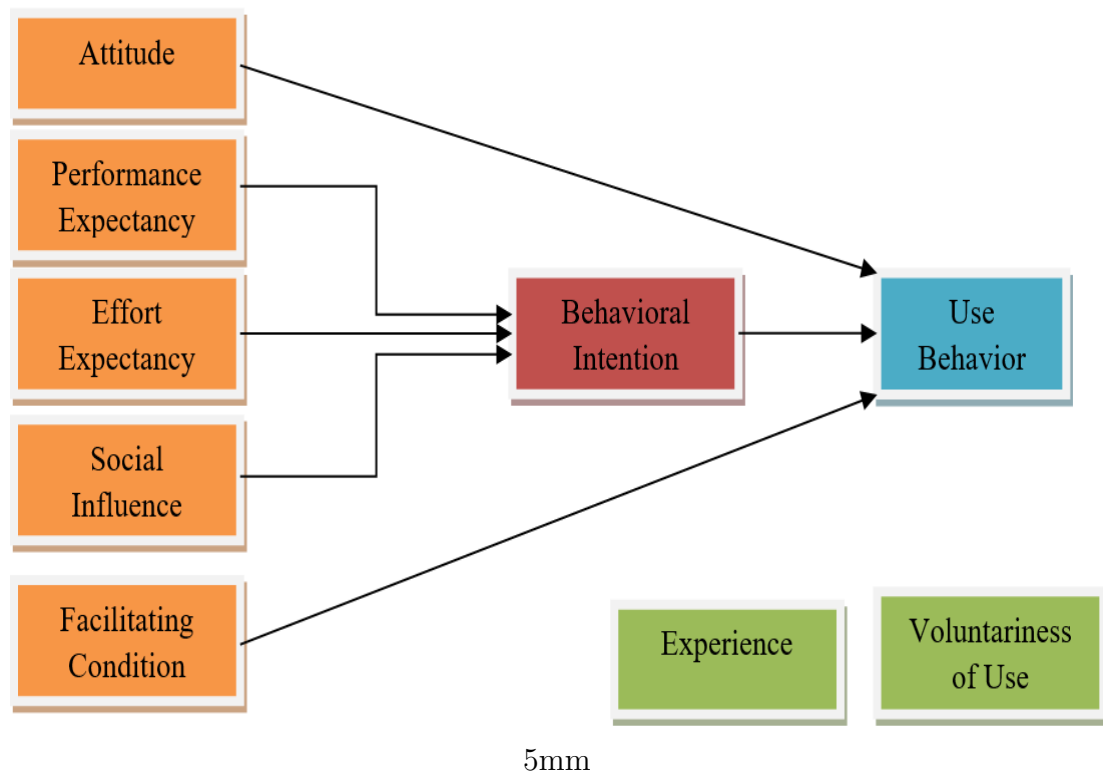


FIGURE 2.11: Proposed framework for UTAUT model as applied to BIM [98].

The study findings also indicate that, contrary to previous research, PE has no affect on BI in the context of BIM. This association appears to be moderated by BIM experience, wherein greater experience is linked to lower perceived performance expectations. Attitude also has a favorable impact on User Behavior, which lends credence to the original UTAUT model for BIM modification.

In order to provide insight on how these variables impact BIM dissemination, the model also finds correlations between a number of variables, including PE, AT, SI, and FC. Notably, the factors that have the most effects on user behavior and behavioral intention, respectively, are SI and FC. This highlights the significance of organizational resources and leadership support in the adoption of BIM. The study also emphasizes the possibility that performance expectations would not be viewed as substantially helpful for improving work performance, underscoring the necessity of thorough employee education on the advantages of BIM in order to guarantee effective implementation and team dedication.

The study [99], creates a theoretical model to examine the factors impacting college students' BIM-related study habits by incorporating learning attitude variables into the UTAUT. Undergraduate students from China took part in the study by filling out online surveys facilitated by peer-to-peer interactions with representative institutions and universities. A total of 1,090 valid responses were collected. The student sample was drawn from China's northeast, north, east, south, center, northwest, and southwest regions. Private, applied, research, and application oriented institutions were the four groups into which the participating universities were split.

In Figure 2.12, the study model preserves the classic UTAUT framework's key aspects, including PE, EE, SI, and enabling circumstances. Furthermore, the study includes "attitude" as a major feature in the model, acknowledging its important impact on behavioral intention. While most UTAUT studies remove moderating variables including age, gender, and experience when examining factors influencing students' usage of network-based distant education, this study does not. This is due to the fact that most Chinese institutions demand BIM technology for AEC majors. Consequently these elements are incorporated into the proposed theoretical framework.

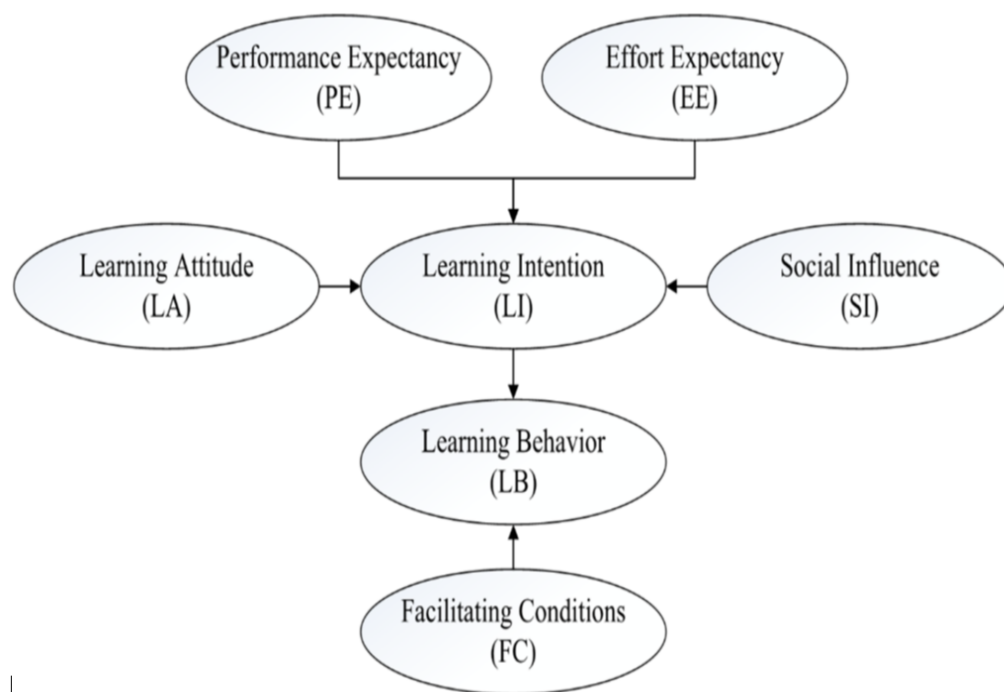


FIGURE 2.12: Theoretical framework model of BIM learning behavior [99].

The results demonstrate the learning intentions of college students, which in turn shape their learning behavior, are directly and favorably impacted by their attitudes about learning BIM, performance expectations, and social influence. Furthermore, motivators and learning objectives have a significant, direct, and beneficial impact on learning behavior. Based on these findings, numerous recommendations are made to increase college students' willingness to study BIM technology, including boosting the competency of full-time BIM teachers and expanding the integration of BIM technology in universities and colleges. This method will promote an ongoing cycle of industry growth by allowing educational institutions to constantly create trained BIM experts for the workforce and market [99].

Through the implementation of legislation and the provision of official backing for initiatives, the Chinese government has emerged as a key player in the promotion of BIM adoption. However, the rate of adoption remains inadequate, especially for the cost engineering sector in China. This article investigates the elements that encourage and inhibit the adoption of BIM in order to assess their influence on existing BIM implementation procedures [100]. By using online surveys, the UTAUT and TAM models are used to analyze each person's intention and behavior.

Figure 2.13, incorporates four control variables: gender, age, experience, and voluntariness, with adjustments based on practitioner feedback. Gender is excluded due to balanced representation in cost engineering, while age and experience are combined into a single variable, generation gap, reflecting how generational differences impact behavior and adoption. Voluntariness is deemed non-essential, as project timelines and collaboration are determined by company policies. Instead, managerial attitude is introduced, highlighting how managerial decisions significantly influence practitioners' BIM adoption.

The updated model includes PE, EE, SI, FC, GG, and Managerial AT as key variables. The findings reveal that low awareness and motivation among practitioners hinder BIM adoption, even though some practitioners have favorable perceptions of BIM. BIM usage is limited primarily to design, cost estimation, and construction, with minimal application in building maintenance. The study highlights managerial AT, FC, and BI as critical factors influencing usage behavior, while

PE, EE, SI, and the GG play a role in shaping BI. These findings provide valuable strategies for managers in cost engineering to encourage successful BIM adoption.

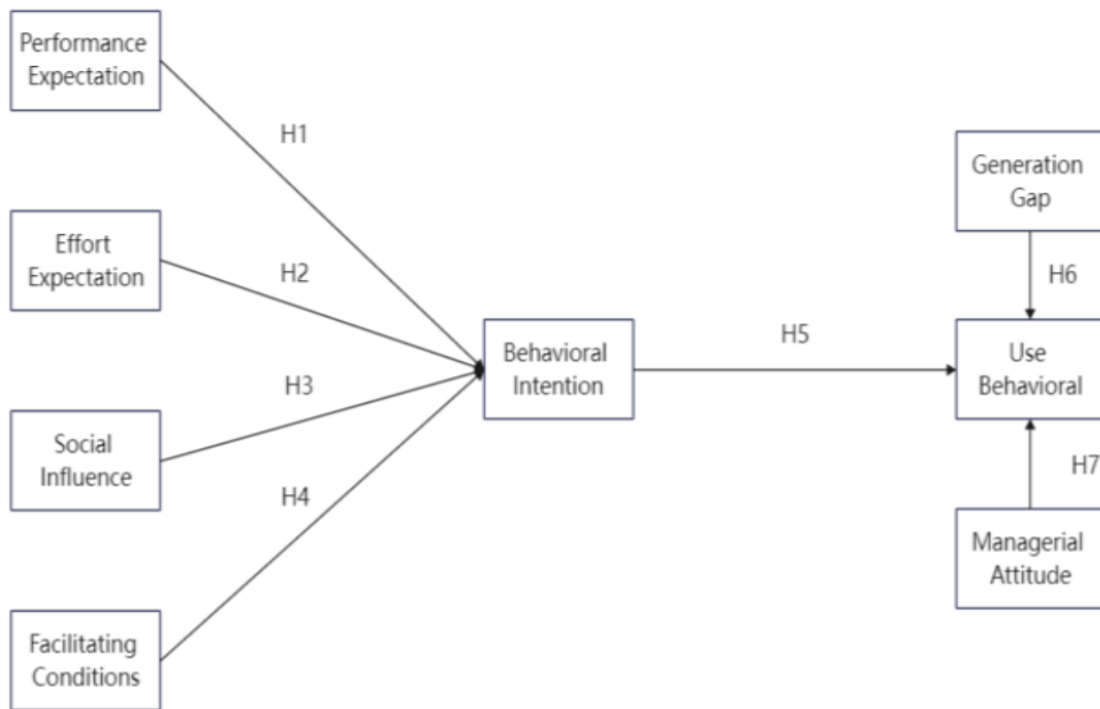


FIGURE 2.13: Variables and hypothesis relation diagram for BIM adoption for cost engineering consultant [100].

## 2.11 Summary of Literature

The literature review in Chapter 2 explores BIM adoption within the construction industry, highlighting its advantages, such as reduced errors, reducing costs, and improving collaboration. BIM's global adoption is influenced by factors like government policies, education, and technological infrastructure, with developed nations leading implementation, while developing countries like Pakistan face challenges due to lack of awareness, skilled personnel, and supportive policies. The chapter highlights theoretical frameworks, particularly the UTAUT, to understand key determinants of adoption, including PE, EE, SI, and FC.

Global case studies reveal successful BIM integration driven by leadership, government mandates, and collaborative efforts in countries like the UK, US, and Singapore. However, challenges persist in regions such as South America, Africa,

and the Middle East due to limited standards and resources. Pakistan's BIM adoption remains low (27% of construction sector), with critical barriers including high costs, policy gaps, and reliance on traditional practices. Comparisons with nations like Vietnam and Nigeria underline the need for government policies, training, and stakeholder (engineers, clients, contractors, project managers) collaboration to overcome adoption challenges.

BIM enhances design accuracy, cost estimation, sustainability, and decision-making, but its application in Pakistan is primarily limited to design and cost estimation. The study identifies managerial attitude, generation gap, and facilitating conditions as critical factors influencing adoption behavior. The current research also identifies gaps that underscore the necessity of developing customized strategies to tackle local challenges and foster greater adoption in Pakistan.

The UTAUT model, with its comprehensive integration of earlier theories (e.g., TAM, TRA, and DOI), is utilized across various sectors, including internet banking, e-government, and BIM. Adoption factors vary by context, influenced by cultural and demographic elements. For BIM adoption, SI and FC have a greater impact than PE, highlighting the importance of tailored strategies such as awareness initiatives and enhanced organizational support. The research advocates for a modified UTAUT model tailored to Pakistan's unique challenges to fully harness BIM's transformative potential for efficiency, productivity, and sustainability in the construction industry. Following a comprehensive literature review, the necessary measurable items for this study have been determined and are presented in the following table 2.3.

TABLE 2.3: Summary of key constructs and their references.

| <b>Items</b>                | <b>References</b> |
|-----------------------------|-------------------|
| Performance Expectancy (PE) | [15, 78, 101]     |
| Effort Expectancy (EE)      | [15, 16, 101]     |
| Social Influence (SI)       | [15, 16]          |
| Facilitating Condition (FC) | [15]              |
| Perceived Cost (PC)         | [15, 16]          |

Table 2.3: (Continued).

| Items                     | References             |
|---------------------------|------------------------|
| Attitude (AT)             | [15, 88, 98, 102, 103] |
| Generation Gap (GG)       | [100, 104]             |
| Behavioral Intention (BI) | [98, 99]               |

Based on the above detailed literature, a comprehensive questionnaire has been prepared for this study (Attached in Appendix-A).

## 2.12 Research Gap

Building Information Modeling (BIM) is well-known for its capacity to boost efficiency, increase cooperation, and improve project results in the construction sector; however, BIM technology adoption in Pakistan is still sluggish, leading to problems like poor productivity, poor communication, overspending, and construction errors. Finding the precise problems and obstacles impeding BIM adoption in Pakistan's distinct building environment is the main difficulty. An extensive review of one hundred and one (101) past papers has been conducted, revealing that while many studies address the slow adoption of BIM in Pakistan, but there is still room to analyze the barriers to BIM technology adoption using different adoption theories. Consequently, the main goal of this research is to employ a modified version of UTAUT (Unified theory of acceptance and use of technology) model to explore technology adoption behavior within Pakistan's construction industry. This research gap highlights the importance of addressing local challenges and providing valuable insights for promoting BIM adoption in Pakistan, giving stakeholders useful advice to increase project efficiency and success.

## 2.13 Conceptual Framework

The main goal of this study is to look into how user behavior and the use of BIM

technology are related, with a specific focus on the Rawalpindi/Islamabad region. As highlighted in the literature review, multiple theoretical frameworks [98–100], There are four core constructs of the unified theory of acceptance and use of technology (UTAUT): performance expectancy (PE), effort expectancy (EE), social influence (SI), and facilitating conditions (FC), which together provide a comprehensive framework for understanding technology adoption. However, within the UTAUT framework, there is limited exploration of constructs such as attitude (AT) and perceived cost (PC), which are critical in influencing user behavior and decision making processes. While UTAUT presents a comprehensive grasp of the elements influencing adoption, further research is needed to incorporate additional variables like attitude and perceived cost to enhance the model’s effectiveness and relevance across varied adoption scenarios.

To address these shortcomings in the model, various researchers commonly incorporate these external factors into their studies as needed. Taib et al. [100] have added two variables “managerial attitude” and “generation gap” in his model to investigate the attitudes and decisions of the company managers, which significantly influence the likelihood of users adopting BIM for engineering projects. In another study, Zhang et al. [101] have included the two external variables “perceived cost ” and “user trust” to assess the adoption of BIM technology by analyzing their intention to adopt, which also reflect their faith in accuracy and financial considerations. To enhance the research model’s robustness, this study preserves the foundational elements of the classic UTAUT model, encompassing key factors such as PE, EE, SI, and FC. Unlike standard office software, BIM-related software requires significant time and financial investment for learning and expertise development. As this software is designed to replace manual processes that demand high precision, users may hesitate to adopt it if they doubt the accuracy of its automated calculations. Recognizing the crucial roles of attitude (AT) and perceived cost (PC) in shaping behavioral intention, this research integrates these two factors into the traditional UTAUT model. By acknowledging their substantial impact on user acceptance and adoption, the study enhances the capacity of the model to describe technology adoption, especially in the context of BIM implementation.

Four control variables; gender, age, experience, and voluntariness of use are also included with modest modifications to the classical UTAUT model while maintaining its essential components. Based on insights from several practitioners, it appears that there's a relatively equal distribution of males and females within civil engineering. Therefore, the selection of "gender" as variable seems reasonable. Age and experience can be combined to create a single variable called "generation gap". The length of their employment experience may have an impact on the way they think and behave [100].

For instance, the adoption behavior is impacted by the generation difference resulting from the age disparity given [105]. Regarding the variable voluntariness, it has been discovered that every organization has a unique work schedule for finishing the project and effectively interacting with the other members of the project team. Therefore, the variable is not deemed essential at this moment. The practitioners are required to finish their task in accordance to the company's specifications. That is why, the voluntariness of usage needs may be eliminated [100].

Therefore, total seven constructs have been employed in the proposed framework, consisting of four constructs from classic UTAUT model and three redefined constructs. The next part gives a detailed discussion of these seven constructs, providing an comprehensive understanding of their significance and relevance to this research.

## 2.14 Development of Research Hypotheses

The current study seeks to integrate UTAUT (Unified theory of acceptance and use of technology) [16] to measure consumers' willingness to embrace BIM technology. Hypotheses have been formulated to examine the relationships proposed by the UTAUT model. As illustrated in Figure 2.14, the model comprises a total of eight variables, including one dependent variable and seven independent variables.

The dependent variable, BI (behavioral intention), represents an individual's intention to adopt technology. The model predicts that PE (performance expectancy),

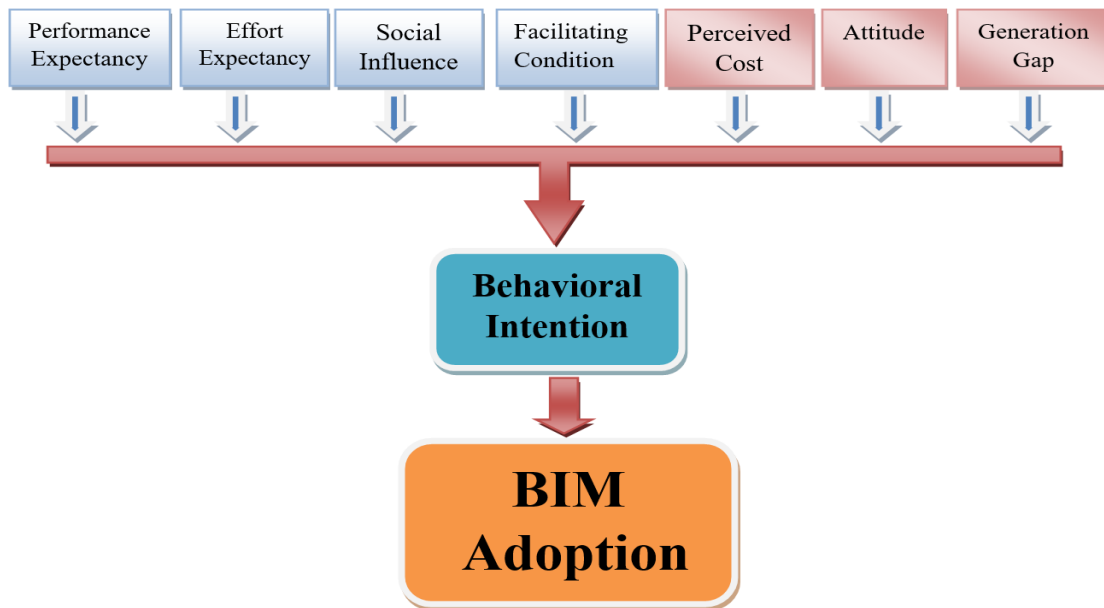


FIGURE 2.14: Modified UTAUT model for BIM adoption.

EE (effort expectancy), SI (social influence), FC (facilitating conditions), PC (perceived cost), AT (attitude), and GG (generation gap) can all have significant impact on this variable. Consequently, the model suggests that individual's intention to adopt BIM technology is directly influenced by these seven factors. Accordingly, the hypotheses formulated in this study are based on the key components of this modified UTAUT framework.

### 2.14.1 Performance Expectancy (PE)

PE is defined as at what extent an individual perceives that such a system will improve his performance at work [15]. This idea is based on a number of theoretical frameworks, including the IDT (innovation diffusion theory), SCT (social cognitive theory), MM (motivational model), MPCU (model of personal computer utilization), TAM1 (technology acceptance model1) and 2.

Research [78] shows that users' intentions to embrace technology across a range of situations, including both voluntary and required scenarios, are highly influenced by PE. It has been identified as the most important indicator of desire to use any technology. This study also emphasizes how crucial is to take user expectations into account for design mobile banking features to live up to their expectations.

The study [101] emphasizes how important user perceptions are influencing the adoption of BIM, especially when they are related to BIM's perceived ability to increase efficiency and effectiveness. Furthermore, the task-technology fit, which measures how well BIM aligns with users' job activities, has a major impact on both PE and BI towards BIM adoption. The study provides actionable advice on how to improve inter-operability to boost user trust through software up-gradation and encouraging BIM adoption at the organizational and governmental levels for practitioners, businesses, and politicians. In summary, the research offers significant understanding of the obstacles that individuals face while using BIM, offering practical methods to encourage its application in the building sector. Based on all available empirical data, the following hypothesis has been brought forward:

**H<sub>1</sub>:** Performance expectancy plays a pivotal role in influencing individuals' behavioral intention to adopt BIM.

### 2.14.2 Effort Expectancy (EE)

EE refers to the an individual's belief regarding how easy it is to use the system [15]. The terms "complexity" and "ease of use" are taken from the model of pc utilization (MPCU), the technology acceptance model (TAM), and innovation diffusion theory (IDT). They all have the same definitions and assessment system and serve as the foundation for effort expectations. However, research [16], implies that extended use of technology reduces the relevance of this construct's influence. Although the model's significance in shaping users' behavioral intention has been recognized, questions have been raised about its capacity to sufficiently explain behavioral intention in a variety of contexts. Extensions of the model with additional determinants and moderating effects have been made in an attempt to strengthen its robustness. Effort expectancy significantly impacts user's behavioral intention to adopt BIM, suggesting that users who find BIM to be user-friendly are more likely to include it into projects. Effort expectancy is considered crucial for behavioral intention across the globe such as in UK, Ghana, and China [101]. The following hypothesis has been proposed based on all known empirical data:

**H<sub>2</sub>:** Effort expectancy positively impacts individuals' behavioral intention to use BIM.

### 2.14.3 Social Influence (SI)

The degree to which a person believes that important people encourage or support their adoption of a new system is known as social influence (SI). This concept closely aligns with social factors and subjective norms reported in various theories such as the TRA, TAM2, TPB, CTAMTPB, MPCU, and IDT. These constructs collectively suggest that individuals' behaviors are impacted by how they believe others see them. The impact of SI is particularly noteworthy in contexts where technology use is mandated [15]. In situations where technology use is obligatory, individuals may engage with technology primarily to fulfill compliance requirements rather than the personal inclination. This phenomena may explain the inconsistent influence on this construct, which is noted in later research projects that seek to validate the concept [16]. The biggest factor influencing behavioral intention is social influence. Positive communication and the effective sharing of influential individual's favorable views on BIM have had the most significant impact on people's intention toward adopting BIM. Efforts to enhance Behavioral Intention might involve better industry stakeholder interactions and more effective communication on implementing BIM.

**H<sub>3</sub>:** Social influence will exert a positive influence on the individual's behavioral intention to use BIM.

### 2.14.4 Facilitating Condition (FC)

Facilitating condition (FC) refer to the extent to which individuals believe that adequate technical and organizational infrastructure exists to support system usage. These conditions are vital in encouraging the intention to adopt a system. However, their influence tends to diminish after the initial adoption phase. Despite this decline in influence on usage intention, the model emphasizes that FC continue

to have a substantial and direct effect on actual usage behavior. This highlights the enduring importance of organizational and technical support in sustaining the long term use of a system beyond its initial adoption [15].

**H<sub>4</sub>:** Facilitating conditions positively influence individuals' usage and learning behavior in the context of BIM adoption.

#### **2.14.5 Perceived Cost (PC) as a New Construct in the Model**

Software connected to BIM technology differs from standard office software, which requires a specific level of skill and incurs costs in terms of time and money throughout the learning process. The perceived cost variable originates from the perceived risk hypothesis, which holds that consumers' adoption responses of goods and technologies are impacted by the perceived risks and costs [106]. Initially, the relation between PC and usage intention was considered negligible. However, upon further examination, it became evident that a subtle connection exists, with perceived cost having a meaningful impact on shaping usage intention. Even with the availability of free learning opportunities and other resources for gaining BIM-related knowledge, the cost factor continues to influence users' decisions. This suggests that while cost may not be the primary determinant, it remains a relevant consideration in the adoption of BIM, especially in resource constrained environments. Therefore, the organizations should carefully assess and address perceived cost concerns to facilitate smoother BIM adoption [101]. Based on all available empirical data, the following hypothesis has been developed:

**H<sub>5</sub>:** Perceived cost negatively affects individuals' behavioral intention to adopt BIM.

#### **2.14.6 Attitude (AT) as a New Construct in the Model**

Attitude (AT) is an additional variable included in the model, which refers to the context to which a person has, whether favorable or unfavorable, towards an act-

ivity concerning a particular issue, significantly influencing user behavior in a direct manner. Thus, by including an additional construct that influences user behavior, the suggested adjustment improves the predictability of the model [98]. The suggested variant offers a greater match to explain building information modeling (BIM) acceptance at the individual level compared to the classical UTAUT model. Considering that a significant proportion of individuals work in environments where BIM is essential, the attitude variable demonstrated a considerable influence on users' behavioral intentions. This result is aligned with previous studies on the compulsory technology adoption [88, 102, 103]. However, it differs from the studies that show how behavioral intention is influenced by attitude and is related to PE and EE. However, the relationship between AT and PE appears to be supported by the correlation that was discovered between them. Accordingly, it is argued that in the context of BIM acceptability, attitude need to be considered a distinct characteristic [15]. Based on all the above discussion, the hypothesis related to attitude (AT) has been developed as follows:

**H<sub>6</sub>:** Individuals' attitude has a positive impact on behavior to adopt BIM.

#### **2.14.7 Generation Gap (GG) as a New Construct in the Model**

Another new variable in the current study. The study combined the age and experience variables into one factor termed as the "generation gap," within the framework of the standard UTAUT model. Depending on how long a person has worked, his choices in behavior and thought processes may differ [100].

For instance, the adoption behavior is impacted by generation difference resulting from age disparity given. Users with varying age groups and professional backgrounds have diverse perspectives on how to use BIM. However, the impact of age on job performance is also evident from the work of other researchers [104], which elucidates that older workers are unlikely to take the initiative to adopt emerging technology and are more likely to use conventional technologies. Based on all available empirical data, following hypothesis has been brought forward:

**H<sub>7</sub>:** A negative correlation exists between Generation Gap and user behavior in the context of BIM technology adoption.

### 2.14.8 Behavioral Intention (BI)

Understanding people's behavioral intentions towards adopting BIM within the construction sector in the UK business is the main goal of the study conducted by Howard et al. [98]. It is noted that experience, attitude, social influence, and facilitating conditions all play important roles in influencing people's behavioral intentions and actual behavior; whereas, performance expectancy might not significantly influence an individual's intention to adopt BIM. It is found that the user behavior is significantly impacted by facilitating conditions. Attitude favorably affects user behavior while social influence considerably controls behavioral intention and experience moderates the impression of performance expectancy. This represents how crucial organizational support and leadership endorsement are in helping staff members to embrace and use BIM.

Another study [99] used the UTAUT model to examine the variables affecting college students' behavior and learning intention when it comes to adopting BIM technology. The results highlighted the significant direct impact of key factors, including EE, PE, SI, and learning AT, on shaping students' learning intentions. It is noteworthy that these key characteristics were found to mediate learning intention and hence exerting considerable indirect influence on students' future learning behavior. This empirical finding highlights the complex dynamics at work in how students interact with BIM technology and illuminates the various channels through which their intentions to learn become actions. Based on all available empirical data, the following hypothesis has been brought forward:

**H<sub>8</sub>:** Behavioral intention can increase an individual's inclination toward BIM technology.

# Chapter 3

## Research Methodology

The methodology for this study is presented in this chapter; it uses the modified UTAUT paradigm to look at the adoption of BIM across various organizational structures. It also covers the procedures and tactics utilized in this inquiry to achieve accurate results. The appropriate equipment and processes are employed to collect primary data, which is subsequently evaluated using statistical techniques. This chapter largely discusses the conceptual framework, research flow chart, sample characteristics, study design, and numerous tests used in the study.

### 3.1 Research Flow Chart

In this work, first step involves identification of an appropriate technology adoption theory through a comprehensive literature review. The UTAUT (unified theory of acceptance and use of technology) were selected after a thorough examination of the literature about technology adoption theories. Subsequently, a modified model was designed to address the specific needs of this research by incorporating three new constructs into the conventional UTAUT model. A questionnaire was designed based on eight factors and responses were collected from various registered and well reputed construction firms/organizations. Advanced testing techniques were then applied to examine the data and to test the hypotheses. Finally, conclusions were derived based on the outcomes of the data analysis (Fig 3.1).

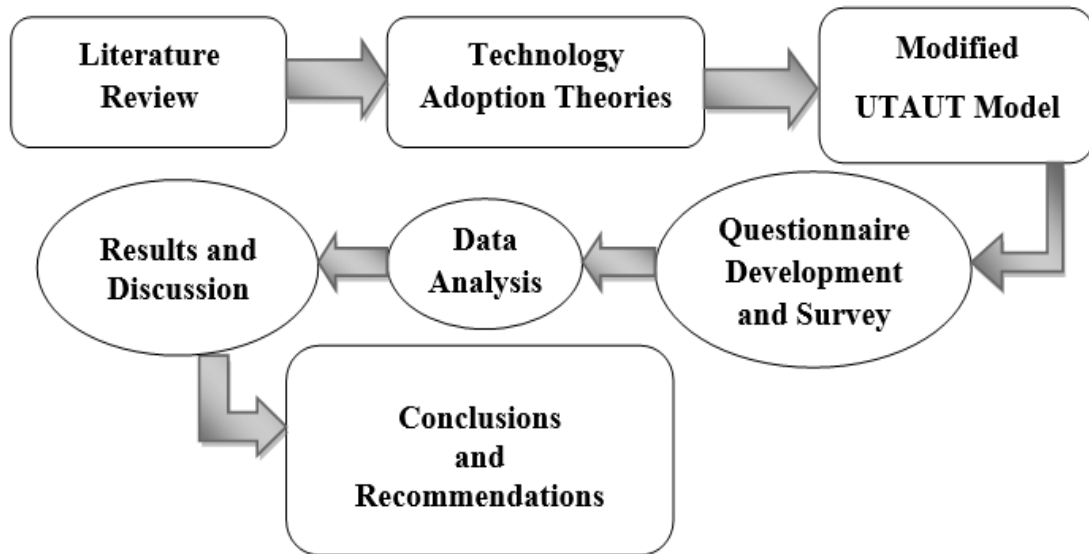


FIGURE 3.1: Research Flow Chart.

## 3.2 Questionnaire Development

In the present study, the measuring scale was written in simple language, incorporating similar phrases from various research studies. The constructs for this study were developed by deep study of relevant literature to establish a strong theoretical foundation for understanding BIM adoption. The constructs for performance expectancy (PE) and effort expectancy (EE) were formulated using insights from [15, 16, 78, 101], which highlights the significance of expected performance benefits and the crucial role of ease of use in adoption. The constructs for social influence (SI) and perceived cost (PC) were developed using insights from [15, 16], and the constructs for facilitating condition (FC) were grounded in research from [15], which underscores the importance of available resources, training programmes, and organizational support enabling BIM adoption. Similarly, the constructs for attitude (AT) towards BIM adoption were generated using studies [15, 88, 98, 102, 103], which emphasize the role of an individual's attitude in shaping their intention to adopt the technology. Furthermore, the constructs for generation gap (GG) were developed using research from [100, 104], which explores generational differences in technological adoption. Lastly, the constructs for item behavioral intention (BI) were based on studies [98, 99].

In the present study, the measuring scale is written in simple language, incorporating similar phrases from various research studies. The questionnaire underwent careful proofreading to eliminate spelling and syntax errors before distribution. It consisted of two parts: the first covers demographic questions such as gender, age, qualification/education, job title, and experience, all while maintaining the respondents' total secrecy. The second portion offers questions about the theory. A five-point Likert scale is utilized, with the following response options: 1 - Strongly disagree; 2 - disagree; 3 - neutral; 4 - agree; and 5 - strongly agree.

### **3.2.1 Research Philosophy**

This research work uses well-established theoretical frameworks from a variety of previous research studies to check and validate these theories before empirically verifying them. Several research studies have utilized a quantitative approach to ensure robust and reliable data analysis. For addressing the research questions and objectives of the current study, different variables have been carefully measured and quantified by examining their interrelationships. The findings are drawn from the hypotheses based on the pass/fail criteria that are established through judgment and data analysis

### **3.2.2 Unit Analysis**

The analysis identifies the stakeholders, organizations, and geographic areas relevant to the current research in the construction sector. Participants in this study are selected from technical backgrounds having reasonable knowledge and hands-on experience in all aspects covered in the research framework. Inputs for the current study are taken from various types of construction-related organizations such as contractors, engineering firms, and regulatory bodies. An online Google Form is constructed for data collection, utilizing a questionnaire prepared in English and tailored for the construction industry. As explained by Fischer et al. [107], the process of collecting data online is characterized by its simplicity, convenience, and cost efficiency, making it an accessible, user-friendly, and economically

advantageous method. It is important to note that the participants of the study have the necessary experience in BIM technology. The participants guarantee the collected data represents a basic understanding of the technology, giving valuable information into the factors shaping attitudes and behaviors towards BIM. To explore the challenges and barriers to adopting digital modeling solutions in construction projects, the study targets individuals likely to be involved in BIM adoption. This study targets individuals with a foundational knowledge of BIM technology to gain meaningful information about the factors influencing the adoption of digital modeling solutions. The results aim to guide the creation of strategies and initiatives that encourage widespread BIM adoption, fostering a digitally advanced and suitable future with in the construction industry.

### 3.2.3 Population

For this study, a total of 1988 registered firms and contractors from Rawalpindi/Islamabad (Pakistan) region were chosen [108]. The first 30 responses were selected for pilot testing in the first phase. Total 294 valid responses have been chosen from 332 and these responses are further used for various analyses and testing of research hypotheses. Professionals working in the construction field with titles such as project managers, project leaders, team leaders, engineers, advisors, experts, and supervisors account for the population. A Google form (questionnaire) was used to gather data (online) [109]. There were two sections of questionnaire; the first one asks for personal details such name, age, gender, qualification, and experience while the second part includes the 26 constructs that make up all eight independent and dependent variables of modified UTAUT model. The online mode was used to distribute the survey forms and obtain responses. After that, from the chosen sample, the data was used for analyses.

### 3.2.4 Sampling Technique

For current research work, a sample size of 294 participants is used, which is a perfect and trustworthy number to achieve the research objectives. It is decided

based on the registered construction firms and organizations in Islamabad and Rawalpindi region as well as by keeping in view of the targeted accuracy level. Increased resources and effort are needed for larger sample sizes but the results are more trustworthy. It is noted that this sample size is suitable given the available resources and the required degree of accuracy. To guarantee the fair representation and provide each person an equal chance of being selected, the probability sampling method is employed. The sample size is calculated using Taro Yamane's formula, ensuring a 0.05 margin of error [110].

In Rawalpindi and Islamabad, there are 1988, registered contractors and firms in categories C-A through C-6, according to the most recent update on the PEC website [108]. By sending a questionnaire via email to a sample of registered businesses in Islamabad and Rawalpindi, their opinions/responses are gathered. About four hundred construction firms/enterprises from these areas responded to the survey. The information is also gathered directly from specialists at different organizations in addition to the online distribution the questionnaire.

It is needed that the suitable sample size should be determined for the present investigation in order to secure the appropriate data for solid conclusion. The maximum variability ( $p = 0.5$ ) is assumed because the population of firms in Rawalpindi/Islamabad is huge and the adoption rate of the new practice is unknown (it may be anywhere from 0% to 100%). Therefore, it is aimed to achieve 95% confidence in the findings with a margin of error of no more than  $\pm 5\%$  [111]. To achieve this aim, the Yamane's formula 3.1 is used, which allows to obtain the optimal sample size based on the required levels of precision and confidence.

$$n = \frac{N}{1 + Ne^2} \quad (3.1)$$

Where:

$n$  = Sample size required,

$N$  = Population size, = 1988

e = Allowable error (%)

Let e = 0.05 (to achieve 95% of confidence with margin of error  $\pm 5\%$ )

$$n = \frac{1988}{1+1988(0.05)^2}$$

$$n = \frac{1988}{5.97}$$

$$n = 332$$

The chosen sample size is regarded as an appropriate to attain the specified degree of accuracy. This sample size is determined using probability sampling; therefore, it guarantees that each person has an equal opportunity of being represented.

### 3.3 Data Analysis

The process of extracting useful information from data using statistical and computational techniques is known as data analysis [112]. The Cronbach's alpha approach is utilized to assess the consistency and reliability of the responses. The data analysis requires a broad range of skills, including technical competence, social intelligence, and result interpretation expertise. Complete data sets are examined using the AMOS (analysis of moment structures) module of SPSS (statistical package for social sciences) in conjunction with SEM (Structural Equation Modeling). Moreover, the hypotheses are tested to evaluate the study results and model suitability. The analyses of results have made it easier to explore unexplored ground by classifying new variables with careful investigations. Following tests are conducted to investigate and evaluate the data to conclude the study.

- Descriptive Statistics
- Reliability Analysis
- Regression Analysis
- Pearson Correlation Analysis
- Confirmatory Factor Analysis (CFA)

# Chapter 4

## Results and Discussion

The study's extensive methodology, which includes survey data gathering and statistical analysis, is described in Chapter 3. After using purposeful sampling to choose participants according to predetermined standards, demographic information is presented. The Likert scale is used to assess respondents' opinions on a range of topics. The collected data underwent thorough statistical analysis using SPSS, and the results are presented in detail with an emphasis on important findings and consequences. As previously mentioned, certain tests relevant to the investigation were carried out, allowing for the evaluation of theories and the ultimate decision to accept or reject hypotheses.

### 4.1 Results and Demographics

Demographics consist of the respondent's gender, age, qualification, designation and experience, represented via a graphical display illustrating percentages.

#### 4.1.1 Gender

Figure 4.1 depicts distribution of the gender's response and it reveals that 24 respondents identified as female, representing 8% of the sample population. Conversely, the maximum numbers of respondents, totaling 270 individuals or 92%,

identified as male. These figures indicate a significant gender disparity within the sample, highlighting a predominance of male participants.

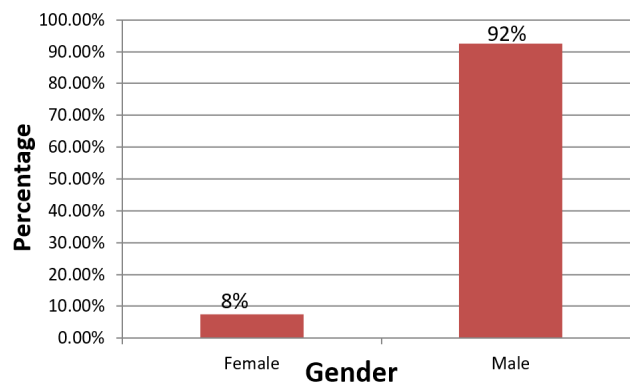


FIGURE 4.1: Gender Category Respondents.

### 4.1.2 Age

In figure 4.2, the results reveals that, 15 respondents (5%) are below or 25 years old, 53 respondents (18%) are between 25-30 years old, 161 respondents (55%) are in the 30-40 age range, 60 respondents (20%) are aged between 40-50, and 5 respondents (2%) are above 50 or more years old. These findings provide a detailed overview of how age groups are distributed within the sample of 294 participants.

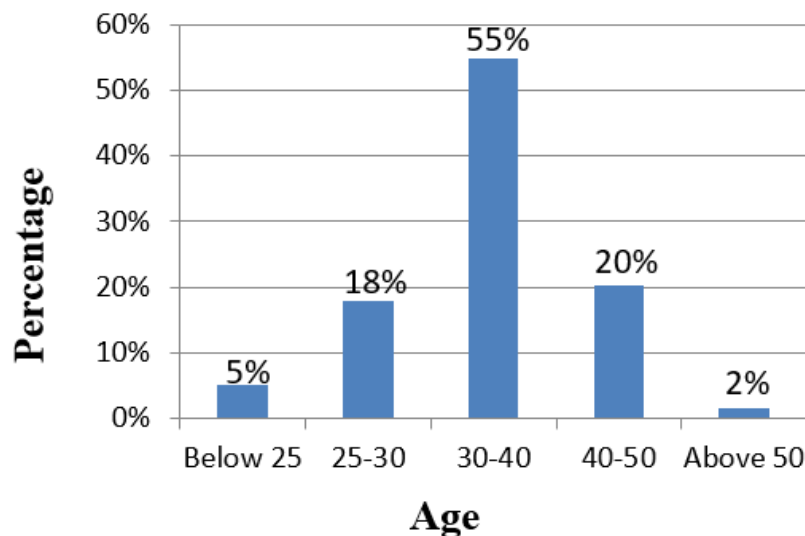


FIGURE 4.2: Age Category respondents.

### 4.1.3 Qualification / Education

Figure 4.3 shows the qualification distribution among participants. It can be

noted that 173 respondents (59%) hold a Bachelor's degree, and 121 respondents (41%) possess a Master's degree. These figures offer a comprehensive breakdown of the educational backgrounds within the sample, highlighting the diversity of qualifications in terms of education.

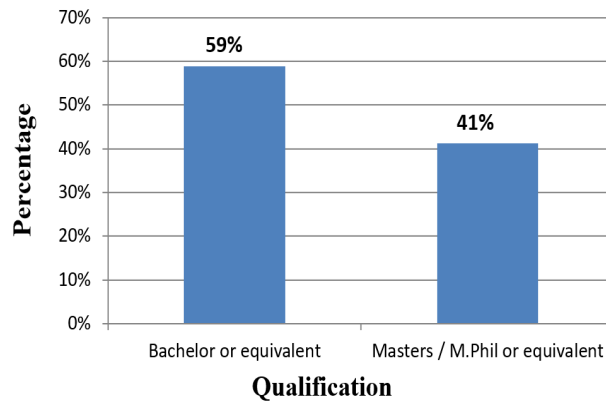


FIGURE 4.3: Qualification/Education Category respondents.

#### 4.1.4 Designation

Figure 4.4 depicts the distribution of designations among respondents; 52 respondents (18%) are Project Managers, 129 respondents (44%) are Engineers, 57 respondents (19%) hold Project-related different positions, 35 respondents (12%) are advisor and expert, and 21 respondents (7%) are project leader. These figures provide a clear overview of the distribution of job titles within the sample of 294 participants, showcasing the diverse range of roles present in the study population.

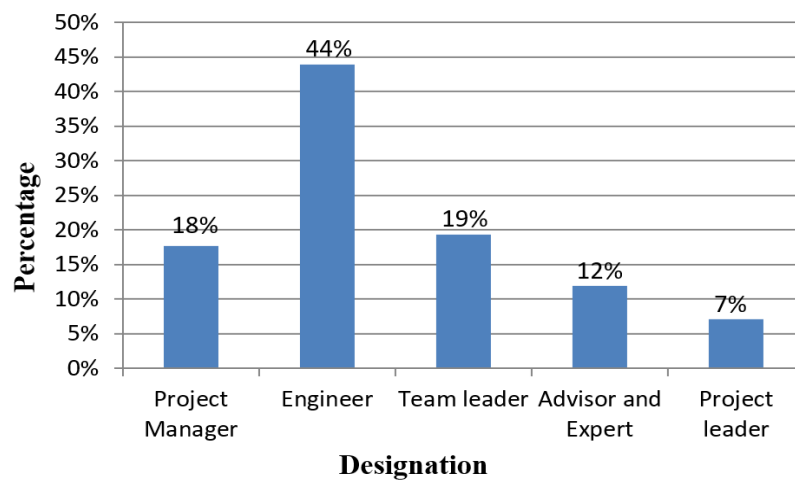


FIGURE 4.4: Designation Category of respondents.

### 4.1.5 Experience

The distribution of experience among respondents is shown in Figure 4.5. It represents that only 15 respondents (5%) have below or 5 years of experience, 118 respondents (40%) have 5-10 years of experience (although the ages of eight respondents fall between 40 to 50 years, their reported experience in this section is only between 5 to 10 years. However, upon reconfirmation, it was confirmed that they provided only their BIM-related knowledge and experience for this study), 104 respondents (35%) have 11-15 years of experience, 38 respondents (13%) have 16-20 years of experience, and 19 respondents (6%) have 20 years or more experience. These percentages and frequencies provide a detailed view of the range of professional experience levels within the sample, offering insights into the diverse career backgrounds of the study population.

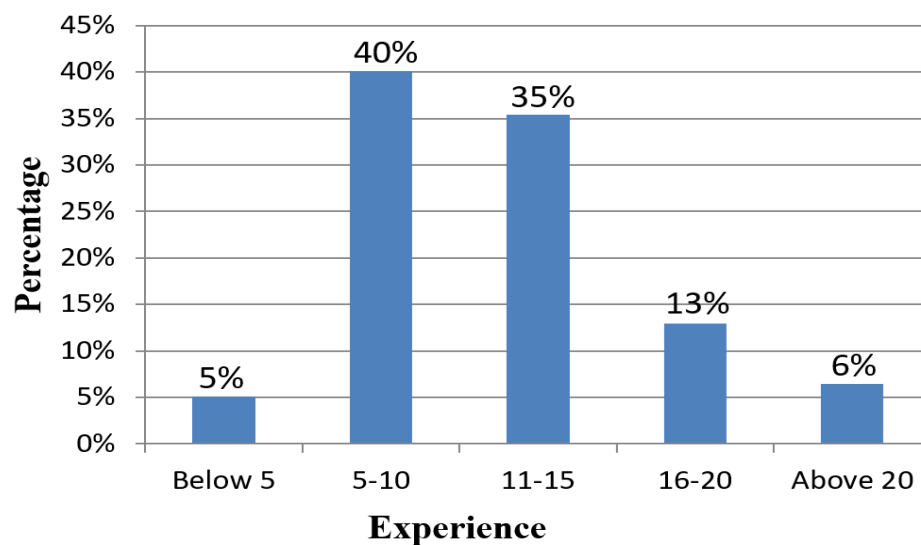


FIGURE 4.5: Experience Category of respondents.

## 4.2 Pilot Testing

Various uncertainties emerged during the initial phase of distributing the questionnaire, particularly concerning the reliability and validity of the questions. A pilot test was carried out with at least 30 responses in order to solve these problems, as outlined by Smith [113].

For ensuring the reliability of the current research study, variable errors are analyzed and corrected through data validity checks in the questionnaire. Initially, more than 30 responses were collected to conduct a reliability test. In this study, 30 responses were collected, accounting for 10.20% of the sample size, to evaluate the questionnaire reliability. During pilot testing, one variable recorded a Cronbach's alpha value below 0.7, so the item "SI1" from social influence (SI) was removed due to inconsistent and disruptive responses. After removing this item, the reliability of SI increased from 0.68 to 0.717, falling within an acceptable range.

### 4.3 Reliability Test

Using SPSS software, data is assessed for the Cronbach's alpha reliability test. A reliability analysis method is chosen, and a scale is analyzed. subsequently, the Cronbach's alpha value of each variable is checked and analyzed [114]. All variables are processed through the program for the analysis process in accordance with the classical theory of assumption, and the value is increased by removing the items. It is recommended that the Values ranging from 0.6 to 0.7 reflect acceptable reliability, while those exceeding 0.8 indicate strong reliability. However, extremely high values above 0.95 might signal redundancy [115]. In order to do this, first choose the analyze tab, then scale it and select the reliability analysis. Cronbach's alpha values indicated that an appropriate degree of internal consistency is considered to be 0.6 or higher, with values below this threshold deemed insufficient.

In the current study, Table 4.1 shows reliability test values for various variables analyzed using SPSS. It includes the variable names, item's number, and Cronbach's Alpha values. The item's number represents the specific survey questions employed to measure each construct. Cronbach's alpha, which ranges from 0 to 1, assesses the reliability of these items, with values above 0.70 considered acceptable and values above 0.80 representing strong reliability. Performance expectancy (PE) is assessed through 4 items, the analysis resulted in a Cronbach's alpha of 0.814, indicating strong internal consistency. Likewise, Effort expectancy (EE),

assessed with just 2 items, despite the limited number of items, an alpha value of 0.836 demonstrates a high reliability. Social influence (SI), evaluated using three items, achieved a Cronbach's alpha of 0.798, further validate robust internal consistency. The facilitating condition (FC) construct, also measured with 3 items, has a Cronbach's alpha of 0.791, validate the scale's good reliability in assessing facilitating conditions. The perceived cost (PC) construct, which was assessed using 5 items, shows an alpha value of 0.783, reflecting good internal consistency and suggesting that the items effectively measure perceived cost. The attitude (AT) construct, measured through 3 items, presents a high alpha value of 0.814, signifying strong internal consistency. Generation gap (GG), also measured using 3 items, has an alpha value of 0.826, indicating that this construct is also reliable. Behavioral intention (BI) demonstrates the highest reliability among all constructs, with a Cronbach's alpha of 0.846 across 3 items, indicating excellent internal consistency in measuring behavioral intention.

TABLE 4.1: Cronbach's Alpha values.

| <b>Variables</b>       | <b>SPSS Name</b> | <b>No. of Items</b> | <b>Cronbach's Alpha Values</b> |
|------------------------|------------------|---------------------|--------------------------------|
| Performance Expectancy | PE               | 4                   | .814                           |
| Effort Expectancy      | EE               | 2                   | .836                           |
| Social Influence       | SI               | 3                   | .798                           |
| Facilitating Condition | FC               | 3                   | .791                           |
| Perceived Cost         | PC               | 5                   | .783                           |
| Attitude               | AT               | 3                   | .814                           |
| Generation Gap         | GG               | 3                   | .826                           |
| Behavioral Intention   | BI               | 3                   | .846                           |

The study's measured values exhibit overall good internal consistency and reliability, as evidenced by the high alpha values noted for the majority of the variables. These results strengthen the validity of the data gathered and provide validity to the later studies that evaluate the correlations and results among different variables under study. This study improves the understanding of the elements that

impact technology adoption and usage behaviors within the examined context by providing a reliable measurement of the relevant constructs.

## 4.4 Descriptive Statistics

Table 4.2 presents the descriptive data for all eight factors, each evaluated on a 5-point scale from a sample of 294 respondents. The data comprises the key measures like the minimum and maximum scores, along with the standard deviation and mean values for all factors. The sample size for all factors is 294, with response scores ranging from 1.00 to 5.00, indicating that the full range of the scale was utilized. The mean reflects the central tendency, where higher values suggest more favorable responses, while the standard deviation shows the extent of variation in responses. A lower standard deviation signifies that the responses are tightly grouped around the mean, while a higher standard deviation indicates greater variability in the data.

TABLE 4.2: Descriptive Statistics.

| <b>Factors</b> | <b>N</b> | <b>Minimum</b> | <b>Maximum</b> | <b>Mean</b> | <b>St. Deviation</b> |
|----------------|----------|----------------|----------------|-------------|----------------------|
| PE             | 294      | 1.00           | 5.00           | 4.22960     | 0.813820             |
| EE             | 294      | 1.00           | 5.00           | 4.03571     | 0.957363             |
| SI             | 294      | 1.00           | 5.00           | 4.21315     | 0.827231             |
| FC             | 294      | 1.00           | 5.00           | 4.06689     | 0.750926             |
| PC             | 294      | 1.00           | 5.00           | 4.00408     | 0.844670             |
| AT             | 294      | 1.00           | 5.00           | 4.15192     | 0.812778             |
| GG             | 294      | 1.00           | 5.00           | 3.99093     | 0.998369             |
| BI             | 294      | 1.00           | 5.00           | 4.04081     | 0.845170             |

For performance expectancy (PE), the mean score is 4.22960, indicating that respondents generally view the ease of use positively. The standard deviation value of 0.813820 shows that responses were relatively consistent, with some variability. Effort expectancy (EE) has a mean of 4.03571, suggesting a favorable perception

of the effort required, though the standard deviation of 0.957363 indicates slightly more variability in responses compared to PE. Social influence (SI) received a mean score of 4.21315, close to PE, indicating that respondents also perceive social influence favorably. However, with a standard deviation of 0.827231, there is a bit more spread in the responses. Facilitating conditions (FC) has a mean of 4.06689, suggesting respondents perceive the conditions as supportive, with a relatively lower variability in standard deviation of 0.750926 compared to other factors. In contrast, perceived cost (PC) shows a slightly lower mean of 4.00408, indicating that respondents perceive cost less favorably than other factors, with a moderate standard deviation of 0.844670. Attitude (AT) has a mean of 4.15192, demonstrating a generally positive attitude among respondents, with moderate variability in standard deviation of 0.812778. For generation gap (GG), the mean is 3.99093, similar to PC, indicating relatively neutral views. However, GG has the highest standard deviation of 0.998369, suggesting more diverse opinions on this factor. Finally, behavioral intention (BI) received a mean of 4.04081, indicating a generally positive intention among respondents, with moderate variability in standard deviation of 0.845170. Overall, the data reflects positive attitude and perceptions towards the factors examined, with relatively low dispersion, indicating agreement among respondents.

## 4.5 Regression Analysis

A statistical technique such as regression analysis is used to investigate the connection between independent and dependent variables by fitting a regression model to observed data. In order to make predictions and comprehend the underlying relationships in the data, it is helpful to quantify the effect of changes on the dependent variables by independent variables [116].

Arkes explained that the main objective of regression analysis's main objective is to determine causal links by examining how variations in the outcome variable (dependent variable) are influenced by changes in the treatment variable (independent variable).

This statistical technique helps researchers in explaining processes underlying observable occurrences and permits predictions based on the links found. It also gives insights into the degree and direction of these effects. Regression analysis helps to make well-informed decisions and build treatments that target particular variables to achieve desired results by quantifying the relationships between them [117].

Table 4.3 presents the results of a regression analysis that examines multiple independent variables PE, EE, SI, FC, PC, AT, GG, and their relationship with the dependent variable BI. The Beta ( $\beta$ ) coefficients indicate the strength and direction of the correlations, whereas p-values determine statistical significance. A p-value  $< 0.05$  indicates a statistically significant association. Furthermore, R-square values represent the amount of variation in the dependent variable BI explained by the independent variables, with larger R-square values indicating stronger explanatory power.

TABLE 4.3: Regression Analysis.

| Variables   |           | Regression Values |                   |          |         |
|-------------|-----------|-------------------|-------------------|----------|---------|
| Independent | Dependent | Beta ( $\beta$ )  | p-Value           | R-square | t-Value |
| PE          | BI        | .223              | .000 <sup>b</sup> | .050     | 4.094   |
| EE          | BI        | .222              | .000 <sup>b</sup> | .049     | 4.076   |
| SI          | BI        | .347              | .000 <sup>b</sup> | .121     | 6.625   |
| FC          | BI        | .369              | .000 <sup>b</sup> | .135     | 7.062   |
| PC          | BI        | .419              | .000 <sup>b</sup> | .175     | 8.246   |
| AT          | BI        | .462              | .000 <sup>b</sup> | .214     | 9.27    |
| GG          | BI        | .260              | .000 <sup>b</sup> | .068     | 4.823   |

PE has a positive and significant impact on BI, with a  $\beta$  of 0.207 and an R-square of 0.043, suggesting that PE introduces 4.3% of the variance in BI. EE is similarly positively related to BI, with a  $\beta$  of 0.249 and an R-square of 0.062, accounting for 6.2% of the variance. Both PE and EE show moderate effects but exhibit relatively small portions of the variance in BI. SI exhibits a stronger positive effect on BI with a  $\beta$  of 0.297 and an R-square of 0.088, explaining 8.8% of the variance, making

it a more substantial predictor compared to PE and EE. FC also demonstrates a notable positive influence on BI, with a  $\beta$  of 0.385 and an R-square of 0.148, indicating that FC accounts for 14.8% of the variance in BI. Similarly, PC has a  $\beta$  of 0.383 and an R-square of 0.146, explaining 14.6% of the variance in BI, which suggests that FC and PC are stronger predictors.

AT demonstrates the strongest positive relationship with BI, with a  $\beta$  value of 0.442 and an R-square of 0.180, explaining 18% of the variance, making it the most influential predictor in the model. Lastly, GG had a positive impact on BI, accounting for 6.9% of the variation ( $\beta = 0.263$ , R-square = 0.069).

In conclusion, all independent factors have a statistically significant positive connection with BI. Perceived cost (PC), facilitating conditions (FC), and attitude (AT) have the most effects on behavioral intention (BI). Effort expectancy (EE) and performance expectancy (PE) generate less variance in BI and have lower  $\beta$  values. According to these findings, the most significant factors influencing behavioral intention in this situation are attitude, perceived cost, and facilitating conditions.

## 4.6 Pearson Correlation Analysis

Pearson correlation approach is used to evaluate the correlations between the variables of the model [118]. This analysis indicates the direction and degree of the link, demonstrating how changes in variables affect each others. Pearson correlation is a fundamental statistical technique commonly used for such analysis due to its widespread application and simplicity.

The table 4.4 demonstrates the relationships among various factors: PE, EE, SI, FC, PC, AT, GG, and BI. Correlations can range from -1 to +1, where +1 denotes a complete positive association between two factors, meaning that when one rises, the other does too. On the other hand, a complete negative connection is represented by a value of -1, which means that as one element rises, the other falls. No association between the components is indicated by a value of 0.

TABLE 4.4: Pearson correlation analysis of factors under study.

| Factors   | PE      | EE      | SI      | FC      | PC      | AT      | GG      | BI |
|-----------|---------|---------|---------|---------|---------|---------|---------|----|
| <b>PE</b> | 1       |         |         |         |         |         |         |    |
| <b>EE</b> | 0.137*  | 1       |         |         |         |         |         |    |
| <b>SI</b> | 0.239** | 0.147** | 1       |         |         |         |         |    |
| <b>FC</b> | 0.075   | 0.264** | 0.209** | 1       |         |         |         |    |
| <b>PC</b> | 0.195** | 0.282** | 0.245** | 0.255** | 1       |         |         |    |
| <b>AT</b> | 0.233** | 0.255** | 0.207** | 0.316** | 0.376** | 1       |         |    |
| <b>GG</b> | 0.189** | 0.205** | 0.221** | 0.216** | 0.326** | 0.247** | 1       |    |
| <b>BI</b> | 0.207** | 0.249** | 0.297** | 0.385** | 0.383** | 0.442** | 0.263** | 1  |

\*. Correlation is significant at the 0.05 level (2-tailed).

\*\*. Correlation is significant at the 0.01 level (2-tailed).

PE shows small but significant positive correlations with other factors, such as SI ( $r = .239$ ) and BI ( $r = .207$ ). The relationships are statistically significant at the 0.01 level, denoted by the double asterisks (\*\*). EE (Effort Expectancy) also has weak but significant positive correlations with SI ( $r = .147$ ) and BI ( $r = .249$ ) at the 0.01 significance stage. SI demonstrates a moderate positive correlation with several factors, particularly with BI ( $r = .297$ ). This suggests that social influence moderately affects behavioral intention. FC is positively correlated with numerous factors, with particularly strong correlations with BI ( $r = .385$ ) and AT ( $r = .316$ ).

This implies that improved facilitating conditions can lead to increased behavioral intentions and more positive attitudes. PC exhibits moderate correlations with BI ( $r = .383$ ) and AT ( $r = .376$ ), indicating that perceived cost significantly influences both attitudes and behavioral intentions. AT has one of the strongest correlations with BI ( $r = .425$ ), indicating that more favorable attitudes toward technology strongly influence behavioral intention. GG shows moderate but significant correlations with BI ( $r = .263$ ) and PC ( $r = .326$ ), which suggests that both behavioral intentions and perceived cost are affected moderately.

The crux summarize all the above results is that the BI has the strongest correla-

tions with AT ( $r = .425$ ), FC ( $r = .385$ ), and PC ( $r = .383$ ). These findings indicate that attitude toward technology, perceived cost, and facilitating conditions play substantial roles in shaping behavioral intentions. In summary, the table underscores that attitude, cost, and facilitating conditions are significant factors influencing behavioral intentions, with attitude having the strongest impact.

## 4.7 Confirmatory Factor Analysis (CFA)

CFA is a statistical method employed to assess the model fit by analyzing the relationships between observable variables in the model. This method is commonly applied in conjunction with SEM (structural equation modeling) to investigate the hypothesized correlations among observable variables [119].

To conduct CFA for a model, researchers must first identify components and their expected correlations. CFA is used to determine whether the indicators (observed variables) accurately represent the constructs (latent variables) within the model. Process involves analyzing data to explore interrelationships among variables. The adequacy of the observed variables is assessed against hypothesized relationships.

CFA validates the dependencies among variables and finds the best fit for the model, although no single model can be considered entirely accurate or optimal in terms of fit and effectiveness. There are ongoing debates about the reliability of the calculated fit indices. However, CFA still serves to validate the factors, assesses convergent validity, and discriminates validity, thereby providing a comprehensive measurement of the model.

According to Hu and Bentler [120], values obtained from the model are considered excellent and significant, making them suitable for further analysis. Figure 4.6 represents the complete CFA Model values of the current study. The results of CFA (Table 4.5), suggest that hypothesized model exhibits a satisfactory fit to data, supported by the several key model fit indices. Each index provides valuable insights into extent to which model aligns with observed data and meets established benchmarks for an acceptable model fit.

**CMIN**

| Model              | NPAR | CMIN     | DF  | P    | CMIN/DF |
|--------------------|------|----------|-----|------|---------|
| Default model      | 80   | 411.360  | 271 | .000 | 1.518   |
| Saturated model    | 351  | .000     | 0   |      |         |
| Independence model | 26   | 3304.250 | 325 | .000 | 10.167  |

**Baseline Comparisons**

| Model              | NFI<br>Delta1 | RFI<br>rho1 | IFI<br>Delta2 | TLI<br>rho2 | CFI   |
|--------------------|---------------|-------------|---------------|-------------|-------|
| Default model      | 0.876         | 0.851       | .954          | .943        | .953  |
| Saturated model    | 1.000         |             | 1.000         |             | 1.000 |
| Independence model | .000          | .000        | .000          | .000        | .000  |

**RMSEA**

| Model              | RMSEA | LO 90 | HI 90 | PCLOSE |
|--------------------|-------|-------|-------|--------|
| Default model      | .042  | .034  | .050  | .949   |
| Independence model | .177  | .171  | .182  | .000   |

FIGURE 4.6: CFA Model Fit Values.

TABLE 4.5: Model Fit Indices (summary taken from figure 4.6).

| Model              | Variables | RMSEA | CMIN/DF | NFI      | CFI   | TLI   | IFI   |
|--------------------|-----------|-------|---------|----------|-------|-------|-------|
| Hypothesized Model | 08        | 0.042 | 1.518   | 0.876    | 0.953 | 0.943 | 0.954 |
| Reference          |           | 0-1   | <5      | 0.8-0.95 | >0.90 | >0.90 | >0.90 |

#### 4.7.1 Root Mean Square Error of Approximation (RMSEA)

The root mean square error of approximation (RMSEA) for the hypothesized model is 0.042, suggesting an excellent fit as shown in table 4.5, because it is

much lower than the suggested threshold of 0.05. RMSEA is one of the most informative model fit indices, with values less than 0.05 indicating a strong or close fit, 0.05 to 0.08 showing a decent fit, and 0.08 to 0.10 indicating a moderate fit. Scores greater than 0.10 is suggestive of a poor match. The observed RMSEA value of 0.042 suggests a low approximation error and a good fit between the calculated covariance structure and the observations. An RMSEA score around zero is extremely desired since it demonstrates the model's capacity to effectively capture the underlying correlations between variables. This outcome demonstrates the suggested model's resilience and usefulness for future study and analysis.

#### **4.7.2 Chi-Square/Degree of Freedom (CMIN/DF)**

The proposed model has a CMIN/DF of 1.518, suggesting an excellent match as shown in table 4.5. This result is substantially lower than the acceptable criterion of 5, with values less than 2 or 3 often indicating a good match. The observed CMIN/DF indicates that the predicted structure captures the interactions between variables while striking a balance between simplicity and explanatory power. A lower CMIN/DF ratio indicates that the model is neither over fitted nor unduly complicated, eliminating extraneous parameters while still giving a good fit to the data. Furthermore, this statistic emphasizes the model's suitability in describing the data without introducing bias or over complication. It confirms that the predicted model is consistent with the theoretical background and empirical data. Overall, this discovery highlights the model's stability and ability to serve as a dependable foundation for further research and validation.

#### **4.7.3 Normal Fit Index (NFI)**

The proposed model has a Normal Fit Index (NFI) of 0.876 as shown in table 4.5, indicating a slightly satisfactory fit. The NFI compares the hypothesized model to a null model with no variable associations, with values more than or equal to 0.90 indicating a good fit and values ranging from 0.80 to 0.89 deemed acceptable. Although the NFI value is somewhat lower than the optimum threshold of 0.90,

it nevertheless shows that the model significantly outperforms the null model. This result indicates that the model properly represents the underlying structure of the data and is consistent with the theoretical framework. While there is still potential for improvement to attain an optimal fit, the NFI score verifies the model's suitability for further analysis and interpretation. Furthermore, the observed NFI value demonstrates the model's balance of complexity and explanatory power, since the model continues to give a meaningful representation of the data. This conclusion validates the model's potential value in understanding variable interactions, as well as its applicability to the study environment.

#### 4.7.4 Comparative Fit Index (CFI)

The hypothesized model's Comparative Fit Index (CFI) is 0.953 as shown in table 4.5, suggesting an excellent match that exceeds the specified cutoff value of 0.90. The CFI is a widely used incremental fit measure that compares the hypothesized model to the null model while accounting for model complexity. Values close to 1.0 are preferable, with values over 0.90 typically indicating a good match and values above 0.95 indicating an exceptional fit. The high CFI score of 0.953 demonstrates the model's resilience and ability to explain observed data remarkably well when compared to a baseline model. This result demonstrates the model's ability to effectively capture underlying connections between variables while remaining simple. The excellent CFI result increases confidence in the model's validity and applicability for future analysis.

#### 4.7.5 Tucker-Lewis Index (TLI)

The Tucker-Lewis Index (TLI) for the hypothesized model is 0.943 as shown in table 4.5, indicating an excellent fit as it exceeds the recommended threshold of 0.90. Similar to the Comparative Fit Index (CFI), the TLI assesses the improvement of the hypothesized model over a null model, with an additional penalty for model complexity to ensure parsimony. Values greater than or equal to 0.90 represent a good fit, while values exceeding 0.95 denote an excellent fit. The observed TLI

value of 0.943 highlights the model's ability to strike a balance between goodness of fit and model simplicity, further supporting its alignment with the observed data. This result not only confirms the robustness of the model but also strengthens confidence in its capacity to accurately capture the underlying relationships among variables while maintaining a parsimonious structure. The excellent TLI value provides further evidence of the model's suitability for use in subsequent research and analysis.

#### 4.7.6 Incremental Fit Index (IFI)

The hypothesized model's Incremental Fit Index (IFI) is 0.954 (4.5), suggesting an outstanding fit because it exceeds the required threshold of 0.90 and the 0.95 benchmark for an excellent fit. Similar to the Comparative Fit Index (CFI), the IFI assesses how well the hypothesized model fits the data when compared to a null or baseline model. Values close to 1.0 are ideal, with values above 0.90 indicating a strong match. The observed IFI value of 0.954 demonstrates that the model outperforms the null model, indicating its robustness and efficacy in capturing the connections between variables. This exceptional IFI score further supports the validity and suitability of the model for additional research and analysis by demonstrating its capacity to represent the data accurately without over fitting.

In conclusion, the hypothesized model satisfies the majority of the criteria for a good model fit. Most fit indices, including the RMSEA, CMIN/DF, CFI, TLI, and IFI, fall comfortably within their acceptable ranges, reinforcing the reliability of the model. Although the NFI falls slightly short of the optimal threshold, it remains close enough to be considered acceptable. Taken together, these CFA results indicate that the hypothesized model offers a solid representation of the underlying data structure, providing confidence in its validity for further analysis.

#### 4.7.7 Covariances Between Variables

Interpreting the model requires an understanding of the fundamental elements of

confirmatory factor analysis (CFA). Latent variables are inferred from observable variables, which are openly measurable components like survey questions, but are abstract ideas like performance expectancy and attitude that cannot be measured directly. Rectangles in the model represent observable variables, whereas ellipses represent latent variables. linkages within the model are depicted by arrows; single-headed arrows highlight proposed causal linkages between latent variables, while standardized regression coefficients ( $\beta$ -values) reflect the direction and intensity of effect. Double-headed curving arrows, on the other hand, show correlations without suggesting a cause-and-effect relationship.

Error terms (e1 to e26), which represent the percentage of variation in an observed variable that cannot be explained by its latent variable, are another crucial component. Lastly, factor loadings measure the relationship between a latent construct and an observable variable. Gaining knowledge of these components facilitates the efficient analysis of CFA models and the understanding of variable interactions.

Figure 4.7 represents a structural equation modeling (SEM) framework, specifically illustrating a CFA that explores the relationships between latent constructs and their corresponding observed indicators. The primary purpose of this CFA is to assess how well the observed indicators represent their respective latent variables. The latent variables are represented by ellipses and capture key constructs in the model. PE reflects the belief that using BIM will improve performance and is measured by four indicators (PE1 to PE4). EE represents the perceived ease of BIM use, evaluated by two indicators (EE1, EE2), while SI captures the influence of others' opinions on BIM adoption, measured by three indicators (SI2 to SI4). FC assess the availability of organizational and technical support for BIM, with three indicators (FC1 to FC3). PC reflects the financial cost of BIM adoption, represented by five indicators (PC1 to PC5), while AT measures feelings toward BIM, based on three indicators (AT1 to AT3). GG explores generational differences in BIM adoption, measured by three indicators (GG1 to GG3), and BI captures the intention to adopt BIM through three indicators (BI1 to BI3). Observed variables, depicted as rectangles, are measured through surveys, and factor loadings indicate the strength of the relationship between latent and observed variables.

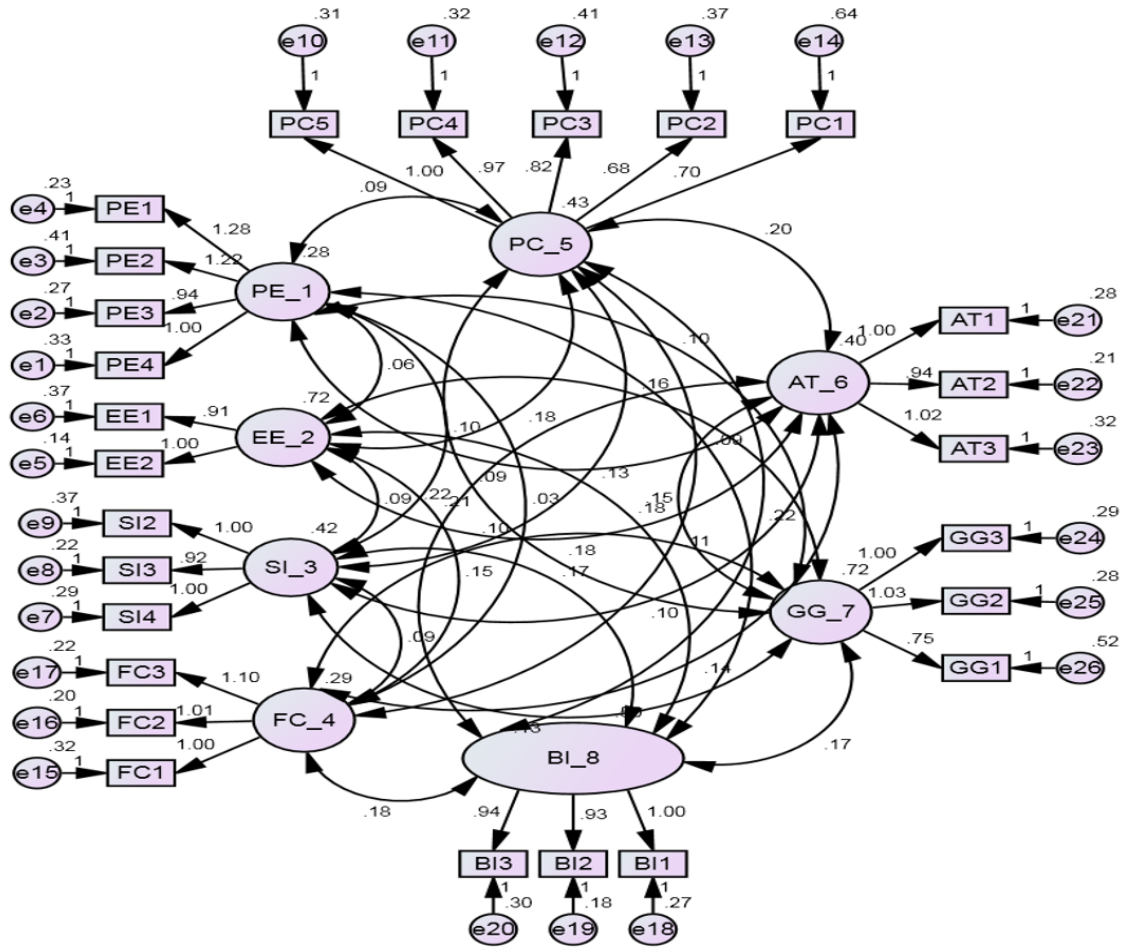


FIGURE 4.7: CFA Complete Model.

The strength and direction of links between latent constructs are shown by the numerical values linked to these linkages. A number of significant covariances between independent latent variables are noted. There is a large positive connection between (PE↔EE=0.72), indicating that those who think highly of the system also typically find it easy to use. A moderate association between (PE↔SI=0.42) suggests that social influence and performance expectancy are related. (PE↔FC=0.29) shows a lesser connection, suggesting that performance expectancy and facilitating conditions have a limited relationship. Social influence and facilitating conditions also interact to some extent (SI↔FC= 0.09), while effort expectancy and social influence have a modest relationship (EE↔SI= 0.22). The modest connection between (PC↔AT=0.43) indicates that attitudes toward system utilization are influenced by perceived cost. AT and GG have a comparatively substantial association (0.20), indicating that generation gap and attitude have a significant

impact on one another. Generation gap have a limited direct influence on behavioral intention, nevertheless, as seen by the lesser connection between (GG↔BI =0.17). The structural linkages that lead to the dependent variable BI is examined and it is shown that FC has a lesser direct effect (0.18) on BI, indicating that facilitating conditions only marginally affect behavioral intention. Although it has little direct influence on behavioral intention, AT also contributes to BI (0.40). In a similar vein, GG has a negligible impact on BI (0.17), indicating that although generational gap is important, they do not dominate behavioral intention.

In summary, this CFA model provides a visual representation of the correlations between various components as well as the links between observable indicators and their latent structures. A useful tool for theory testing and validation in structural equation modeling (SEM), the factor loadings and covariance offer important insights into the model's validity and measurement reliability.

## 4.8 Summary of Accepted and Rejected Hypotheses

This study rigorously tested proposed hypotheses through a systematic protocol, utilizing a tailored questionnaire to gather data from respondents. The gathered data underwent various statistical analyses using SPSS and AMOS software, which confirmed predictions made by the hypotheses. The empirical findings strongly supported all the hypotheses, resulting in their acceptance or rejection.

### 4.8.1 H<sub>1</sub>: Performance Expectancy Plays a Pivotal Role in Influencing Individuals' Behavioral Intention to Adopt BIM

The Performance expectancy (PE) construct is very reliable, as demonstrated by the Cronbach's Alpha of 0.814, reflecting good internal consistency. Descriptive

statistics indicate a mean of 4.22, implying that participants generally agree that BIM adoption will enhance their performance. Regression analysis further confirms this positive relationship, with PE having a significant effect on BI ( $\beta = 0.207$ ,  $p = 0.000$ ). However, the  $R^2$  value of 0.043 suggests that PE explains only 4.3% of the variance in BI, indicating that while the effect is statistically significant; its magnitude is relatively modest. Moreover, the correlation between PE and BI (0.207) is statistically significant at the 0.01 level, further substantiating the connection between these variables. Overall, the hypothesis is supported, affirming that performance expectancy plays a vital, though limited, role in influencing BI (behavioral intention) to adopt BIM.

#### **4.8.2 H<sub>2</sub>: Effort Expectancy Positively Impacts Individuals' Behavioral Intention to Use BIM**

The Effort expectancy (EE) construct demonstrate strong reliability, reflected in a Cronbach's Alpha of 0.836, indicating strong internal consistency. Descriptive statistics show a mean score of 4.03, suggesting that participants generally perceive BIM as relatively easy to use. Regression analysis reveals a significant positive effect of EE on BI, with a  $\beta$  value of 0.249 and a p-value of 0.000. However, the  $R^2$  value of 0.062 indicates that EE explains only 6.2% of the variance in BI, implying a modest effect size. Furthermore, the correlation between EE and BI is 0.249, statistically significant at 0.01 levels, further supporting the positive relationship. In conclusion, although effort expectancy significantly influences BI, its overall impact is relatively modest.

#### **4.8.3 H<sub>3</sub>: Social Influence Will Exert a Positive Influence on the Individual's Behavioral Intention to Use BIM**

The Behavioral intention (BI) is positively supported by social influence (SI) to adopt BIM. The SI variable demonstrates high reliability, with a Cronbach's Alpha of 0.798. Descriptive statistics suggest a mean value of 4.21, reflecting a favorable

perception of social influence among respondents. Regression analysis confirms a significant favorable impact of SI on behavioral intention ( $\beta=0.297$ ,  $p=0.000$ ), accounting for 8.8% of the variance in BI ( $R^2 = 0.88$ ). Additionally, the relationship between SI and BI is significant at the 0.01 level ( $r=0.297$ ), further highlighting the strength of this relationship. In summary, social influence has a more substantial impact than both PE and EE in influencing individuals' behavioral intention to adopt BIM technology.

#### **4.8.4 H<sub>4</sub>: Facilitating Conditions Positively Influence Individuals' Usage and Learning Behavior in the Context of BIM Adoption**

In the current study, the data strongly supports the role of facilitating conditions. The facilitating conditions (FC) variable demonstrates good reliability, with a Cronbach's Alpha of 0.791, indicating solid internal consistency. Descriptive statistics reveal a mean value of 4.06, suggesting that respondents generally agree that the necessary conditions for BIM adoption are in place. Regression analysis reveals a strong positive correlation between FC and BI ( $\beta = 0.385$ ,  $p = 0.000$ ), accounting for 14.8% of the variance in BI ( $R^2 = 0.148$ ), which is considered moderate compared to other factors. Additionally, the correlation between FC and BI is 0.385, significant at the 0.01 level, further strengthening the relationship. Overall, FC plays a crucial and moderately strong role in influencing behavioral intention towards BIM adoption.

#### **4.8.5 H<sub>5</sub>: Perceived Cost Negatively Affects Individuals' Behavioral Intention to Adopt BIM**

The findings do not support the hypothesis that perceived cost (PC) negatively affects individuals' behavioral intention to adopt BIM. However, the perceived cost variable shows strong reliability, with a Cronbach's Alpha of 0.783, indicating high internal consistency. Descriptive statistics show a mean of 3.99, suggesting that

respondents have a neutral to slightly negative perception of BIM's cost. However, regression analysis reveals a significant favorable relationship between PC and BI ( $\beta = 0.383$ ,  $p = 0.000$ ), explaining 14.6% of the variance in BI ( $R^2 = 0.146$ ). This contradicts the initial hypothesis of a negative effect, suggesting a more complex relationship or a possible mis-specification in the hypothesis. The positive correlation between PC and BI (0.383, significant at the 0.01 level) further reinforces this unexpected finding. In conclusion, perceived cost appears to positively influence behavioral intention, prompting a need for re-evaluation or further exploration of the original hypothesis.

#### **4.8.6 H<sub>6</sub>: Individuals' Attitude has a Positive Impact on Behavior to Adopt BIM Technology**

The hypothesis suggests that individuals' attitudes positively influence their behavior towards BIM adoption is strongly supported by the statistical findings. The attitude (AT) variable has a Cronbach's Alpha of 0.814, indicating high internal consistency. Descriptive statistics show a mean of 4.15, indicating that respondents had a good view regarding BIM. Regression analysis further reinforces this, with attitude showing a significant positive effect on behavioral intention ( $\beta = 0.442$ ,  $p = 0.000$ ), explaining 18% of the variance in behavioral intention ( $R^2 = 0.180$ ), which is the highest among all factors analyzed. Additionally, the correlation between AT and BI is 0.442, significant at the 0.01 level, confirming a strong relationship. In conclusion, attitude plays the most substantial role in influencing behavioral intention to adopt BIM technology.

#### **4.8.7 H<sub>7</sub>: A Negative Correlation Exists Between Generation Gap and User Behavior in the Context of BIM Technology Adoption**

The hypothesis suggesting a negative correlation between the generation gap and user behavior in adopting BIM technology is not supported by the statistical ana-

lysis. The generation gap (GG) variable demonstrates good reliability with a Cronbach's Alpha of 0.826. Descriptive statistics indicate a mean of 3.99, showing that generational differences are moderately perceived by respondents. Regression analysis shows a positive correlation between GG and behavioral intention ( $\beta = 0.263$ ,  $p = 0.000$ ), accounting for 6.9% of the variance ( $R^2 = 0.069$ ). Furthermore, the correlation between GG and BI is 0.263, statistically significant at the 0.01 level, contradicting the idea of a negative connection. Finally, the hypothesis is not supported since the generation difference has a positive rather than a negative impact on behavioral intentions toward BIM adoption.

#### 4.8.8 H<sub>8</sub>: Behavioral Intention Can Increase an Individual's Inclination Toward BIM Technology

The hypothesis that behavioral intention increases an individual's inclination toward adopting BIM technology is well-supported by both correlation and regression analyses. Behavioral intention (BI) is positively and significantly correlated with all other variables in the model. The reliability of the BI scale is high, with a Cronbach's Alpha of 0.846, further reinforcing this hypothesis. In addition, the model fit indices from the CFA (confirmatory factor analysis) demonstrate a good overall fit, with key values such as  $RMSEA = 0.042$ ,  $CFI = 0.953$ , and  $NFI = 0.876$ , confirming the structural validity of the relationships between BI and other factors. In conclusion, the hypothesis is supported, indicating that a higher behavioral intention is strongly linked to an increased likelihood of adopting BIM technology.

Table 4.6 shows the summaries form of the Accepted/rejected hypothesis.

TABLE 4.6: Hypothesis Acceptance/Rejection.

| Hypothesis | Statement   | Status          |
|------------|---|-----------------|
| H1         | PE plays a pivotal role in influencing IB intention to adopt BIM. | <i>Accepted</i> |

Table 4.6: (Continued).

| <b>Hypothesis</b> | <b>Statement</b>  | <b>Status</b>   |
|-------------------|---|-----------------|
| H2                | EE positively impacts individuals' behavioral intention to use BIM.                                   | <i>Accepted</i> |
| H3                | SI will exert a positive influence on the individual's BI to use BIM.                                 | <i>Accepted</i> |
| H4                | FC positively influences individuals' usage and learning behavior in the context of BIM technology.   | <i>Accepted</i> |
| H5                | PC negatively affects individuals' BI to adopt BIM.   | Rejected        |
| H6                | Individuals' AT has a positive impact on behavior to adopt BIM technology.                            | <i>Accepted</i> |
| H7                | A negative correlation exists between GG and user behavior in the context of BIM technology adoption. | <i>Rejected</i> |
| H8                | BI can increase one individual's inclination toward BIM technology.                                   | <i>Accepted</i> |

# Chapter 5

## Conclusion and Recommendations

This chapter provides a summary of the analysis, conclusions, and recommendations for future research. It provides an in-depth analysis of the study's insights and offers recommendations for future research. Additionally, it presents a detailed discussion of the theoretical implications, strengths, limitations, and practical suggestions derived from this research.

### 5.1 Strength of the Research

This research presents a comprehensive analysis of the barriers and facilitators influencing the adoption of BIM (building information modeling) in construction sector, focusing specifically on the Pakistani context. It makes a significant contribution by addressing a critical research gap, going beyond general observations of slow BIM adoption to explore localized challenges using a modified UTAUT model. By incorporating BIM-specific variables such as perceived cost (PC), generation gap (GG), and attitude (AT) with traditional UTAUT constructs—performance expectancy (PE), effort expectancy (EE), social influence (SI), and facilitating conditions (FC)—the study provides a nuanced framework to explain the behavioral intention (BI) toward BIM adoption.

The empirical results highlight several key findings. The analysis reveals that attitude (AT) has the strongest positive influence on behavioral intention ( $\beta = 0.442$ ), underscoring the importance of personal attitudes in shaping technology adoption. Similarly, facilitating conditions ( $\beta = 0.385$ ) and social influence ( $\beta = 0.297$ ) emerge as significant drivers, emphasizing that both external support and social dynamics play pivotal roles in encouraging BIM adoption. Although performance expectancy (PE) and effort expectancy (EE) are statistically significant, their influence is modest compared to other variables. An unexpected finding is the positive impact of perceived cost on behavioral intention ( $\beta = 0.383$ ), which challenges the initial hypothesis that high costs would serve as an obstacle. This suggests that stakeholders (engineers, clients, contractors, project managers) may perceive BIM as a worthwhile investment despite its initial expenses, possibly due to its long-term benefits for project efficiency and outcomes.

The study's methodological rigor is another key strength. It employs regression and correlation analysis along with model fit testing (RMSEA, CFI), ensuring the accuracy and reliability in hypotheses validation. Cronbach's Alpha is used to evaluate internal consistency further strengthens the research, with all variables exceeding the acceptable threshold of 0.7, confirming reliability. The sample size of 294 respondents, acquired from various stakeholders (engineers, clients, contractors, project managers) within the construction sector, enhances the study's external validity, ensuring the findings are applicable across similar contexts.

The multi-level analysis, which examines both individual and organizational factors provide a thorough understanding of variables affecting the adoption of BIM, reflecting the complexity of the construction sector of Pakistan. The research also offers practical recommendations for construction industry including policymakers to address the identified barriers and the promote BIM adoption. These recommendations are crucial for fostering collaboration, overcoming resistance, and enhancing efficiency in construction projects.

The research also offers practical recommendations for stakeholders, including policymakers and construction firms, to address the identified barriers and the promote BIM adoption. These recommendations are crucial for fostering collaboration, ove-

coming resistance, and enhancing efficiency in construction projects. For instance, addressing generational gaps through targeted training programs and reducing cost-related concerns through policy interventions could significantly accelerate the BIM adoption.

In summary, the current study not only fills a significant research gap by providing localized insights into BIM adoption in Pakistan but also offers a robust and modified UTAUT model that can serve as a framework for future research in similar settings. The findings highlight the importance of attitude (AT), social influence (SI), and facilitating conditions (FC) in driving BIM adoption, while challenging assumptions about the negative impact of perceived cost. The study's broad scope, methodological rigor, and practical relevance make it a valuable resource for stakeholders seeking to improve project outcomes through the effective adoption of BIM technology.

## **5.2 Limitations of the Research**

Despite its strengths, this study has several limitations that must be acknowledged. One key limitation is its geographical focus on Pakistan, which means this study may not be entirely relevant to other regions or countries with differing socio-economic and cultural contexts. Furthermore, the research employs a cross-sectional design, gathering data at a single point in time. This limits the ability to observe changes in attitudes or behaviors over time and presents challenges in establishing causal relationships. Another limitation is the potential for response bias, as the data relies on self-reported responses. Participants may over-report favorable attitudes toward BIM adoption due to social desirability or other biases, possibly compromising the findings' accuracy. Although the study customizes UTAUT model with additional variables, such as perceived cost, generation gap, and attitude, it still excludes other industry-specific challenges, such as the regulatory environment, project complexity, and client requirements. Including these variables could have provided a more comprehensive understanding of the BIM adoption barriers.

The study also excludes qualitative data, relying solely on quantitative methods, which limits the depth of insights. Incorporating qualitative approaches, such as interviews or case studies, could have enriched the understanding of contextual challenges faced by construction industry of Pakistan in adopting BIM. Furthermore, the research does not capture the longitudinal impact of BIM adoption, which is often a gradual process influenced by evolving factors, including technological advancements and changes in organizational practices. Without longitudinal data, it becomes difficult to analyze how these factors might shape adoption behavior over time.

These limitations highlight areas for future research, such as conducting studies in different regions, incorporating qualitative data, or adopting a longitudinal design to better understand the evolving nature of BIM adoption.

### 5.3 Conclusion

This research provides a valuable framework for understanding the adoption of BIM (building information modeling) in the Pakistani construction sector through the application and modification of the UTAUT model. The findings emphasize the importance of both individual and organizational factors in shaping stakeholders' behavioral intentions toward BIM adoption. The Key barriers identified include perceived cost (PC) and the generation gap (GG), while facilitators such as organizational support and performance expectancy (PE) positively impact behavioral intention (BI). These findings suggest the need for organizations to reduce cost perceptions through targeted training programs. The study highlights the critical role of organizational support and individual attitudes in driving BIM adoption. Facilitating conditions (FC) and attitude (AT) play pivotal roles, suggesting that firms must actively promote positive attitudes toward new technologies while ensuring adequate support structures. The regression analysis further supports these conclusions, with attitude emerging as the most influential factor ( $\beta = 0.442$ ,  $p < 0.01$ ), followed closely by perceived cost ( $\beta = 0.383$ ,  $p < 0.01$ ). These findings demonstrate that beyond ease of use, stakeholders' attitudes and cost perceptions

are decisive factors in the decision-making process. Although performance expectancy (PE) and effort expectancy (EE) contribute to the BIM adoption, their impact is relatively modest compared to other factors, such as social influence (SI) and attitude (AT).

The study also validates the modified UTAUT model by integrating BIM-specific variables like perceived cost, attitude, and generation gap, proving the model's relevance in explaining BIM adoption for the construction sector. The model fit indices (RMSEA = 0.042, CFI = 0.953) confirm the robustness of the framework. These findings reveal complex and sometimes counterintuitive relationships among the variables, such as the unexpected positive impact of perceived cost on behavioral intention.

The research underscores the need for policy interventions to address these unique challenges in the Pakistani construction industry. In conclusion, this study offers practical insights and a reliable framework for understanding BIM adoption. It also demonstrates that attitude, social influence, and facilitating conditions are key drivers along with the cost perceptions playing a more complex role than initially expected.

## 5.4 Future Recommendations

A number of suggestions are made for future research and industry practices in order to improve the adoption of BIM and tackle the issues that have been found, based on the results of the current study.

- One key area for future exploration is the unexpected positive relationship between perceived cost (PC) and behavioral intention (BI). Further research may investigate whether stakeholders (engineers, clients, contractors, project managers) view the perceived cost as investment that yields long-term benefits or other unmeasured factors influence this perception.
- To gain broader insights, future research may incorporate qualitative methods such as stakeholder (engineers, clients, contractors, project managers) intervi-

ews to capture insights beyond quantitative data. Exploring the role of external stakeholders (regulatory authorities, consultant, financial institutions, insurance companies, legal and contractual advisors) and the impact of emerging technologies like building information modeling (BIM) will provide a more comprehensive awareness of the deployment of BIM and support effective integration of innovations into practice.

- From a policy perspective, reducing cost barriers through governmental support and industry incentives are crucial in promoting BIM adoption. Policymakers and industry leaders may collaborate to subsidize implementation costs, making the technology more accessible to construction industry of Pakistan.
- By highlighting BIM's everlasting advantages and successful case studies, engineering firms may encourage favorable attitudes about the technology. One way to change the view of cost from one of a burden to one of a value-driven opportunity is to frame BIM as a strategic investment.
- Engage early adopters and influential team members to advocate for BIM and inspire broader acceptance. Leadership endorsement and peer support can foster a collaborative culture that reinforces BIM's value and relevance.
- "Attitude" is the strongest driver of BIM adoption, authorities (like DHA, RDA, and NHA) should promote BIM through policy endorsements, public project success stories, and potential mandates. They should also ensure that contractors and consultants meet requirements for BIM infrastructure, technical support, and trained staff, reinforcing the importance of 'Facilitating Conditions'.
- Adopt BIM within DHA/NHA/RDA's own design review, project management, and facility management processes to showcase organizational commitment and strengthen internal capabilities.

## 5.5 Future Directions

This research presents an efficient and reliable methodology. Future studies could

explore the adoption of BIM technology through a broader range of questions and diverse approaches. The current study focuses on specific regions with distinct cultural contexts, which may limit the generalization of the findings to other cultures or populations. Variations in users' perceptions and behaviors across different settings may yield different outcomes.

Future research should explore the unexpected positive relationship between perceived cost and behavioral intention to determine if it reflects perceptions of long-term investment or other influencing factors. Generation-specific interventions, such as tailored training programs are needed to bridge the generational gap and facilitate smoother technology adoption. Incorporating qualitative methods, including stakeholders (engineers, clients, contractors, project managers) interviews, would uncover deeper insights into barriers and facilitators that may or may not emerge through quantitative data. Longitudinal research and comparative studies across regions could provide broader, evolving insights, helping refine strategies to enhance BIM integration.

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# Appendix A

The appendix portion contains the questionnaire of the research. The collection of responses is taken out through Google Forms source and participants fill out the questionnaire online. The questionnaire contains two main sections first is related to demographics and the second section contains twenty six constructs of eight variables named Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Facilitating Condition (FC), Perceived Cost (PC), Attitude (AT), Generation Gap (GG ) and Behavioral Intention (BI).

## Section-I

Please tick (✓) in the box for the appropriate answer.

Gender

Male

Female

Age (in years)

Below 25

25-30

30-40

Above 40

Qualification / Education

Matric / O-level or equivalent

|                       |                                      |                          |
|-----------------------|--------------------------------------|--------------------------|
|                       | Intermediate / A-level or equivalent | <input type="checkbox"/> |
|                       | Bachelor or equivalent               | <input type="checkbox"/> |
|                       | Masters / M.Phil or equivalent       | <input type="checkbox"/> |
|                       | Ph.D                                 | <input type="checkbox"/> |
| Designation           |                                      |                          |
|                       | Project Manager                      | <input type="checkbox"/> |
|                       | Engineer Manager                     | <input type="checkbox"/> |
|                       | Project Leader                       | <input type="checkbox"/> |
|                       | Team Leader                          | <input type="checkbox"/> |
|                       | Engineer                             | <input type="checkbox"/> |
|                       | Advisor and Expert                   | <input type="checkbox"/> |
|                       | Supervisor                           | <input type="checkbox"/> |
| Experience (in years) |                                      |                          |
|                       | Less than 5                          | <input type="checkbox"/> |
|                       | 5-10                                 | <input type="checkbox"/> |
|                       | 11-15                                | <input type="checkbox"/> |
|                       | 16-20                                | <input type="checkbox"/> |
|                       | 21-25                                | <input type="checkbox"/> |
|                       | Above 25                             | <input type="checkbox"/> |

## Section-II

Instructions: Please rate each statement below based on your level of agreement using a 5-point Likert scale, where: **1 - Strongly Disagree 2 - Disagree 3 - Neutral 4 - Agree 5 - Strongly Agree**

| Sr. | Var. | Questions  | 1 | 2 | 3 | 4 | 5 |
|-----|------|--|---|---|---|---|---|
| 1   | PE1  | The use of Building Information Modeling (BIM) will enhance your job performance.  |   |   |   |   |   |
| 2   | PE2  | The BIM technology offers relatively better advantages as compared to the traditional methods used in construction industry. |   |   |   |   |   |

- 
- |    |     |  |
|----|-----|--|
| 3  | PE3 | The BIM technology is compatible with the tasks you undertake at work.   |
| 4  | PE4 | The utilization of BIM technology may contribute to the overall performance of the organization.   |
| 5  | EE1 | Does it require extensive efforts to become proficient in using BIM?   |
| 6  | EE2 | The complexity of BIM technology affects the willingness to adopt it for construction projects.  |
| 7  | SI2 | The opinions of key individuals in the organization influence the intention to use BIM technology.   |
| 8  | SI3 | The increasing trend, promotion, and popularization of BIM technology in construction industry inspired you to learn BIM tech.                             |
| 9  | SI4 | The involvement of stakeholders and effective communication about the application of BIM could enhance the organization's intention to use BIM technology. |
| 10 | FC1 | Do you think that your organization provides adequate technical support for using BIM technology?  |
| 11 | FC2 | According to your experience, to what extent the facilitating conditions influence your intention to use BIM technology?                                   |
| 12 | FC3 | The presence of organizational and technical support significantly influences the usage and learning behavior towards BIM technology.                      |
| 13 | PC1 | The set-up cost of BIM software is too high and creates financial barriers.  |
| 14 | PC2 | The perceived cost of BIM technology influe-   |

- 
- nces the intention to adopt it.
- 15 PC3 You may be willing to purchase BIM software if its prices are reduced.
- 16 PC4 The overall perceived cost of BIM adoption could impact the end-user product/service/-facility.
- 17 PC5 The overall perceived cost significantly influences an organization's intention and decision to adopt BIM technology.
- 18 AT1 The BIM technology is beneficial in performing your professional activities.
- 19 AT2 Your perception towards BIM technology influences your actual behavior in adopting it.
- 20 AT3 It is more likely to adopt BIM technology if its learning is facilitated by the organization.
- 21 GG1 Do you feel that you are more familiar and comfortable while using BIM as compared to your colleagues having the same age and experience?
- 22 GG2 The age and experience influence one's willingness to adopt new technologies like BIM.
- 23 GG3 The older workers in your organization are reluctant to embrace new technologies like BIM as compared to the younger workers.
- 24 BI1 Do you intend to start/continue learning and working on BIM technology in the future?
- 25 BI2 The organizational support and leadership endorsement influence your intention of BIM adoption.
- 26 BI3 The effort, performance expectancy, social influence, and learning attitude influence the intention and decision to learn and adopt BIM.
-