Drivers for Effective BIM Implementation: PEST and Analytic Hierarchy Process Approach for Sustainable Construction Decision-Making in UAE

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Abstract

Building Information Modeling (BIM) is a cutting-edge technology revolutionizing the construction sector. By strategically adopting and implementing BIM, organizations will significantly improve performance in many aspects, such as programs' efficiency, design quality, waste reduction, and environmental performance of built environment projects. The use of BIM has been widely embraced in the building sector, especially in the UAE, where the presence of foreign enterprises engaged in the building industry has made the monarchy's construction industry one of the most significant marketplaces. The building industry has played a vital role in the UAE's enormous expansion and urbanization of the economy. Thus, BIM is recognized as one of the most significant technological breakthroughs in sustainable construction practice. However, few regulations and policies have been created to implement BIM within the UAE construction industry. The problem is exacerbated by the fact that construction work in the UAE frequently entails high levels of risk, unique technology, and engineering hurdles, such as the ever-changing regulation and environmental risks. Thus, fully implementing BIM presents considerable challenges for the construction industry due to a lack of understanding of the implementation drivers, a lack of BIM assessment tools, and a lack of assessment decision-making tools, which demands constant decision-making-based criteria with continuously renewed project information. Motivated by this need, the study aims to identify and prioritize the main drivers for BIM implementation in the construction industry. To achieve this goal, an integrated PEST and Analytic Hierarchy Process (AHP) analysis were conducted to support the decision maker's understanding of more tangible and practical BIM implementation drivers and examine their ranking and relationships. The study findings showed that the technological aspect was ranked first regarding the main criteria affecting the effective implementation of BIM in the construction industry. In contrast, the socio-cultural aspects were ranked the least compared to the other criteria.

Keywords

BIM, Building Information Modelling, Construction, Sustainability, AHP, PEST, BIM Factors.

1. Introduction

1.1 BIM in the Construction Industry

Building Information Modeling (BIM) has transformed the traditional design and construction process by allowing stakeholders to collaborate on a common digital platform (Azhar et al., 2011). However, there still needs to be a greater understanding of BIM implementation's different aspects and stages, which hinders its full potential (Li & Li, 2013). BIM can transform the construction industry by providing a platform for collaboration and data exchange among various stakeholders. BIM also has the potential to assist in the development of sustainable construction practices using more accurate and efficient energy simulations and life cycle analyses (Rahman et al., 2019). However, the effective implementation of BIM requires meeting specific criteria and has proven to be a challenge in the building sector. Despite the advantages of BIM implementation, several potential issues have been identified recently, such as a lack of standardization in its application to varied building projects, which can result in discrepancies and ineffectiveness in project execution (Bryde et al., 2013; Froese, 2010; Succar, 2009). Venkatachalam. (2017) also notes that the United Arab Emirates is behind other developed countries, such as the United Kingdom and the United States, in terms of implementing BIM; implementation barriers are the primary challenges, such as the lack of BIM proficiency and instruction can hinder teamwork and communication between project participants (Sacks et al., 2018). In addition, Mehran. (2016), discovered that the minimal adoption of BIM in the construction industry in the UAE is the result of a lack of BIM standards and BIM implementation criteria, which leads to resistance to change in the sector. As a result, the United Arab Emirates has not yet caught up with other countries in adopting and implementing BIM for improved performance and efficiency. Various solutions have been proposed to tackle these issues, such as integrating unified country-wide BIM regulations and implementing educational programs for building professionals (Arayici et al., 2011). Overall, BIM adoption can produce a significant enhancement in the construction sector by understanding the main success drivers that take into consideration all the BIM implementation processes (Arayici et al., 2011; Eastman et al., 2011; Bryde et al., 2013; Rahman et al., 2019; Sacks et al., 2018). Many drivers for effective BIM implementation have been identified in the literature. However, till the knowledge of the authors, no studies in the UAE construction industry have grouped and prioritized them according to PEST analysis. As a result, this study aims to identify and prioritize the drivers and factors of BIM implementation as a sustainable construction practice in the UAE, utilizing the Analytical Hierarchy Process (AHP) to prioritize through subject matter experts. In the context of BIM and decision-making, PEST analysis can identify potential risks and opportunities associated with implementing BIM.

1.2 BIM implementation Drivers

BIM implementation factors refer to the characteristics or drivers essential for successfully adopting and using BIM in a construction project or organization. Some of the key BIM implementation attributes include political, economic, socio-cultural, and technological. For example, political factors such as government regulations and policies can affect the usage of BIM in construction plans (Ma et al., 2020; Feng et al.,2020; Dakhil, 2017). Economic factors such as funding and project costs can also impact the implementation of BIM, as mentioned by Du et al. (2018), Kim et al. (2019), and Sabri et al. (2018). Another important driver is the socio-cultural factors, such as the public's perception of BIM and its benefits, which can also play a role in its adoption (Shafiq, M. T, 2021; Li et al., 2020; Bashir & Sika, 2018). Technological factors, such as the availability of BIM software and the level of expertise of users, can also affect the implementation of BIM (Omar et al., 2020). The next part of the literature focuses on identifying the main drivers and factors impacting the BIM assessment and implantation and their contribution to the success of the BIM implementation process grouped as per PEST analysis.

1.3 Political Criteria

A previous study by Dakhil (2017) and Wang et al. (2020) concluded that government policies and regulations play an essential role in facilitating BIM within organizations that adopt policies or regulations that support or mandate the use of BIM, such as building codes or procurement rules. Moreover, previous studies have noted that industry associations may promote the use of BIM through guidelines, standards, or training programs. This has been noted by Ma et al. (2020), Feng et al. (2020), and Keller, K. L. (2016). Dakhil (2017) and Wang et al. (2020)., Another factor influencing BIM implementations is government funding. According to Wang et al. (2020) and Siebelink et al. (2017), governments may provide funding for BIM research and development or for organizations to adopt and implement BIM.

1.4 Economic Criteria

A study by sabri et al. 2018 mentioned that a country's inflation rate might influence the rate of adopting and implementing BIM. This measures the rate at which prices for goods and services are increasing. High inflation can lead to decreased consumer purchasing power and increased business uncertainty. Competitive advantage is another factor tackled in many studies (Chen et al., 2020) and (Alwisy et al., 2019). Adopting BIM may give organizations a

competitive advantage by improving efficiency and quality. This has been noted by Arslan et al. (2020) and Kim et al. (2020) from the Viewpoint of a Construction Project.
Lastly, the cost of implementing BIM and the financial considerations may influence an organization's decision to adopt BIM. This includes the initial investment in software, training, and other resources and the ongoing costs of maintaining and updating the BIM system. Previous studies, such as Du et al. (2018) and Kim et al. (2019), have found that the potential cost savings and efficiency improvements associated with BIM may outweigh the initial investment.

1.5 Socio-cultural criteria:

Adopting BIM may require changes to an organization's culture and values, such as a shift towards collaboration and innovation. This has been noted in a case study from the UAE by (Omar et al., 2020). Another factor is cultural influences; a study of how culture shapes consumer behaviours and decision by Tan et al. (2021) showed that culture could affect the acceptance of new products or services in different regions or countries (Li, Gao, & Lu, 2016). This includes factors such as the population's values, beliefs, and attitudes toward specific industries or technologies (Dalui et al., 2021). Furthermore, previous studies highlighted labour market conditions as one of the main socio-cultural attributes. This includes factors such as unemployment rates and job availability in the construction industry (Kotler, P., 2017; Ma et al., 2018; Lee & Rooke, 2016).
Additionally, skills and training consider one of the factors impacting adopting BIM. Which may require organizations to invest in employee training and development (Wang et al., 2018). According to a study by Ting Wang et al. (2018), the lack of sufficient skills and training is a barrier to adopting and using BIM. The authors found that organizations with more trained BIM personnel were likelier to use BIM effectively. Similarly, a study by Xiaozhi Ma et al. (2018) found that the availability of skilled personnel was a key driver of BIM adoption.

1.6 Technological criteria

The availability of BIM software, hardware, and other technologies may impact an organization's ability to adopt and use BIM (Wang & Feng, 2015). According to a study by Wang and Feng (2015), the availability of BIM technology is a critical factor in adopting and using BIM. The authors found that organizations with access to advanced BIM technology were likelier to use BIM in their projects. Similarly, a study by Xiaozhi Ma et al. (2018) found that the availability of BIM technology was a key driver of BIM adoption. Organizations need the technical infrastructure, software, and training to use BIM effectively. This has been noted by (Xu et al., 2019) and (Babatunde et al., 2018). According to a study by Sabri et al. (2020), the availability of infrastructure and support is a critical factor in adopting and using BIM. The authors found that organizations with robust IT infrastructure and support were more likely to use BIM effectively. Interoperability is one of the main factors addressed by many scholars as one of the BIM implementation drivers. The ability of different software and systems to work together seamlessly is essential to use BIM (Al Hattab et al., 2018). According to a study by Fernanda Leite (2016), interoperability is critical in successfully implementing BIM. The author found that organizations with reliable interoperability between different software systems were more likely to achieve high levels of BIM adoption. Another study by Sander Siebelink et al. (2017) found that interoperability was critical in effectively using BIM in the Dutch construction industry.
Moreover, data management skills are considered another crucial technological factor for BIM implementation. BIM's effective implementation requires the management of large amounts of data, which can be challenging for organizations without robust data management systems. This has been noted by (Guan et al., 2018; Du et al., 2019; Ju & Lu, 2018). To measure the level of BIM implementation within an organization, a variety of dimensions and attributes can be considered, as outlined in Table 1.

Table 1: *Drivers of BIM Effective Implementation.*

No.	***Main Criteria-PEST***	***Sub-criteria Indicator***	
		Name	***References***
1	***Political***	Government Policies and Regulations	Ma et al., 2020; Feng et al., 2020; Keller, K. L., 2016. Dakhil. 2017; and Wang et al., 2020.
		Government Funds	Feng et al., 2019; Zhang et al., 2017;.Wang and Feng (2021),

		Industry Associations	Wang et al., 2019; Wang et al., 2020 and Siebelink et al., 2017; Dalirazar & Sabzi. (2020); Zhang et al., 2017
2	***Economic***	Inflation Rate	Sabri et al., 2018 and Eilifsen et al. (2020)
		Competitive Advantage	Chen et al., 2020; Alwisy et al., 2019; Arslan et al., 2020 and Kim et al. (2020).
		Financial Considerations	Du et al. (2018); Kim et al. (2019); (Wang et al., 2020; Akbarnezhad et al., 2014).
3	***Socio-cultural***	Culture and Values	Kotler, P., 2017; Kazi et al., 2020; Omar et al., 2020.
		Labour Market Conditions	Kotler, P., 2017; Ma et al., 2018; Al Hattab et al., 2018; Sarhan et al. (2019).
		Skills and Training	Ting et al., 2018 ; Xiaozhi Ma et al., 2018; Maskil-Leitan & Reychav, 2018.
4	***Technological***	Availability of Technology	Wang & Feng, 2015; Ma et al., 2018; (Tally, R.S., 2016); Xu et al., 2019; Babatunde et al., 2018
		Interoperability	Wang & Leite, 2016; Siebelink et al., 2017; Hwang & Kim, 2017; (Tally, R.S., 2016)
		Data management skills	Omar et al., 2020.; Sabri et al., 2020; Lucky et al., 2019; Du et al., 2019.

2 Methodology

2.1 Study Area and Data Collection

The study was undertaken in the United Arab Emirates (UAE) and targeted the governmental and private construction sectors. In order to find the drivers for BIM implementation in the UAE, an AHP pairwise comparison questionnaire was constructed. Based on the literature review, 12 factors were selected as sub-criteria according to the most cited literature and then categorized as per PEST analysis, which will be elaborated on in the coming section. The data collection phase was done in two phases, primary and secondary. The primary phase was gathered from a literature review with all driver factors. The second phase was obtained through the questionnaire distributed to the field's subject experts.

2.2 Data Collection and Criteria Selection

At the data collection stage, the data was collected from the population of the United Arab Emirates construction industry. A sample of 48 respondents answered the distributed survey. The selection of BIM implementation drivers required the availability of relevant data; online experts panels interview was used to conduct the multicriteria analysis to rank the drivers based on their importance for the construction industry. To find out the parameters according to expert opinion in prioritizing the BIM implantation driver, an Analytic Hierarchy Process (AHP) pairwise comparison style questionnaire was prepared. Based on the conducted literature review, the following four main criteria and 12 sub-criteria were obtained and applied to the questionnaire construction.

2.3 PEST – AHP Analysis

A PEST analysis is used to study the critical external factors that influence an organization and can guide professionals and senior managers in strategic decision-making. In the context of BIM implementation, a PEST analysis can help identify the political, economic, socio-cultural, and technological factors that may impact the adoption and use of BIM within an organization. AHP is a multicriteria decision-making method developed by Saaty's 1977. Using linear weighing methods of qualitative and quantitative criteria, AHP has been successfully used in many sectors such as government, business, healthcare, and education. Moreover, AHP decision-making includes preferences and experiences. It is the best hierarchical framework for determining each criterion's relative importance. It represents and describes a problem, links its components to the overall objective, and explores alternative solutions to design a decision. AHP helps decision-makers choose the best solution to meet their goal and understand the problem (Abdelkarim et al., 2020; Kuber et al., 2017).

2.3.1 Data Validation and AHP Hierarchical Structure

Once the pairwise comparison matrices had been constructed, the weight of each decision was calculated using standard AHP computation. Then, a consistency ratio was obtained for the consistency of the results (Ng, 2016).
The study built an AHP hierarchy according to the relationship between the main criteria, sub-criteria, and alternatives—the proposed hierarchical structure as illustrated in Figure 1.

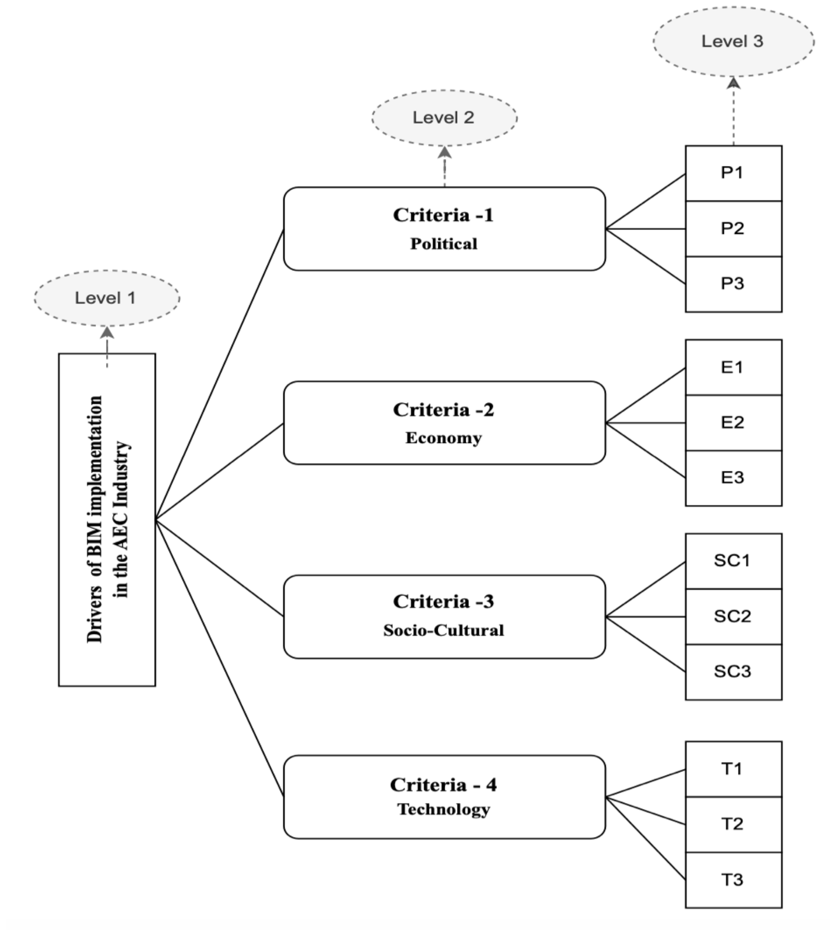

Figure 1:AHP Hierarchy Structure

3 Results

3.1 Demographics Results

After identifying the factors of BIM implementation from the literature review, as shown in Table.1. Some factors were selected which were relevant to the case in this study and categorized based on PEST categorization, as defined in the methodology section and Table.1. The gender distribution was almost 60% males and 40% females. The reason for that percentage is that most of the experts who work in the construction industry are male. The questionnaire targeted subject of experts from different job position levels (15.7% entry level, 35.31% analyst, 44.6% managerial level, and 5.2 % c-suite level) such as project managers, BIM managers, and contracting companies' managers in both private and governmental sector the former with 57% and the latter with 43% of the responses.

3.2 AHP Results

The pairwise comparison matrix was conducted for the main criteria, namely political, economic, socio-cultural, and technology, for all the 48 responses results based on Saaty's scale. Furthermore, all the comparison matrix was aggregated using the geometric mean method in one final comparison matrix (aggregated), and the local weights were calculated from the comparison matrix. The exact process has been followed for all sub-criteria to make the pairwise comparison matrix Table 2 shows the comparison matrix of the main criteria and their respective weights.

Table 2: Pairwise Comparison Matrix of Main Criteria (Aggregated)

Main Criteria	***Political***	***Economic***	***Technology***	***Socio-cultural***	***Criteria Weights***
Political	1	1.461004	0.835084	0.694968	0.242014
Economic	0.684461	1	0.872483	1.697385	0.252193
Technology	1.197485	1.146153	1	1.317931	**0.279641**
Socio-cultural	1.438914	0.589142	0.758765	1	**0.226152**

The exact process for all sub-criteria to do the pairwise comparison matrix has been followed. Tables 3, 4,5, and 6 show the pairwise comparison matrix of political, economic, socio-cultural, and technology, respectively, assigned with their weights.

Table 3: Pairwise Comparison Matrix of Sub-criteria - Political (Aggregated)

Political	***Government Policies and Regulations***	***Government Policies and Regulations***	***Government Policies and Regulations***	***Criteria Weights***
Government Policies and Regulations	1	1.304779	1.054818	0.369584
Government Funding	0.766413	1	1.075166	0.311661
Industry Associations	0.948031	0.930089	1	0.318755

Table 4: Pairwise Comparison Matrix of Sub-criteria – Economic (Aggregated)

Economic	***Inflation Rate***	***Competitive Advantage***	***Financial Considerations***	***Criteria Weights***
Inflation Rate	1	1.70979	2.413424	0.2728
Competitive Advantage	0.584867	1	1.649636	0.3068
Financial Considerations	0.414349	0.606194	1	0.1959

Table 5: Pairwise Comparison Matrix of Sub-criteria – Socio-cultural (Aggregated)

Socio-cultural	***Culture and Values***	***Labour Market Conditions***	***Skills and Training***	***Criteria Weights***
Culture and Values	1	1.077429	1.542646	0.1959
Labour Market Conditions	0.928136	1	1.21038	0.3901
Skills and Training	0.648237	0.826187	1	0.3423

Table 6: Pairwise Comparison Matrix of Sub-criteria – Technology (Aggregated)

Technology	*Availability of Technology*	*Interoperability*	*Data management skills*	*Criteria Weights*
Availability of Technology	1	1.02972	0.55739	0.4975
Interoperability	0.971138	1	0.858323	0.3087
Data management skills	1.794076	1.165063	1	0.4184

The consistency ratio for all criteria is listed in Table 7. All the consistency ratios are less than 0.1. So, all the criteria consistently create the overall weightage for BIM drivers' analysis. After comparing the consistency ratio analysis, the weights of the main criteria and their respective sub-criteria are multiplied to create overall global weights. The overall global weights are multiplied by 100 to calculate the percentage of every sub-criterion. Table 8 presents the percentage of every sub-criteria weights.

Table7: Consistency Ratio for All Criteria

Main and Sub-criteria	Consistency factors	Consistency Ratio
Main criteria	*Political* *Economic* *Socio-cultural* *Technological*	**0.005134**
Political	*Government Policies and Regulations* *Government Funding* *Industry Associations*	**0.008869**
Economic	*Inflation Rate* *Competitive Advantage* *Financial Considerations*	**0.003228**
Socio-cultural	*Culture and Values* *Labour Market Conditions* *Skills and Training*	**0.021302**
Technological	*Availability of Technology* *Interoperability* *Data management skills*	**0.0026938**

Table 8: Weights Derived from Performing Analytical Hierarchical Process

Main Criteria	*Weights of Main Criteria*	*Sub Criteria*	*Weights of sub criteria*	*Global weights (%)*	*Global Rank*
Political	0.2420	*Government Policies and Regulations*	**0.3696**	**8.94 %**	**3**
		Government Funding	0.3117	7.54 %	10
		Industry Associations	0.3187	7.71 %	8

Economic	0.2522	*Financial Consideration*	0.2728	7.63 %	9
		Competitive Advantage	0.3068	7.73 %	7
		Inflation Rate	**0.1959**	**4.94 %**	**12**
Socio-cultural	**0.2264**	***Culture and Values***	**0.3901**	**8.82 %**	**4**
		Labour Market Conditions	0.3423	7.77 %	6
		Skills and Training	0.2675	6.05 %	11
Technological	**0.2796**	***Availability of Technology***	**0.4975**	**12.55 %**	**1**
		Interoperability	0.3087	8.63 %	5
		Data management skills	0.4184	11.70 %	2

4. Discussion

The technological aspect was ranked first in terms of the main criteria. Overall, the technological aspects of the availability of technology and data management skills were ranked higher globally, contributing to the highest rank of the technological driver. This means that the technological capabilities of an organization are considered a key factor when implementing BIM, which complies with Wang & Feng (2015) and Ma et al. (2018). The last ranked factor in this aspect was Interoperability. Although the BIM implementation required a complex interaction between different data types and activities, understanding this concept would take much work in certain areas. It would not be capable of operating with that challenge.

The second-ranked main driver was economics. In this crucial aspect, it was provided by the expert panel that the competitive advantage was the highest ranked, as this means that the implementation can only achieve with an understanding of the competitive advantages of implementing BIM effectively. In addition, the financial consideration that would support the adoption was ranked second due to the importance of the financial support to facilitate the process of implementation in terms of resources and the financial capacity to withstand the demanding of this technology within the industry, which conform with the same findings of Du et al. (2018) and Kim et al. (2019), as they support this by indicating the importance of a well-planned financial plan and cash flow to support the BIM implementation in the construction industry. The inflation rate was ranked the least in terms of importance as understanding the indirect financial dimensions. The inflation rate might affect the BIM implementation at the regional level rather than the organizational level, which complies with Sabri et al. (2018) and Eilifsen et al. (2020).

However, the result indicated that the political driver was ranked third in importance for BIM implementation. The Government Policies and Regulations factors were ranked third globally. Wang et al. (2020) and Siebelink et al. (2017) note that governments may fund BIM research and development for organizations to adopt and facilitate BIM implementation in the construction industry.

Moreover, the socio-cultural aspect was ranked the least in terms of the main criteria. Because it does not provide a significant impact, technology can be rented to do particular work within the industry. However, from this aspect, the value and cultural norms were ranked fourth in the global ranking as the cultural norms and values of the different industry parties affect the BIM implementation. BIM adoption may also require changes to an organization's inherent culture and values, such as a shift toward collaboration and innovation. This factor was noted in a previous study by Shafiq, M. T. (2021) about client-Driven Level-2 BIM implementation.

5. Conclusions and Recommendations

The literature indicated that BIM is essential to enhance construction project performance throughout the project lifecycle. Moreover, it demonstrated that effective implementation and assessment of the BIM process increase the project's productivity, profitability, and business opportunities created by assessing and enhancing the management process, consequently enhancing the project performance. The BIM technique is used to retain and create information on a project's construction during each phase of its life cycle. This process comprises the formation of a coordinated visual depiction of each element of the produced thing utilizing suitable technology. Therefore, AHP analysis was done to assess the drivers gathered from the literature review hindering BIM implementation in the construction industry. The drivers were categorized into four main criteria based on PEST analysis: political, economic, socio-cultural, and technology, and under each criterion, three sub-criteria.

Moreover, the study sought to quantify and rank the relevant BIM drivers to assist decision-makers in deciding on their BIM implementation level. The results showed that the main driver influencing the BIM implementation was technology which ranked first among them. In summary, the construction sector can benefit from this study to develop a more reliable framework and assessment tool to measure the level of BIM implementation using the extracted factors and to overcome the challenges related to practical implementation to satisfy the targeted stakeholders.

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