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# A Literature Review of Technology Adoption theories and Acceptance models for novelty in Building Information Modeling

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## Abstract

Building Information Modeling (BIM) is the backbone of the Architecture, Engineering, and Construction (AEC) industry. BIM is the collection of Information and Communication Technologies (ICT), interacting policies, and procedures. BIM generates a methodology to manage the project data in digital format throughout the building's life-cycle. Despite the numerous benefits and features of BIM, its proliferation remains limited and facing adoption issues. Although many existing studies discussed BIM adoption from contextual lenses, discipline-focused, there is still a scarcity of a comprehensive overview of technology adoption models and frameworks in BIM research. The purpose of this Systemic Literature Review (SLR) is to evaluate the current status of BIM adoption, technology acceptance theories, models used and find the research challenges. Furthermore, to identify the roles of independent constructs, dependent construct, moderators, and mediators in BIM adoption research. Also, the findings provide an in-depth description of the different stages of BIM adoption. Finally, this SLR will help the researchers for further research in the field of BIM adoption.

**Keywords:** Building Information Modeling (BIM), Systematic Literature Review (SLR), Technology acceptance, BIM Adoption.

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## Introduction

The construction sector's key challenges are automation, digitization, competitive pressure, and greater value for capital. A competitive advantage is achieved through collective project execution and information processing (Akdogan, 2020; Shehzad et al., 2020). BIM facilitates design preparation, 3D modeling, simulation, risk assessment, environmental analysis, site control, project control, identification, and collision detection (Al-Hammadi & Tian, 2020; Shehzad et al., 2021). BIM is the use of a shared digital representation of a built environment data to facilitate the whole construction activity from design to model, model to schedule, schedule to estimate, estimate to construct, and construct to deliver the project by generating a methodology for managing the project data in digital format throughout the building's life-cycle (ISO, 2016; Park, Kwon, & Han, 2019; Shehzad et al., 2021). BIM is a set of related policies, processes, and ICT technologies that help construction activities during the project's life cycle and incorporate data contributions from all project teams (Grilo & Jardim-Goncalves, 2010). Construction design, 3D modeling, simulation, cost estimating, forensic analysis, collision detection, building maintenance, project management, and fabrication are areas where BIM is used (Georgiadou, 2019; Muhammad et al., 2020).

The primary capability of BIM provides collaboration and information integration between all the construction project stakeholders (Juan, Lai, & Shih, 2017; Shehzad et al., 2021). The successful BIM implementation is used to enhance the stakeholder's capabilities for managing and planning construction activities (Mahamadu, Mahdjoubi, & Booth, 2014). Existing studies in this area identify BIM awareness in different countries, BIM diffusion, identification of influencing factors on BIM adoption, and BIM adoption level (Akdogan, 2020; Lee & Yu, 2015). Other current studies on understanding the Intention to use BIM and motivations for adopting BIM (Ahmed & Kassem, 2017; Shehzad et al., 2019). These existing studies provide valuable insight into the BIM adoption process. Hence, there is limited use of technology adoption theories and models in existing studies. Technology adoption is the acceptance and use of new technology. Researchers use technology acceptance theories such as diffusion of innovation and the Technology acceptance model to examines the technology adoption process.

However, the actual benefits of BIM are not yet realized due to the low adoption of professionals. For that purpose, there is a need for adoption studies that focus on understanding, predicting, and finding the influencing factors at organizational and individual levels. A compressive analysis of the existing technology acceptance theories and models is needed to understand the BIM adoption phenomena better. Consequently, this Systematic Literature Review (SLR) objective is to provide a detailed explanation of BIM adoption research. Also, it is intended to describe the technology acceptance theories and models used in previous studies for highlighting the adoption process from an information system perspective. The contributions of this SLR are defined as given below:

- To identify the technology adoption theories/models used for the BIM adoption.
- To categorize independent constructs, dependent construct, moderators, and mediators in BIM adoption research.
- To provide an in-depth description of different stages of the BIM adoption process.

This SLR is organized as follows: Literature review section discusses the related works and existing studies. The systemic literature review protocols and methodologies are explained in the methodology section. The findings and analysis section provides the results of the study. The overall summary of the SLR is presented in the discussion and conclusion sections.

## Literature Review

In this section, we review and analyze the existing literature reviews and survey for BIM adoption. BIM adoption is a complex phenomenon, and several studies investigated BIM adoption between 2013 and 2019; few literature reviews are published (Gamil & Rahman, 2019; Moreno, Olbina, & Issa, 2019; Olawumi & Chan, 2019). Ahmed and Kassem (2018) investigate the existing adoption studies and proposed a conceptual model to identify factors affecting BIM adoption. Another study identifies adoption drives and factors while categorizing them into three groups (Chan, Olawumi, and Ho, 2019). These three groups include innovation characteristics, internal environment characteristics, and external environment characteristics. A study on BIM conceptual constructs, discusses many BIM adoption stages, for example, the BIM readiness stage, BIM implementation stage, BIM adoption stages, and BIM diffusion stage (Ahmed & Kassem, 2018). These terms are confused in literature and need to be clarified and defined. Drivers of BIM adoption are categorized into three clusters: the BIM innovation cluster, external environments cluster, and internal environment cluster collectively called adoption taxonomy. This division helps identify adoption factors and determinants as micro-level, macro-level, and meso-level. Another study finds limited BIM adoption inhibitors and categorized the negative elements into five dimensions. technology dimension, legal dimension, cost dimension, personnel dimension, and management dimension (Jiang et al., 2017). It highlights the factors that negatively affect BIM adoption.

Similarly, from a technology adoption perspective studies include, assessing motivations for adopting BIM, understanding Intention to use BIM, factors effect on BIM adoption, BIM diffusion, BIM awareness in developing countries, and level of BIM adoption. Similarly, the studies investigate external environmental factors that affect BIM diffusion using institutional theory (Delgado et al., 2017; Ghaffarianhoseini et al., 2017; Hosseini et al., 2019). It categorized the factors into coercive pressure, normative pressure, and mimetic pressure. Similarly, a conceptual model of factors proposed examines BIM adoption with limited technology acceptance theories (Succar & Kassem, 2015). Another study categorizes factors into external environment characteristics, internal environment characteristics, and innovation characteristics (Ahmed et al., 2017). A BIM conceptual construct survey is done to clarify the stages of BIM adoption as diffusion stage, implementation stage, and readiness stage and to assess macro-level BIM adoption (Succar and Kassem, 2015). Similarly, BIM inhibitors are categorized as management dimension, personnel dimension, cost dimension, legal dimension, and technology dimension with limited utilization of technology adoption concepts (Ahmed et al., 2017).

It is evident from the studies that BIM adoption and awareness are discussed in general with limited technology adoption theories and models. Additionally, a comprehensive review and detailed understanding of adoption processes are missing. In contrast to existing studies addressing barriers and factors, this review provides a more comprehensive overview of BIM adoption studies from an information system perspective in light of technology acceptance models and theories. Furthermore, it identifies the roles of independent constructs, dependent constructs, moderators, and mediators used by researchers. This review's other contribution is the categorization of research based on technology adoption processes such as BIM perceptions, BIM readiness, BIM acceptance, BIM adoption, BIM Implementation, and BIM diffusion. This SLR is intended to form the basis for future research in the BIM adoption domain.

## Methodology

The research methodology consists of guidelines to follow for systematically planning and analyzing the studies. The research methodology guides this study for conducting SLR by (Kitchenham & Charters, 2007). The review starts with defining the research questions. The questions for this SLR are (1) What are the Technology adoption Models/frameworks used in Building Information Modeling (BIM) research, (2) How technology adoption theories penetrate in BIM adoption, (3) What are research gaps in BIM adoption research. (4) How technology adoption theories penetrate in BIM research, as shown in Table 2. The second step is the selection of a database for articles. The databases selected for this SLR are Wiley Online Library, Scopus, Taylor & Francis, Google Scholar, Web of Science, and Science Direct, as shown in Table 1.

A detailed explanation of the research methodology is shown in Figure 1.This review covers the article publication period of 2013-2019. After article selection, duplicated studies are removed. The quality assessment, inclusion, and exclusion criteria are defined to ensure the reliability of the review. Only English language articles, available full length, published in selected time frames are included. Quality assessment is critical for ensuring the worthiness of selected studies (Khurshid et al., 2020; Kitchenham et al., 2009). Quality instruments are developed, consist of factors to be checked and verified by asking some questions for each study (Bandara, Miskon, & Fielt, 2011; Kitchenham et al., 2009). The questions described in Figure 1. are applied to 93 extracted studies to ensure the credibility of the article selected. The levels (Low, High, Medium) are assigned for quality schema, and each study depends on accumulated scores (Ali et al., 2020; Srinivas et al., 2012). For meeting full criteria, the study is given 2, for partial fulfillment 1, and if fulfillment 0 is assigned. After the accumulation of score studies, the total score of 5 or above is considered high. While studies having a score of 4 in total is medium and below four is low. Applying quality assessment resulted in 49 studies, while these studies are considered for full synthesis and data analysis. At this stage, data recording is done using excel sheets to record information appropriately and Mendeley's application as a reference manager. We adopted the framework proposed in existing studies for recording elements in BIM adoption research (Ahmed & Kassem, 2018; Khurshid et al., 2020). It includes study ID, author, year, country, and publisher, data analysis methods, adoption theories, and study level, factors. After that, the analysis is performed.

Table 1. Database for data extraction for BIM SLR

| **Database** | **URL** |
|---|---|
| Science Direct | http://www.sciencedirect.com/ |
| Springer | http://www.springer.com/ |
| Taylor & Francis | http://taylorandfrancis.com/ |
| Web of Science | https://apps.webofknowledge.com/ |
| Wiley Online Library | http://onlinelibrary.wiley.com/ |
| Scopus | https://www.scopus.com/ |

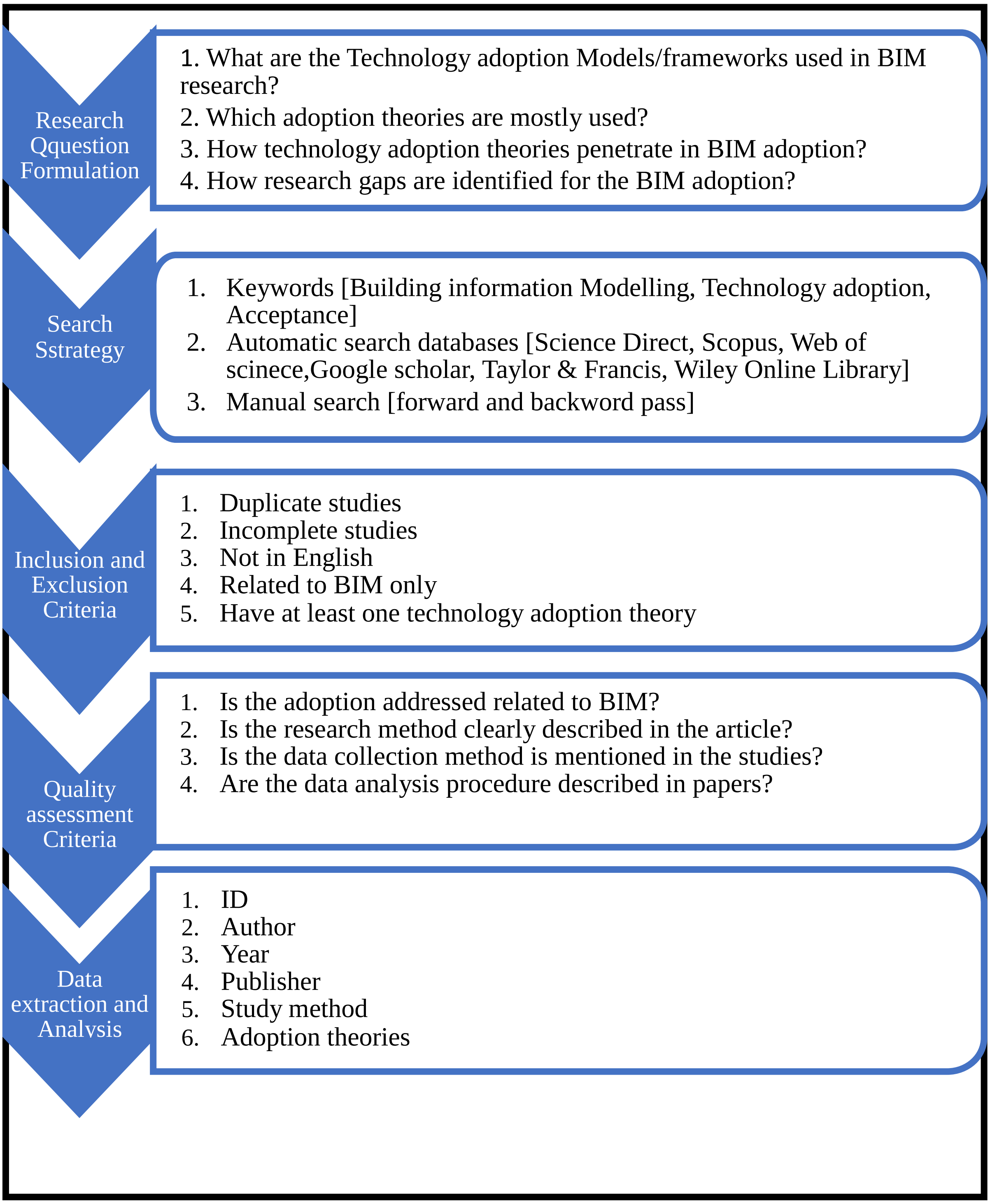


Figure 1. The Review Extraction Process

Table 2. Research Questions and research Motivation for BIM SLR

| Questions | Motivation |
|---|---|
| 1. What are the Technology adoption Models/frameworks used in Building Information Modeling (BIM) research? | 1. To identify the current use of information system models/frameworks in investigating BIM adoption. |
| 2. Which adoption theories are mainly used? | 2. To analyses the theories/models' strengths and limitations to address BIM adoption. |
| 3. How do technology adoption theories penetrate BIM adoption? | 3. To find the scope of information system theories/frameworks in BIM adoption research |
| 4. How are research gaps identify for BIM adoption? | 4. To identify the current challenges for the development of BIM adoption. |

# Findings and Analysis

## 1.1 Technology Adoption Theories in BIM adoption research

This section discusses the theories and models adopted in primary studies. Technology adoption is the acceptance and use of new technology. Studies on adoption focus on understanding, predicting, and finding the influencing factors at organizational and individual levels. Such research guided the development of frameworks and models to assess the use and influence of technology acceptance factors (Date, Gangwar, & Raoot, 2014). As shown in Table 3 and Table 4, most of the studies used the TAM and DOI to assess individuals and organizations' acceptance levels and diffusion levels. Subsequently, the most used theory is institutional theory. Other theories used in studies are the UTAUT, Technology Organization Environment frameworks (TOE), Theory of Reasoned Action (TRA), Information System Success Model (ISSM), Theory of Planned Behavior (TPB), and Institutional Theory. Also, a detailed list of comparison of adoption theories with references and comparison of the technology acceptance studies used in BIM research is shown in Table 5; the results indicate that 32% of the studies use TAM to assess the acceptance level of BIM in industries.

Similarly, the same trend is found for DOI as the second most used theory to assess the diffusion of BIM concerning technology adopters with technology attributes. Institutional Theory (INT) contributed to 15% of studies to find the effect of the external factors on BIM adoption. The TOE is at the fourth number to address the factors in technology, organization, and environmental dimension; however, using TOE compared to other theories is recoded low. On the other hand, few theories with limited use are the IS Success Model, TRA, and TPB. Other theories used with a combination of theories are TEDM, DTPB, Knowledge Management system (KMS), and Social network analysis (SNA) represent different aspects of BIM adoption.

Table 3. Technology Adoption Theories

| | **Theories** | **References** | **No of Articles** |
|---|---|---|---|
| 1 | TAM | (Davis, 1989) | 13 |
| 2 | DOI | (Rogers & Shoemaker, 1983) | 07 |
| 3 | UTAUT | (Venkatesh., Morris., Davis., & Davis., 2003) | 03 |
| 4 | TOE | (Tornatzky and Fleischer, 1990) | 05 |
| 5 | INT | (Scott, 2004) | 04 |

Table 4. Hybrid Technology Adoption Theories

| | **Theories** | **References** | **No of Articles** |
|---|---|---|---|
| 1 | TRA +DOI+TAM+TPB+UTAUT | (Fishbein & Ajzen, 1975) | 01 |
| 2 | ISSM+TAM | (DeLone & McLean, 1992) | 01 |
| 3 | TPB+TOE | (Ajzen, 1991) | 01 |
| 4 | DOI+TAM | | 06 |
| 5 | DOI+INT | | 06 |
| 6 | TAM+TOE | | 01 |

Table 5. Technology Adoption Theories

| Reference | DOI | INT | TAM | UTAUT | TPB | TOE | Others |
|---|---|---|---|---|---|---|---|
| (Yoon & George, 2013) | | | | | | ✔ | |
| (Gao, Li, & Tan, 2013) | ✔ | | ✔ | | | | TEDM |
| (Davies & Harty, 2013) | | | | ✔ | | | |
| (Tsai, Fang, & Chou, 2013) | ✔ | | ✔ | | | | |
| (Takim, Harris, & Nawawi, 2013) | | | ✔ | | | | |
| (Singh, 2013) | ✔ | | | | | | |
| (Enegbuma, Dodo, & Ali, 2014) | ✔ | | ✔ | ✔ | ✔ | | TRA, DTPB |
| (Mahamadu et al., 2014) | | | | ✔ | | | |
| (Miller, 2014) | | | ✔ | | ✔ | | |
| (Xu, Feng, & Li, 2014) | ✔ | | ✔ | | | | |
| (Cao, Li, & Wang, 2014) | | ✔ | | | | | |
| (L. Wu & Chen, 2014) | ✔ | | | | | | |
| (Oliveira, Thomas, & Espadanal, 2014) | ✔ | | | | | | |
| (Merschbrock & Munkvold, 2015) | | | | | | | |
| (Shibeika & Harty, 2015) | ✔ | | | | | | |
| (S. Lee, Yu, & Jeong, 2015) | | | ✔ | | | | |
| (Succar & Kassem, 2015) | ✔ | ✔ | | | | | |
| (Yalcinkaya & Singh, 2015) | ✔ | | | | | | |
| (Ramanayaka & Venkatachalam, 2015) | | | ✔ | | | | |
| (Hyojoo Son, Lee, & Kim, 2015) | | | ✔ | | | | |
| (Seed, 2015) | ✔ | | | | | | |
| (Fareed, Bazzoli, Mick, & Harless, 2015) | | ✔ | | | | | |
| (Babic & Rebolj, 2016) | | ✔ | | | | | |
| (Y. W. Wu, Wen, Chen, & Hsu, 2016) | | | ✔ | | | | |
| (Sherer, Meyerhoefer, & Peng, 2016) | | ✔ | | | | | |
| (Cao, Li, Wang, & Zhang, 2016) | ✔ | ✔ | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| (Ahuja, Jain, Sawhney, & Arif, 2016) | ✔ | ✔ | | | | ✔ | ✔ |
| (Hosseini et al., 2016) | ✔ | | | | | | |
| (Merschbrock & Nordahl-Rolfsen, 2016) | | | ✔ | | | | |
| (Kim, Park, & Chin, 2016) | ✔ | | ✔ | | | | |
| (Howard, Restrepo, & Chang, 2017) | | | | ✔ | | | |
| (Bosch-Sijtsema, Isaksson, Lennartsson, & Linderoth, 2017) | | | | | ✔ | ✔ | |
| (Kassem & Succar, 2017) | ✔ | ✔ | | | | | |
| (Juan et al., 2017) | | | ✔ | | | | KMS+BSC |
| (Lee,Yiu, & Cheung, 2018) | | | ✔ | | | | |
| (Lee & Yu, 2015) | | | ✔ | | | | IS success Model |
| (Cao, Li, Wang, & Huang, 2017) | ✔ | ✔ | | | | | |
| (Song, Migliaccio, Wang, & Lu, 2017) | ✔ | | ✔ | | | | |
| (Ahmed Louay Ahmed & Kassem, 2018) | ✔ | ✔ | | | | | |
| (Acquah, Eyiah, & Oteng, 2018) | | | ✔ | | | | |
| (D. Liu, Lu, & Niu, 2018) | | | ✔ | | | | |
| (Okakpu et al., 2018) | | | ✔ | | | | Social Network Analysis |
| (Hong & Yu, 2018) | | | ✔ | | | | |
| (Ahuja, Sawhney, Jain, Arif, & Rakshit, 2018) | | | | | | ✔ | |
| (Chen, Yin, Browne, & Li, 2019) | | | | | | ✔ | |
| (Park et al., 2019) | | | ✔ | | | | |
| (Mohammad, Abdullah, Ismail, & Takim, 2019) | | | | | | ✔ | |
| (Gong, Zeng, Ye, & König, 2019) | | | ✔ | | | ✔ | TPC(Technology-to-Performance) |
| (Ismail, Adnan, & Bakhary, 2019) | | | ✔ | | | | |

**Theory of Planned Behavior (TPB):** The theory of planned behavior declares that a person's Intention to do any act is based on individual attitude toward that action and perceived behavioral control and subjective norms, as shown in Figure 2. This theory provides a psychological model to study behavior. It explains that people have more control over behaviors that need less effort and resources than behaviors that require more effort (Salahshour, Nilashi, & Dahlan, 2017). Perceived behavioral control plays its role as a proxy to demonstrate the difficulty or easiness of doing a particular behavior (Ajzen, 1991).

**Technology Acceptance Model (TAM):** TAM is developed by Davis (1989) and is the most widely used acceptance model. It explains the role of attitude, Intention, behavior in accepting or rejecting technologies. According to this model, external variables influence Perceived Ease of Use and Perceived Usefulness and attitude. Attitude leads to behavioural Intention. Behavioral Intention influences actual use, as shown in Figure 3.

**The Unified Theory of Acceptance and Use of Technology (UTAUT):** UTAUT is the combination of eight theories, including TAM, TRA, Combined TAM, and DOI, to predict behavioral intentions to use technology, as shown in Figure 4. It is also a widely used theory as it contains elements from other theories also. However, it has some limitations and is revised by Venkatesh *et al.* (2003). This theory consists of seven components: facilitating conditions, social influence, performance expectancy, effort expectancy, behavioral Intention, and use behavior.

**Diffusion of Innovations (DOI):** The diffusion of innovation theory is proposed by Rogers & York (1995). This theory is based on the belief that innovation diffusion determinants are innovation attributes. The theory's construct includes observability, complexity, compatibility, trialability, and relative advantage, as shown in Figure 5.

**Technology Organization Environment Framework:** The innovation process at the enterprise level can be better described with the TOE (Tornatzky & Fleischer, 1990). The frameworks divide characteristics into three dimensions. First is the Technology dimension, second is organizational, and third is the environment. The technology dimension represents internal and external technologies, availability of technology, and technology characteristics, as shown in Figure 6. An environmental context consists of industry characteristics, the role of government, competition, and environment structure. In organizational context size, formal, informal structures, processes, and practices are included.

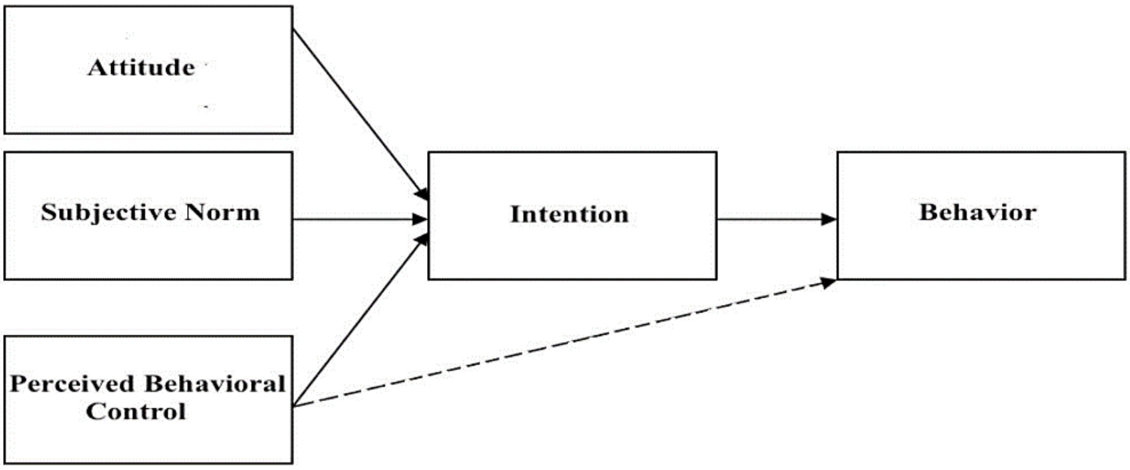


Figure 2. Theory of Planned Behaviour (Ajzen, 1991)

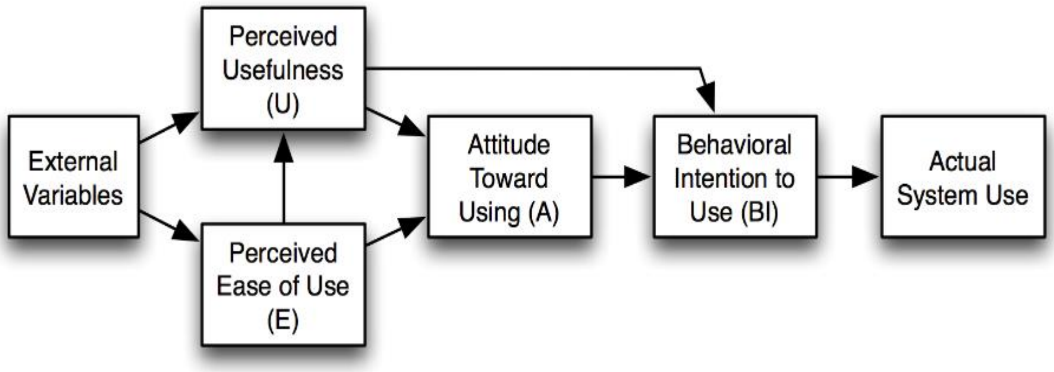


Figure 3. Technology Acceptance Model (Davis, 1989)

**Theory of Reasoned Action:** TRA is developed by Fishbein & Ajzen (1975), is a social science theory and is applied in many areas. The approach is used to find relationships of attitude and behaviour concerning human action. It measures how an individual behaves with existing behavioural Intention and attitude, as shown in Figure 7. The constructs of this theory are the attitude toward the act of behaviour and subject norm. Attitude and behaviour influence behavioural intentions and behavioural intentions influence actual behaviour.

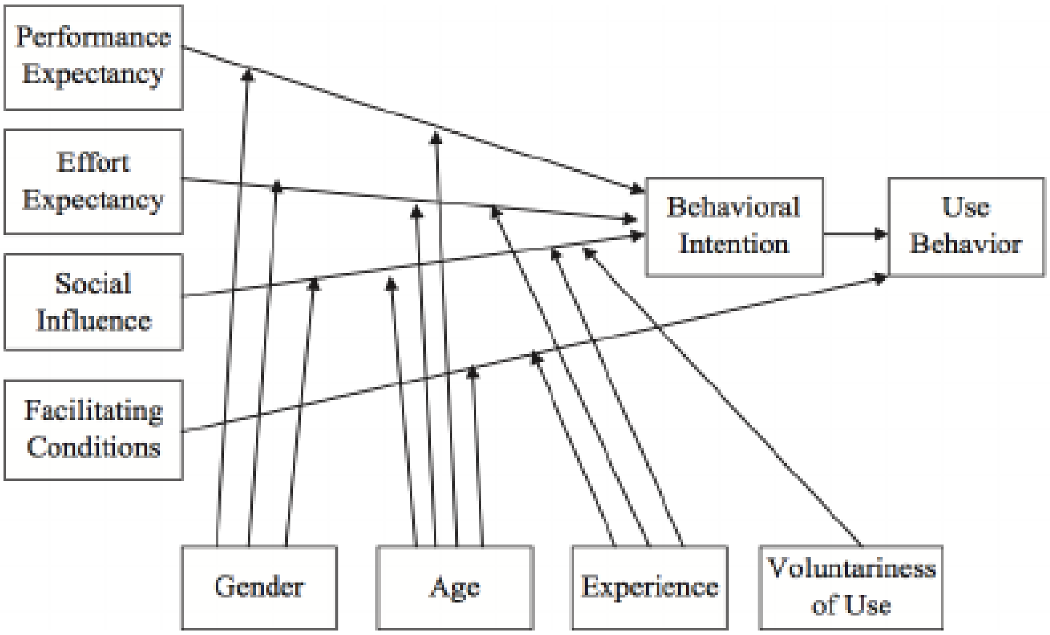


Figure 4. Unified Theory of Acceptance and Use of Technology (Venkatesh. et al., 2003)

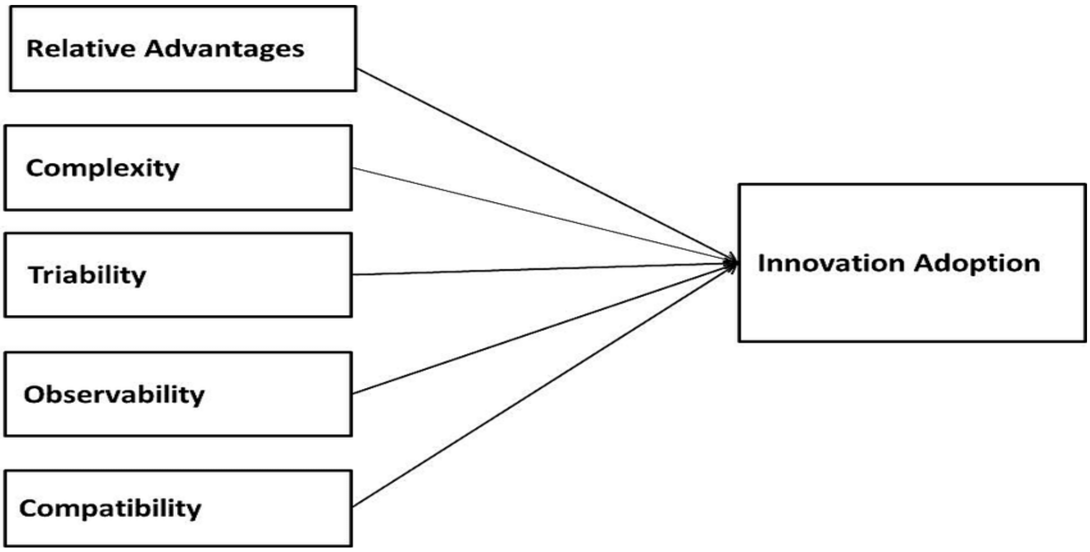


Figure 5. Diffusion of Innovation Theory (Rogers & York, 1995)

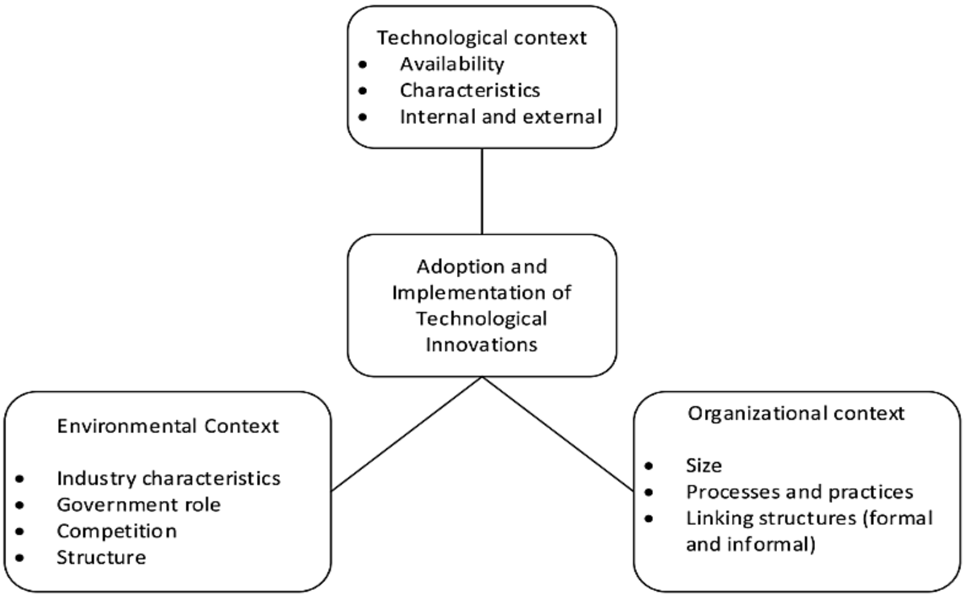


Figure 6. TOE Framework (Tornatzky and Fleischer, 1990)

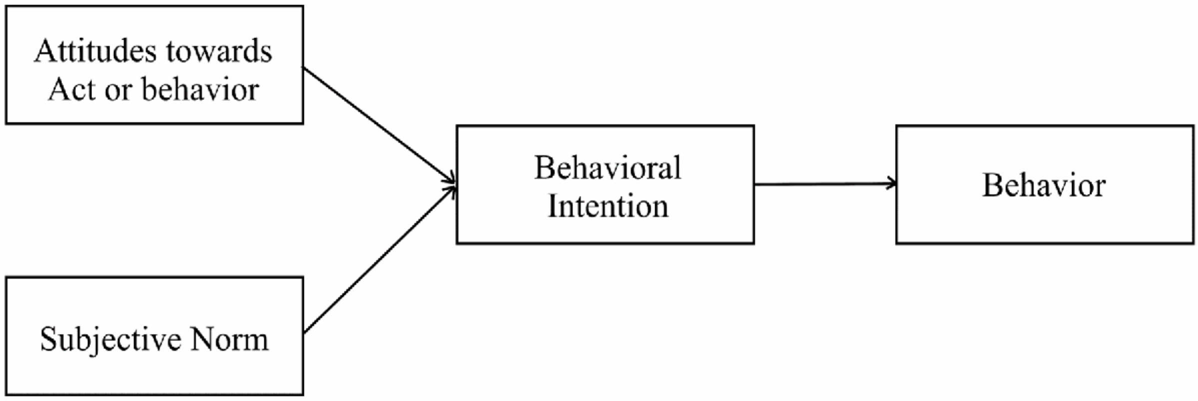


Figure 7.TRA (Fishbein & Ajzen, 1975)

**Information System Success Model (ISSM):** The information system success model is developed by DeLone & McLean (1992) and evaluates its failure or success. This model's independent constructs are System quality, Information quality, and service quality, as shown in Figure 8. Information quality measures the semantic dimension of information, and system quality measures technical success. The independent variable affects the Intention to use and user satisfaction. Use and user satisfaction assess the overall system effectiveness.

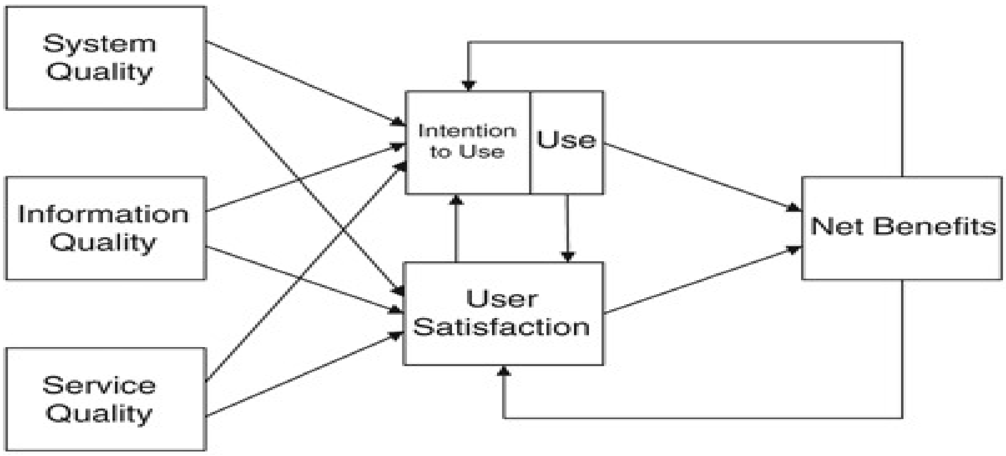


Figure 8. ISS Model (DeLone & McLean, 1992)

**Institutional Theory:** Institutional theory is developed by Scott (2004), and it focuses on the role of the institutional environment in shaping behavioral changes and obtaining social legitimacy. The primary construct of this theory is an isomorphism. Three types of isomorphic pressure are coercive, mimetic, and normative. Coercive isomorphism is the study of changes due to pressure from an external organization. Mimetic isomorphism focuses on imitating one organization's hierarchical form in the hopes of reaping the same advantages as other organizations. The pressure from regulatory bodies and practitioners interested in-licenses and certifications is known as normative isomorphism.

### 1.2 Independent variables in BIM Adoption Studies

Each theory or model's capability to explain a behavior depends on the predictors or construct of the theory. The better variance between constructs broadly explains a particular scenario. To better understand the theory fit for the study, it is necessary to compare the study's constructs and moderators. Table 6 summarizes the constructs and moderators of the theories. The analysis shows that constructs in each theory range between 2-8, and most theories consist of three or four constructs. The moderator's comparison shows a significant deviation in each study as no moderator was used in some studies, and some are using up to four moderators such as UTAUT. The most common moderators are age and experience. However, research argues that the models or theories with more explanatory power and fewer constructs are most suitable for research. The use of Independent variables varies in different studies. The researchers selected the most commonly used independent variables found in studies and are defined in Table 6. The analysis shows that mixed variables from other theories are standard practice in the research community. The most dominant independent variables in BIM research are social influence, subjective norms, and self, with the highest number of articles.

Similarly, two constructs, perceived risk, and perceived cost are the second-highest in the number mentioned in BIM studies. On the other hand, DOI constructs such as compatibility, complexity, and relative advantage have appeared in six articles. The definitions of each construct are shown in Table 7.

Table 6. Independent Variables

| Theory | Independent Variables | Moderators |
|---|---|---|
| TAM | Subjective Norm, Perceived Ease of Use, Perceived Usefulness | Voluntariness, Experience, Gender |
| DOI | Voluntariness of use, Compatibility, Visibility, Trialability, Image, Relative advantage, Ease of use, Result demonstrability | Experience |
| UTAUT | Social influence, Facilitating conditions, Effort Expectancy, Performance expectancy | Voluntariness, Experience, Gender, Age |
| TPB | Attitude, Subjective Norm, Behavioural Control | Voluntariness, Experience, Gender, Age |
| TOE | Technology: Availability Characteristics, Internal, and external organization: Size, Process, and Practices. Linking structure (formal & informal) Environment: Industry Characteristics, Government Role, Competition, Structure | Not Mentioned |
| TRA | Attitude, Subjective Norm | Voluntariness, Experience |
| ISSM | User Satisfaction, Use, Information Quality System Quality | Not Mentioned |

Table 7. Description of Independent variables

| Independent Variables | Descriptions | References |
|---|---|---|
| Perceived usefulness | An indicator of a person's ability to use a certain device that improves employee productivity. | (Davis, 1989) |
| Perceived ease of use | The degree to which the individual expects that the use of a certain device might be pain-free. | (Davis, 1989) |
| Attitude | The strength of an outcome towards or against a certain entity, or literally, emotions about engaging in such activities. | (Ajzen & Fishbein, 1977) |
| Trust | A party's ability to be open to another party's conduct in the hope that the other would do something specific. | (Shin, 2010) |
| Social influence | The extent to which a person believes significant people think he or she can use the new program. | (Venkatesh, 2000) |
| Subjective norms | The range of assumptions about normative behaviour can be accessed. | (Ajzen, 1996) |
| Compatibility | The degree to which an idea aligns with the adopter's previous knowledge or beliefs. | (Rogers & Shoemaker, 1983) |
| Perceived risk | The risk of failure when achieving the desired outcome. | (Featherman & Pavlou, 2002) |
| Perceived enjoyment | Apart from any output effects arising from software use, the degree to which the task of using a given system is viewed as pleasant in its own right. | (Venkatesh, 2000) |
| Relative advantage | The extent to which the information system is thought to be superior to its predecessor. | (Moore, 1991) |
| Self-efficacy | Belief in one's ability to execute a certain action. | (Compeau, Higgins, & Huff, 1999) |
| Facilitating conditions | The extent to which an individual assumes that an organizational and technical infrastructure supports the system's usage. | (Venkatesh, 2000) |
| Performance expectancy | The extent to which an individual feels that using the system would help to improve job efficiency. | (Venkatesh, 2000) |
| Personal innovativeness | The extent to which a single person or other units of adoption embrace new concepts more quickly than other parts of society. | (Rogers & Shoemaker, 1983) |

| | | |
|---|---|---|
| Effort expectancy | The system's degree of ease/effort. | (Venkatesh, 2000) |
| Security | The level of confidence that users have in a given service's protection. | (Shin, 2010) |
| User satisfaction | Following user experience, the user's response or feeling toward the information system. | (Molla & Licker, 2001) |
| Complexity | The level to which users consider the information system is cumbersome to use. | (Moore, 1991) |
| Perceived behavior control | A person's understanding of how easy or difficult it is to execute the desired action. | (Ajzen, 1996) |
| Perceived cost | The amount of monetary and mental commitment people believe it takes to implement and use an information system. | (Premkumar, Ramamurthy, & Nilakanta, 1994) |
| Image | The extent to which one uses an invention is thought to improve one's social appearance or reputation. | (Luo, Gurung, & Shim, 2010) |
| Anxiety | The degree to which people experience negative emotions when they use or imagine using a specific technology, such as anger, anxiety, or terror. | (Venkatesh, 2000) |
| Service quality | The level of an information system's and associated facilities' overall efficiency. | (DeLone & McLean, 1992) |
| System quality | The usability and performance characteristics of an information system are accounted for by the system's desired characteristics. | (Baker, 2012) |
| Information quality | The degree to which the website provides consumers with full, reliable, structured, readable, up-to-date, and timely knowledge on any of their stated aims. | (Shareef, Kumar, Kumar, & Dwivedi, 2011) |
| Privacy | The right of a citizen to monitor the circumstances on which their data is collected and used. | (Metzger, 2004) |

### 1.3 Dependent Variables in BIM Adoption Studies

Dependent variables are the actual indicators or measured output of the independent variables. The dependent variable is tested with input from the independent variable. Table 8 defines the most used dependent variables. The first variable is the Intention to use, which measures the organizational Intention to use a particular technology. Next is adoption that measures the degree of adoption of a particular technology. The Actual system use measures the frequency of use of technology in an organization. The fourth variable is the continuance of use, which tests the organizational Intention to adopt technology in the future. Similarly, some studies also use a combination of the dependent variables to measure a particular situation called the mixed-use of variables.

Table 8. Dependent Variables

| **Dependent Variable** | **Definition** | **Reference** | **No of papers** |
|---|---|---|---|
| Intention to use | The desire of an individual or organization to use or adapt an invention in the future. Forward-looking remarks that capture a person's or organization's goal are often used to assess this. | (Jeyaraj, Rottman, & Lacity, 2006) | 14 |
| Adoption | If an individual or a company is an early adopter or a late adopter of new technology. This is usually assessed as a binary variable dependent on self-reporting. | (Jeyaraj et al., 2006) | 27 |
| Actual System Use | An individual's or an organization's actual use of technology. This is a common objective metric derived from logs.” | (Jeyaraj et al., 2006) | 1 |
| Continuance of Use | An individual or company continues to put using or adapting technologies in the future. | (Jeyaraj et al., 2006) | 1 |
| Mixed Variables | As dependent variables, consider two or three variables. | (Jeyaraj et al., 2006) | 3 |

## 1.4 Discussion on BIM Research Themes

This section provides the detailed descriptions and categorization of themes found in different studies based on adoption stages, as shown in Figure 9.

**BIM Perceptions:** Davies and Harty (2013) develop scales for measuring individual beliefs for BIM's future usage and acceptability. This study applied the UTAUT Theory to predict perceptions of individual BIM users. Survey data is collected from 762 employees of construction organizations and argues that BIM expectations for enhancing job performance align with employees' expectations; however, some factors such as BIM Compatibility and complexity may influence the perceptions (Davies & Harty, 2013). The study used behavioral Intention and user behavior as a dependent variable and facilitating condition, effort expectancy, performance expectancy, social influence, and attitude as the independent variable and The study modified the existing UTAUT model and introduced attitude as a new variable, and argue that Performance Expectancy does not affect behavioral Intentions directly, it is the attitude of the person that directly affects. As BIM use is mandatory in many organizational existing UTAUT theory cannot accommodate mandatory BIM usage.


Figure 9. Innovation Diffusion Process (Rogers & Shoemaker, 1983)

Moreover, another study identifies determinants of BIM acceptance in the supply chain industry in terms of technology, organization, and environmental dimensions and introduced an integrated model based on UTAUT constructs to address the uncertainty of BIM usage in the supply chain and argued that addressing these determinants is crucial for successful BIM implementation (Mahamadu et al., 2014). It is also found that external factors as normative, mimetic, or other factors can affect attitude towards Smart systems and ultimately influencing technology adoption (Liu et al., 2018). The main driver for BIM is the individual perception, whether positive or negative, that hinder or facilitates BIM adoption (Bosch-Sijtsema et al., 2017; Lee et al., 2015). A survey of 114 professionals confirms that external variables such as organizational competence and technology quality affect perceived ease of use and perceived usefulness and perceived usefulness affect intention to accept technology. A study for design organizations using the TAM found that top management support, subjective norm, compatibility, and computer self-efficacy affect user behavior towards intention to adopt BIM (Son, Lee, Hwang, & Kim, 2014). Another survey of 162 architects by the same author shows that perceived ease of use, technical support, and perceived usefulness affect behavioral intention (Son et al., 2015). Other factors influencing intentions include financial benefits, technical support, and competitors' motivations (Juan et al., 2017) and external factors influence the practitioner's attitude toward BIM adoption (Ramanayaka & Venkatachalam, 2015). Assessing new technology users' perceptions requires the linking of perception factors into three dimensions: technology, process, and people. These perception factors influence Collaborative environments and IT implementation strategies in the industry (Enegbuma et al., 2014). People's perception of BIM affects the business process and integrated construction as well as collaborative environments. Process perception influences collaborative environments and technology perception, Influence on business Process and collaborative environment and collaborative environment influence BIM adoption. A notable finding is that most architects have negative intentions for BIM adoption and hence causes a barrier to changing practices and opting BIM (Kim et al., 2016). The reason for such an attitude is the perceptions about the nonobservability of BIM and clash with existing work practices. The Major barrier to BIM adoption is willingness and interest as well as low knowledge of BIM users (Xu et al., 2014).

**BIM Motivation:** In studies of innovation diffusion, the behavioral characteristics of actors in organizations are generally not considered. Every actor in the organization has a different hierarchy of needs related to technology adoption. Maslow's theory of motivation and IDT lays the foundation of primary and secondary conditions in organizations. Adoption needs can be in a stable state or exciting state. These states help in systematically planning and designing adoption in the construction Industry. This hierarchical structure can be used to study individual and organizational actors' behavior regarding technology adoption and technology diffusion (Vishal & Holmström, 2015). Analysis of the survey shows that economic motivations and social images are not inverses of each other. There is no need to decrease images with an increase in BIM capabilities. Also, ownership types and project characteristics are associated with BIM implementation (Cao et al., 2017). BIM implementation motivations influence BIM Implementations practices in design originations. Four types of motivation are Project-based economic motivation, image motives, cross-project financial motivation, and reactive motivations. Analysis of data collected from designers shows that Image motives and Project-based motives are significantly associated with BIM implementation. However, Cross project motivations and Reactive motivations have no significance in BIM implementation. Understanding these motives helps BIM implementation tactically in design organizations to reduce heterogeneity in BIM implementation practices. Also, client and owner support work as a moderator between BIM practices motivations and Implementation motivations (Cao et al., 2016).

**BIM Readiness:** The organizational readiness assessment for architectural firms in Taiwan shows that governmental policies can influence the willingness to adopt BIM (Juan et al., 2017). Other factors influencing intentions include financial benefits, technical support, and competitors' motivations. The study's findings are BIM is already adopted by one-third of firms, and the other half are willing to adopt BIM (Ramanayaka & Venkatachalam, 2015). A study done in South Africa to assess BIM readiness in the prematurity stage argues that external factors influence the practitioner's attitude toward BIM adoption. The findings regarding technical readiness are the unavailability of protocols and guides, prevailing data misinterpretations, and complicated BIM models. Unknown financial sustainability affects organizational readiness. Concerning procurement, there is a dearth of procurement practices that can support BIM. Also, there is a limited initiative for policy readiness, as industry stakeholders are reluctant to take policymaking steps. All the mention factors above need support from state-level reforms to enhance BIM acceptance in the South African AEC industry. In a recent study Lee & Yu (2015) address factors hindering readiness in non-prepared organizations using the TAM and a survey of 164 practitioners. The constructs used in this study are organizational efficacy, organizational innovativeness, and personal efficacy, personal innovativeness, consensus on appropriation, collaboration easiness, organizational support, and organizational pressure. These factors influence BIM readiness in the organization, and considering these variables can lead to BIM acceptance success. At the project level, BIM readiness assessment is done in Norway's airport terminal project by involving workers working on-site with reinforcing bars. Qualitative analysis of data shows that even low IT knowledge workers are aware of BIM capabilities and are ready to adopt BIM; however, they are reluctant due to the additional workload incurred due to BIM use.

**BIM Acceptance:** A study on technology acceptance argues that the technology acceptance model can be used to test the acceptance or rejection of digital technologies (Liu et al., 2018). However, TAM cannot capture changes in user behavior over time. The author extended TAM with the attitude construct and did action research to study the BIM user's acceptance behaviour. It is discovered that attitude is never changing towards perceived ease of use and perceived usefulness; therefore, system developers should focus on enhancing the usefulness and friendliness of the interface to improve BIM adoption. This study gives insight into the measurement of acceptance in different stages of projects. It provides a guide to managers for managing acceptance in their organization. Another study assessed the degree of acceptance of BIM in the Korean AEC industry (Kim et al., 2016).

**BIM Adoption:** A recent study shows the influencing factors of BIM adoption in India using the Technology organization Environment framework and categorizes the factors into three dimensions (Ahuja et al., 2016). A sample survey of 184 respondents from the Indian Architecture firm is selected and analyzed to identify factors. The study found that Indian BIM users are aware of BIM potential and capabilities, but the other construction players still have not realized the BIM diffusion. Moreover, adoption barriers and facilitators of BIM at the organizational level using technology organization environment framework and TPB are identified. The main obstacles to BIM implementations are the lack of normative pressure and the main driver for BIM is the individual perception, whether positive or negative that hinder or facilitates the BIM adoption (Bosch-Sijtsema et al., 2017). Also, lack of knowledge about BIM, low demand from customers and limited readiness of BIM from industry partners are influencing BIM adoption. Another study determines the influencing factors for effective BIM intake in refurbishment and proposes a framework comprised of four components; refurbishment attributes, environmental factors, structure optimization, and stakeholders' interaction. The author argued that the adoption of BIM in the renovation field should be studied in the four dimensions mentioned above. Also, there is a need for review investigation for effective BIM adoption (Okakpu et al., 2018). Another issue hindering BIM adoption is the low IT capability of site engineers. Lastly, there is a lack of appropriate contracts for the use of BIM in projects. The findings suggest using BIM in reinforcing bars to improve productivity; however, some costs associated with BIM implementation may influence BIM adoption (Merschbrock & Nordahl-Rolfsen, 2016). In addition to this, the trialability and complexity of BIM also play a role in negative perceptions about BIM. Also, some BIM users are not aware of the BIM processes and benefits toward performance enhancement because they are reluctant to adopt BIM (Kim et al., 2016). In another study done by Gao et al. (2013) proposes a conceptual model for the factors hindering innovation adoption in the construction industry using TAM and IDT. Influencing factors are compatibility, external influence, performance justification, and organizational variety, and perceived risk.

Moreover, the inhibitors of low BIM adoption are high complexity, limited trialability. However, the increased relative advantage is supporting BIM adoption. All these factors are subject to perceptions of the adopter, their level of innovation diffusion. For large companies supporting dynamics are different such as government mandates and for small-scale companies inhibiting dynamics are different such as implementation cost (Seed, 2015). BIM adoption in China is slow and study finding indicates that organizational dimensions, user attitude, and technological dimensions have an indirect influence on BIM's actual use. However, the attitude dimension has a positive influence on BIM's actual Use. perceived usefulness is influenced by compatibility, BIM standard, monitoring, visualization, relative advantage, and BIM standards.

On the other hand, complexity, perceived cost, organizational support, interest, professionals, willingness, and training positively affects perceived ease of use. The Major barrier to BIM adoption is willingness and interest and insufficient knowledge of BIM users (Xu et al., 2014). For BIM mobile applications such as BIMsight, BIMX, and Formit, the influencing factors are quality of content, utility, the faith of application, price, design, interaction. information offer, collaboration environment, and instant connectivity as an external variable affecting BIM acceptances (Hong & Yu, 2018). Adoption drivers and factors are categorized into three groups. First innovation characteristics, second internal environment characteristics, and external environment characteristics (Ahmed & Kassem, 2018). This grouping provides a more comprehensive collection of factors affecting BIM adoption and diffusion. The internal factors are organizational culture, top management support, and willingness to change. External characteristics are mimetic pressure and normative pressure. These factors are mapped with stages of adoption and BIM innovation can give a plan for the diffusion of BIM in markets.

**BIM Implementation:** Another study provides determinants and implementation gaps of BIM in the Malaysian construction industry (Takim et al. 2013). The study is based on the case study approach, and data collection was done through a workshop on the BIM market situation. Stakeholders from the public and private organizations participated in seminars and gave feedback to implement BIM in Malaysia successfully. According to the study, national-level BIM determinants are a benefit, regulation support, policy standards, competitive advantage, championship, and economic demand. At the organizational level, factors such as clarity of project, business agility, cost of implementation and support, fidelity, and continuity are the dominating factors.

**BIM Diffusion:** BIM is perceived as technological innovation, and the adoption of BIM can be assessed with the help of IDT (Oraee et al., 2017). Innovation diffusion theories can explain the factors of adoption, origin, potential impacts, context, and diffusion stages. BIM diffusion in Australian small and medium scale industries is comparatively low, and some of the companies have adopted BIM in level 1 and level 2, respectively. BIM adoption barriers fall into three categories; supply chain barriers, organizational and project barriers, Supply chain barriers influence organizational adoption, and organizational obstacles influence project level adoption. The main barriers to BIM adoption are a lack of interest from trading companies in taking the risk of investment and a large portion of the cost associated with efforts and training for BIM Tools. A low level of BIM knowledge is not a barrier to the Australian industry. There is a need for addressing supply chain barriers not to change organizational policies. The diffusion of innovation at the firm's level is a complex process and nonlinear instead of Rogers's theory of innovation. The analysis shows that innovation context and firm context change over time (Shibeika & Harty, 2015), and organizations need to cope with rapidly changing digital innovation. These changes evolved with different phases of diffusion, starting from centralization to standardization and followed by globalization. In standardization, communication channels are consolidated, and champions for digital leadership are identified. Standardizations include the provision of the platform and digital systems. Globalization covers the development of global capabilities and improving communication channels. This process flow of innovation diffusion is observed in UK firms for four years, and a similar pattern can be observed in other organizations of the same size. Hence diffusion in an organization is context-specific as well as time-sensitive. In another study in the UK identified the forces of BIM adoption (Seed, 2015). The classification of dynamics is done according to IDT. According to the survey, observability has no significance on diffusion; however, other factors such as the relative advantage of BIM are positively influencing adoption.

Similarly, compatibility is also equally important. Isomorphic pressure also influences BIM adoption as the diffusion of BIM is a highly social activity. Social factors such as coercive and mimetic pressure have a significant influence on BIM use at the project level. However, the analysis of survey data shows no sign of normative pressure on BIM influence. Also, support from owner to client can play a mediating role in the impact of such pressures. Hence BIM adoption is a complex social phenomenon, and external pressure influences BIM adoption (Cao et al., 2014). Identification of factors influencing collaboration at the project level is made with the DOI. These factors are divided into individual factors, environmental factors, management factors, technological factors. Individual factors include learning capability, experience, and IT skills. Environmental factors consist of the discussion room's availability, sharing environment. Managerial factors address management approaches toward technology, management support, and technical factors: functionality, speed, and accessibility. Addressing these factors can enhance a collaborative work environment in the hospital.

## Discussion

The research study conducted Systemic Literature Review (SLR) for BIM adoption studies to analyze BIM adoption status. The result shows that most of the studies focus on BIM awareness in construction stakeholders (Sodangi, Salman, & Saleem, 2018), measuring the readiness to adopt BIM (Lee & Yu, 2017; Yusuf, Embi, & Ali, 2017), intension to use BIM (Acquah et al., 2018), motivations to adopt BIM (Cao et al., 2016), linking perception of an individual with BIM adoption (Howard et al., 2017), testing the acceptance level of BIM (Acquah et al., 2018; Juan et al., 2017; Liu et al., 2018) and adoption of BIM at the individual level (Howard et al., 2017; Kalibatas, Kalibatienė, & Kapliński, 2018) and organizational level (Papadonikolaki & Wamelink, 2017). Factors affecting BIM adoptions are identified in several studies (Ahuja et al., 2018; Antwi-Afari et al., 2018). Similarly, few studies have investigated BIM diffusion using institutional theory to analyze the external environmental factors such as mimetic pressure, normative pressure, and coercive pressure (Cao et al., 2014; Kassem & Succar, 2017; Shibeika & Harty, 2015; Succar & Kassem, 2015). The study's findings are that most of the studies are discussing BIM awareness and adoption in general and there is limited use of Information System (IS) theories and frameworks. However, few studies are focusing on BIM implementation issues and factors of interoperability adoption and they do not provide a comprehensive view and in-depth understanding of BIM implementation issues such as interoperability adoption. Interoperability of BIM is the most dominating factor influencing BIM innovations (Arayici et al., 2018; Timothy et al., 2018; Pishdad-Bozorgi et al., 2018; Tommasi & Achille, 2017). Therefore, there is a need to explore further this area to provide an in-depth understanding of interoperability factors.

Moreover, there is a need to identify other interoperability dimensions such as legal interoperability and semantic interoperability (EIF, 2017). Also, a comprehensive framework to address interoperability adoption issues is lacking in studies. Furthermore, it is necessary to understand what interoperability is and what drives interoperability, and the factors contributing to low BIM adoption.

### Challenges and Future Work

Extension of existing adoption models/theories. The TAM and other technology adoption models need to be modified according to particular attributes of industry and business models such as reinforcing bars, on-site construction, and refurbishment to address BIM acceptance issues (Acquah et al., 2018; Howard et al., 2017; Oliveira et al., 2014; Park et al., 2019). Similarly, to address other social factors, technical factors, and the interrelation among these factors, Diffusion of Innovation Theory with Maslow's theory provides insights about cognitive issues' effects on adoption (Cao et al., 2014; Yalcinkaya & Singh, 2015). The proposed models in different studies need to be extended and validated by industry experts (Davies & Harty, 2013; Hosseini et al., 2016; Lee, Chong, & Wang, 2017; Lee, Eastman, & Lee, 2015; Okakpu et al., 2018).

Use of Moderators. The moderators play a vital role in the decisions of technology adoption. Technology users' intentions are influenced by several moderators such as gender, age, technology use experience, carrier growth, salary expectations, insurance, legal issues, and workload. Similarly, technology experience gained over time also affects technology acceptance. The future work is suggested to consider the above moderators to be used with existing technology acceptance models to comprehensively analyze BIM adoption (Howard et al., 2017; Liu, Li, & Zhang, 2010; Son et al., 2015; Xu et al., 2014).

## Conclusion

BIM is an exciting field of research for its applicability in AEC and related disciplines. The research study conducted SLR for BIM adoption studies to analyze the status of BIM adoption and the use of technology adoption models and theories used by researchers and categorized them and research themes based on BIM adoption stages. The study's findings indicate that most of the research discusses BIM adoption and awareness in general, and there is limited use of IS theories and frameworks. The results show that TAM is the most dominant technology acceptance model in BIM research. The trend of using TOE as compared to other theories is recorded as low.

Similarly, the most cited dependent variable is adoption, and the most dominant independent variables in BIM research are social influence, subjective norms, and self, with the highest number of articles. Even though this research offers a comprehensive view of BIM adoption from an Information systems perspective, it is not without limitations of scope. The first limitation is the selection of studies from selected databases only. The second is the selection of articles with the most common technology acceptance theories. A few critical studies may be omitted. This research will help researchers interested in technology adoption to research the BIM adoption domain further. Future studies should consider the extension of existing adoption models according to the industry's attributes to address BIM acceptance issues. The diffusion of innovation theory with Maslow's theory provides insights into cognitive issues' effects on adoption. It is suggested to investigate external pressures, particularly adverse effects, by using Institutional theory. Future work should consider the moderators to be used with existing technology acceptance models to analyze BIM adoption comprehensively.

## Conflict of interest

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

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