

Assessing the Technology–Organization–Environment Model for Building Information Modelling Acceptance among Malaysian Construction SMEs

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ABSTRACT

The construction industry is experiencing rapid digital transformation to improve project efficiency, collaboration, productivity, and sustainability. Among the emerging digital technologies, Building Information Modelling (BIM) has become one of the most significant innovations for enhancing information management throughout the lifecycle of construction projects. Building Information Modelling (BIM), as one of the most impactful digital transformation technologies, has emerged in the architecture, engineering, and construction (AEC) industry. BIM enables joint project information management during the life cycle of construction assets to facilitate better association, cost management, scheduling, sustainability assessment, and facility management. Although there have been some remarkable initiatives taken by the government to encourage BIM implementation in Malaysia, acceptance of BIM among SMEs has been relatively lower than expected. SMEs make up the vast majority of construction companies and have an essential role to play in the construction process; thus, their poor engagement with BIM hinders the digital transformation of the overall construction industry. This paper will evaluate the suitability of the TOE model in understanding the BIM adoption by Malaysian construction SMEs. The study will propose a research methodology including a sample size of 100 CIDB-registered SMEs. The paper will use a structured questionnaire to study factor analysis, reliability test, correlation analysis, and multiple regression analysis regarding the effect of technological, organizational, and environmental factors on BIM adoption. The results are expected to show that organizational factors influence BIM adoption the most, followed by technological and conservation factors. The study is anticipated to validate the applicability of the TOE framework in the Malaysian construction SME context and provide valuable insights for policymakers, industry practitioners, and technology providers seeking to accelerate BIM implementation and digital transformation within the construction industry.

Keywords: Building Information Modelling (BIM), Technology–Organization–Environment Framework, Construction SMEs, Organizational Readiness, Digital Transformation, Technology Adoption, Malaysian Construction Industry, Industry 4.0.

INTRODUCTION

Architecture, Engineering and Construction (AEC) industry constitutes one of the main driving forces behind the economic development of any nation. For example, in Malaysia, the construction industry plays an important

role in generating the gross domestic product (GDP), providing employment, developing infrastructure and boosting industrialization. Nevertheless, the construction industry is constantly struggling with productivity issues related to its fragmented processes, bad communication practices, poor information management, and unwillingness to innovate using the latest technologies. In particular, these productivity challenges have been intensified by growing project complexity which requires coordination among many stakeholders such as architects, engineers, contractors, clients and authorities (Sarvari et al., 2022; Liao et al., 2022).

In order to deal with these long-standing inefficiencies, the world construction industry turned to digital transformation trends connected to Industry 4.0 and BIM is considered to be one of the most promising technologies for digital transformation of projects. In general, BIM can be seen not only as the technology of 3D visualization but as an information management system involving all project data throughout its life cycle. Modern uses of BIM are not just limited to modelling, but have been extended to scheduling (4D), costing (5D), sustainability (6D), and facility management (7D). This has resulted in the creation of an integrated digital environment for aiding in decision-making (Eastman et al., 2018; Kocakaya et al., 2025).

Many researchers have found numerous advantages to BIM implementation. BIM helps to coordinate projects better, detect clashes, avoid wastage of materials, improve the accuracy of cost estimation, foster good communication among different stakeholders, and make decisions based on proper information. Also, BIM allows organizations to create a digital twin of the physical asset and to manage its lifecycle (Bryde et al., 2013; Azhar, 2011; Succar, 2009).

However, although there is such a number of advantages, not all companies are using BIM in Malaysia. Large organizations have enough funds, skills, and capacities to implement BIM effectively, whereas SMEs have many difficulties due to lack of financial capacity, shortage of staff, lack of digital skills, and uncertainty about return on investment. Since SMEs dominate in the construction market in Malaysia and execute many projects, there are serious problems concerning the adoption of BIM (CIDB & CREAM, 2021; Chen et al., 2025).

Given its strategic significance, various efforts have been taken by the Malaysian Government through agencies like CIDB (Construction Industry Development Board) and PWD (Public Works Department). These efforts include BIM roadmap, BIM guidelines, BIM training, MyBIM Center, and various awareness campaigns. Despite this, the implementation of BIM in Malaysia, especially among small and medium enterprises (SMEs), has been rather poor (Zulkifli et al., 2024; Raja Mohd Noor et al., 2023).

The Technology Organization Environment (TOE) theory provides a very holistic theoretical approach to the adoption of organizational technologies. Unlike the individual level theories such as TAM and UTAUT, TOE looks at the decision-making process at the organizational level through technological, organizational, and environmental lens. As a result, TOE theory is very useful for researching the adoption of BIM technology among SMEs which work in limited resources environments (Tornatzky & Fleischer, 1990; Prakash, 2025).

This study hence seeks to analyse the suitability of the TOE theory in the context of BIM adoption by Malaysian construction SMEs and proposes a conceptual model which would be used to guide future transformations in the industry.

LITERATURE REVIEW

Building Information Modelling

Building Information Modelling marks a paradigm change from conventional drawings-based approach towards models-based approach for project delivery process. Building Information Modelling allows all stakeholders to create, share, analyse and manage project information using digital technologies during the whole lifecycle of the project (Zulkifli et al., 2024; Eastman et al., 2018).

Conceptual roots of BIM technology can be found in the development of object-oriented modeling and parametric design technologies in the 1970s and 1980s. The development of computer technologies and interoperability standards like Industry Foundation Classes allowed BIM to evolve from theoretical technology

into a practical one. In BIM technologies, maturity can be classified into levels 0 to 3, where level 0 means primarily use of paper-based technologies while level 3 means full integration of collaborative digital environments. Despite state support, many Malaysian companies still function at level 0 and 1 of BIM technologies, which indicates great potential of digitalization (Succar, 2009; Howard & Bjork, 2008; Raja Mohd Noor et al., 2023).

Research shows that the implementation of BIM has positively impacted the performance of projects through better design coordination, clash detection, visualization of projects, scheduling, and cost management. Bryde et al. (2013) documented tangible improvements in the quality and productivity of projects, whereas Azhar (2011) focused on the risk reduction capability of BIM and collaboration. It helps to create CDEs, allowing different stakeholders involved in projects to share project data in real-time (Vidalakis et al., 2018; Liao et al., 2022).

Nonetheless, BIM benefits depend significantly on widespread involvement in BIM processes. When SMEs fail to get involved in the BIM process, information sharing becomes inconsistent, and many productivity gains from BIM disappear. Hence, an improvement in BIM uptake by SMEs becomes vital for the overall digital transformation of the industry (Chen et al., 2025; Vidalakis et al., 2018).

BIM Adoption among Construction SMEs

SMEs make up around 96%-99% of all construction firms across the world and form the backbone of the construction industry in Malaysia. In addition to being economically important, SMEs offer crucial skills for carrying out projects and generate most jobs and skills in the sector (Sarvari et al., 2022; Zulkifli et al., 2024).

Even though SMEs are important, there are structural obstacles which hamper innovation due to the following reasons: insufficient financial resources, dependence on owner-managers, lack of strategic planning capacity and technological skills. Construction SMEs tend to work on very small margins and focus mainly on survival rather than growth. Thus, investment into digital technology is difficult to justify (Chen et al., 2025; CIDB & CREAM, 2021).

Several international studies have also identified some recurring themes in terms of adoption barriers of BIM technology among SMEs. Financial problems, shortages of skilled employees, complicated software, absence of technical assistance, and doubts about the return on investment are common issues. Several studies carried out in the United Kingdom, Ghana, China, and other countries indicate that organizational readiness has a crucial role to play in the success of BIM adoption, more than any other technological factors (Qin et al., 2020; Vidalakis et al., 2018; Chen et al., 2019).

In the Malaysian environment, SMEs have been facing issues in the form of high cost of software, training issues, integration problems, and lack of clients demanding BIM technology. Therefore, BIM adoption is still limited only to large enterprises (CIDB & CREAM, 2021; Raja Mohd Noor et al., 2023).

Technology–Organization–Environment Framework

The Technology, Organization and Environment approach was created by Tornatzky and Fleischer (1990) for organizational technology adoption analysis. This framework assumes that the decision-making process is determined by the following three main contextual factors: technological, organizational, and environmental. Unlike the user-based frameworks like TAM and UTAUT, TOE framework is dedicated to adoption at the organizational level, so it can be considered to be a more appropriate tool for analysing SME technology adoption (Prakash, 2025; Wang et al., 2024).

The technological factor considers characteristics of innovations like complexity, compatibility, interactivity, and perceived benefits. The organizational factor takes into account management support, organization's resources, employees' skills, communication within the organization, and strategy. The environmental factor considers such factors as government policy, industry standards, competition, customer needs, and market environment (Prakash, 2025; Zhu et al., 2002).

Many studies have successfully used TOE to understand BIM adoption. For instance, Chen et al. (2019) proved that technological readiness, organizational support, and external pressures jointly affect BIM adoption by construction companies in China. In addition, Liao et al. (2022) found that TOE constructs have an effect on BIM capability formation by construction firms. Therefore, it can be concluded that TOE provides a solid theoretical basis for researching BIM adoption by SMEs in Malaysia.

REVIEW OF LITERATURE

Building Information Modelling has attracted considerable attention from researchers worldwide due to its potential to improve collaboration, information sharing, project quality, cost effectiveness, and lifecycle management. Azhar (2011) reported that BIM improves project visualization, communication, and decision-making while reducing design conflicts and construction risks. Similarly, Bryde et al. (2013) found significant improvements in project performance through enhanced coordination and information integration. These findings demonstrate that BIM is not merely a software application but a comprehensive project information management methodology capable of transforming traditional construction practices.

Several studies have explored barriers and drivers affecting BIM adoption among construction organizations. Vidalakis et al. (2018) highlighted that SMEs often face challenges associated with financial constraints, technical complexity, lack of skilled personnel, and uncertainty regarding return on investment. Likewise, Sarvari et al. (2022) identified cost-related constraints, inadequate training, and organizational readiness as major obstacles preventing widespread BIM implementation among SMEs. These studies suggest that adoption decisions depend on a combination of internal organizational capabilities and external environmental influences.

The Technology–Organization–Environment (TOE) framework developed by Tornatzky and Fleischer (1990) remains one of the most widely accepted theories for investigating organizational technology adoption. The framework proposes that technology adoption decisions are influenced by three contextual dimensions: technology, organization, and environment. Technology refers to the characteristics of available technologies, organizational factors include resources and management support, while environmental factors encompass regulatory requirements, industry competition, and external stakeholder pressures.

Recent studies have successfully applied the TOE framework to BIM research. Chen et al. (2019) demonstrated that technological readiness, top management support, and external market pressure significantly influence BIM adoption among construction organizations. Qin et al. (2020) integrated the TOE framework with the Technology Acceptance Model (TAM) and revealed that organizational readiness significantly affects BIM adoption behaviour. Wang et al. (2024) further confirmed the applicability of TOE variables through a global meta-analysis of BIM adoption studies.

Within the Malaysian construction sector, several studies have highlighted slow BIM diffusion among SMEs despite extensive government promotion. CIDB and CREAM (2021) reported that SMEs continue to encounter challenges including software acquisition costs, limited expertise, and insufficient client demand. Raja Mohd Noor et al. (2023) observed that organizational preparedness remains a significant determinant of BIM implementation readiness among Malaysian SMEs. Similarly, Zulkifli et al. (2024) concluded that insufficient training, inadequate awareness, and resource limitations continue to hinder BIM adoption. Collectively, these studies justify the need for further investigation into BIM adoption using a comprehensive theoretical framework such as TOE.

RESEARCH METHODOLOGY

In this research, a quantitative survey method will be used to assess the impact of TOE factors on BIM adoption by Malaysian construction SMEs. It is reasonable to use quantitative methods since it allows testing relationships between many variables statistically and proving theories empirically (Prakash, 2025; Chen et al., 2019).

The study population will be comprised of registered construction SMEs within CIDB ranging from Grade G1 to G5. A sample size of at least 100 SMEs will be selected using Yamane's sampling formula from a total

population of about 116,440 firms. Stratified random sampling will ensure that contractor grades and firm sizes are represented.

The data will be collected using a structured questionnaire having a total of nineteen Likert scale questions. The technological factors are measured by five items, organizational factors are also measured by five items, environmental factors by five items, and four items are measuring BIM adoption. The questionnaire will be developed from validated TOE-based BIM studies but modified for the Malaysian construction industry (Qin et al., 2020; Wang et al., 2024; Chen et al., 2019).

The steps in data analysis include the calculation of descriptive statistics, exploratory factor analysis (EFA), reliability analysis using Cronbach's alpha, Pearson correlation analysis, and multiple linear regression. Sampling adequacy and factorability will be tested using Kaiser-Meyer-Olkin (KMO) Measure and Bartlett's Test of Sphericity. Multiple regression will be done to examine the effects of factors on BIM adoption.

Expected Findings and Discussion

This research will confirm the TOE model in the context of Malaysian SMEs. The KMO values above 0.80 and statistically significant Bartlett's Test indicate that sampling is sufficient and the study possesses good construct validity (Prakash, 2025; Chen et al., 2019). It is expected that exploratory factor analysis will reveal three main factors related to the technological, organizational, and environmental dimensions with the cumulative variance explained being above 60%.

Descriptive statistics will show that skills shortage, software complexities, budgeting problems, and lack of client demand for services are still critical barriers to implementing BIM technology. In the dimensions of the TOE model, organizational barriers will most probably have the highest scores because of the limited capabilities of SME workers, lack of managers' engagement, and insufficient financing (Chen et al., 2025; CIDB & CREAM, 2021).

It is expected that correlation analysis will prove significant negative correlations between TOE barriers and BIM adoption. Namely, high scores for the TOE barriers will be associated with low levels of BIM adoption. Organizational barriers will most likely have the highest correlation coefficient with the BIM adoption because of the strong reliance of SMEs on managerial support and internal capacities while making any technology changes (Qin et al., 2020; Chen et al., 2025).

It is anticipated that the multiple regression will yield an overall coefficient of determination (R^2) of around 0.58, implying that the three factors of TOE combined can account for roughly 58% of the variance in the adoption of BIM. Organizational factors ($\beta = -0.42$) are projected to have the greatest impact, followed by technological factors ($\beta = -0.31$) and environmental factors ($\beta = -0.24$). Such findings will indicate that organizational readiness is the main challenge impeding the use of BIM among Malaysian construction SMEs (RINA & B1P Group, 2021; Chen et al., 2025).

Additionally, the outcomes would mean that BIM implementation involves much more than just the presence of technology. The effort to develop skills, leadership, planning, and organizational capabilities is imperative. At the same time, there is a need for policymakers to increase environmental enablers through better training programs, BIM awareness programs, procurement policies, and cost-effective BIM technology (Zulkifli et al., 2024; CIDB & CREAM, 2021).

CONCLUSION

This study evaluates the applicability of the Technology–Organization–Environment framework in explaining Building Information Modelling adoption among Malaysian construction SMEs. The research recognises that although BIM provides substantial benefits in project coordination, information management, cost control, scheduling, sustainability assessment, and overall project performance, its implementation among SMEs remains relatively limited. Consequently, understanding the determinants of BIM adoption is essential for supporting the construction industry's digital transformation agenda.

Table 1. Summary of Research Objectives and Expected Outcomes

Research Objective	Expected Outcome	Expected Status
RO1	Technological factors significantly influence BIM adoption	Supported
RO2	Organizational factors significantly influence BIM adoption	Strongly Supported
RO3	Environmental factors significantly influence BIM adoption	Supported
RO4	TOE framework effectively explains BIM adoption among SMEs	Supported

The study has established four research objectives focusing on technological, organizational, and environmental determinants of BIM adoption as well as assessing the suitability of the TOE framework. Based on the proposed research model and evidence from prior studies, it is anticipated that all three TOE dimensions will significantly influence BIM adoption. However, organizational readiness, including management commitment, employee competency, resource availability, and strategic planning, is expected to emerge as the strongest predictor of BIM adoption among Malaysian construction SMEs.

The anticipated findings are expected to support the validity of the TOE framework in explaining organizational technology adoption within the Malaysian construction context. Therefore, the study objective of evaluating the suitability of the TOE framework is expected to be successfully achieved. The findings may contribute to academic knowledge by extending BIM adoption literature while simultaneously providing practical recommendations for policymakers, industry practitioners, and SME managers.

To strengthen BIM implementation nationwide, future efforts should focus on increasing training opportunities, improving digital competencies, enhancing management awareness, providing financial incentives, and creating a supportive regulatory environment. These initiatives could accelerate BIM adoption among SMEs and contribute to the successful modernization and digital transformation of Malaysia's construction industry.

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