Barriers to Integrating BIM and Sustainable Practices in UAE Construction Projects: Analytic Hierarchical Process Approach

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Abstract
The construction sector encounters significant obstacles in its shift to sustainable practices and the adoption of building information modeling (BIM) technologies. In the context of the Middle East, the United Arab Emirates has made significant efforts to integrate BIM into sustainable construction, which is utilized to advance procedures and has gotten extensive action in the literature worldwide. However, some cases in the UAE have taken advantage of this essential synergy between BIM and sustainable practices, while many others have remained on the sidelines, unable to realize the potential of BIM in sustainable initiatives fully. This paper aims to investigate the challenges and barriers faced in integrating BIM and sustainable practice in the UAE construction industry. An extensive literature review is conducted to define the main barriers that are used in designing the survey. The survey was distributed among different parties in the UAE construction industry. After data collection, data analysis took place using the AHP (Analytic Hierarchy Process) technique. Statistical tests were exploited for data analysis and used to elaborate and validate results. This kind of analysis study has been conducted in other developed countries like UK and USA; however, no such study has been done in UAE. The findings revealed that technological and financial factors are the main barriers to implementing BIM in the UAE. The research findings and suggested mitigation plan will facilitate the BIM adoption and integration in sustainable construction projects, allowing decision-makers to address the critical problems and barriers outlined in this study.

Keywords
BIM, UAE, Sustainable, Construction, AHP

1. Introduction

According to the UN's 2020 annual report, the construction industry is considered globally to be one of the largest contributing sectors to greenhouse gas emissions, freshwater consumption, and solid waste production. Aside from that, the sector accounts for more than 10 percent of the total labor force annually. To tackle these global concerns, the UAE government has accentuated regional leadership in its climate change policies, regulations, and green initiatives, among other initiatives which resulted in the country announcing the National Climate Change Plan 2017-2050 according to the ministry of energy and infrastructure in UAE. This plan helped in developing a framework that's aimed at reducing the impact of regional greenhouse gas emissions, achieving climate change adaptation, and enhancing the value of its competitive economic situation. Therefore, achieving sustainable development in the construction sector has become an urgent necessity for safeguarding the long-term resilience of buildings as urbanization continues to accelerate.

However, the construction sector faces significant problems with its shift to sustainable practices in construction. One of these practices is the implementation of building information modeling technologies. According to (Autodesk): "***Building information modeling (BIM) is a holistic process of creating and managing information for built assets of buildings information on a construction project throughout its whole life cycle. "***.

The Building Information Modeling (BIM) concept will improve the construction industry's performance, profitability, and sustainability. In the Middle East, the United Arab Emirates has made remarkable efforts in implementing BIM technology into sustainable practices within construction projects which will help in enhancing the green practices within the building sector. This technology has gotten extensive focus and interest in the literature worldwide. Nonetheless, some cases have taken advantage of this essential synergy between building information modeling (BIM) and green practices in the United Arab Emirates, while others have not fully utilized the potential of BIM in the sustainable construction industry.

The study will help improve the understanding of the Building Information Modeling concept and close the knowledge gap in the UAE construction sector and organizations about the efficient use of BIM. Additionally, the barriers and challenges that have been identified will help in the development of a successful BIM implementation framework that will assist in optimizing the design, resulting in lower capital and lifetime costs due to superior material and energy efficiencies which are considered a crucial element in achieving countries' competitiveness stand. Furthermore, effective implementation will increase the quality of the design and construction of the built design which will give a better living environment.

Objectives

Accordingly, after reviewing the existing literature and previously researching the subject, a noticeable lack of knowledge on BIM's effective implementation process in the UAE construction industry was found to be present. Therefore, this research seeks to fill this knowledge gap where it aims to identify the barriers and challenges facing the effective implementation process of BIM within the construction industry in UAE by answering the following research questions.

- What are the social, economic, and technological barriers facing the implementation of BIM in the UAE sustainable construction industry?
- What are the benefits of achieving successful protocols and frameworks of BIM proper implementation?
- How the effective implementation of BIM in the UAE construction industry helps in achieving the Sustainable Development Goals?

The research aim will be achieved through these objectives:

- Develop a clear understanding of the current stand of the BIM implementation process in the sustainable construction industry globally and the UAE.
- Explore the benefits of successful BIM implementation in sustainable practices in construction projects.

2. Literature Review

Rigorous literature review took place to define the barriers and challenges of integrating BIM in the sustainable construction industry. All previous studies concerning in these areas were reviewed and data was extracted and mentioned in this study.

2.1 Building Information Modelling in The Global Construction Industry

BIM is currently widely used across the world, with several countries indicating that it is having an impact on their businesses at various levels (Mohamed 2018). The developed world's construction sector is hurrying to embrace BIM as a catalyst for improving operational efficiency, saving money, and cutting down costs. With BIM adoption growing dramatically in the previous years, construction firms have indicated a positive return on investment with more savings projected in the future (Mohamed 2018). As Mustafa states in (Mustaffa et al. 2017) that while some countries such as the United States, United Kingdom, Germany, Canada, and France have been leading the way in BIM implementation, relatively new adopters such as Australia, Brazil, Japan, Korea, and New Zealand are quickly gaining traction and even outperforming the more established countries in some areas.

BIM is an intelligent approach in the construction sector, especially in the planning stage and it's being used in many ways and at various levels by governments throughout the world (Charef et al. 2019). According to Robert (Eadie et al. 2013), BIM is mandatory in all the government construction projects in the United Kingdom which indicates that only BIM-enabled firms are qualified to compete on government contracts (Eadie et al. 2013). As a result of the government's strong efforts, the implementation of BIM technology has increased rapidly across the UK. However, in the United States, (Wong et al. 2011) BIM is not yet mandatory in all the states, but it is predicted to grow significantly in the coming years. For example (Cheng & Lu 2015), the state of Wisconsin made it compulsory to implement BIM for public projects that have a total budget of a minimum of $5 million.

There is still a lot of room for BIM to grow and become more generally applied in China. Since 2001, the Ministry of Housing and Urban-Rural Development (MOHURD) has concentrated on implementing BIM technology and broadening its application (Wong et al. 2011). Hong Kong, for example, does have a very high BIM adoption rate and strong BIM standards that are equal to those in the United Kingdom.

When it comes to the Scandinavian countries; Norway, Denmark, Finland, and Sweden were among the first to implement BIM (Smith, 2014). These countries have established mandates for public projects where BIM should be used. They are among the world's pioneers in BIM adoption and implementation.

Another country that has adopted a national BIM strategy in Germany. This has been accomplished through standardizing processes and campaigning for BIM to be made compulsory in public infrastructure projects (Charef et al. 2019). Germany intends to completely adopt BIM in all phases of the construction process by 2025 and to make it compulsory for all transportation and public infrastructure projects. BIM is being implemented all around the world, with different countries mandating its use. In particular, the implementation of BIM is quickly increasing in developed countries such as the United States and the United Kingdom, with government mandates to encourage adoption through the development of plans and initiatives (Mehran, 2016).

2.2 Building Information Modelling in The Context of The UAE Construction Industry

Zaini et al. (2019) points out that the increased adoption of building information modeling (BIM) is based on its potential to transform the construction industry to higher levels, increasing efficiency and productivity. Remarkably, the UAE has witnessed a high level of development over the past 25 years among all sectors, with the construction industry remaining central to its development.

The original mandate for BIM in UAE was first introduced as a requirement in Dubai in 2013 by Dubai Municipality's Circular No. 196, which says that BIM is to be implemented concerning the "architectural and MEP work" (Hore et al. 2016):

- Buildings that have at least 40 floors.
- Buildings with areas at least 300,000 square feet.
- Special buildings such as hospitals and universities.

In the UAE construction industry, BIM has provided a solution for enhanced performance and profitability (Mehran, 2016). This assertion conforms to the findings by Olawumi and Chan (2018), affirming that the adoption of BIM in a given construction industry contributes to informed decision-making among stakeholders. Similarly, a study by Venkatachalam (2017) concluded that BIM is vital for building complex sustainable infrastructures in the UAE construction industry. However, Venkatachalam (2017) also pointed out that the UAE lags in implementing BIM compared to other developed countries such as the UK and the US where the implementation barriers are the main challenge. Furthermore, Mehran (2016) found out that the UAE's minimal adoption of BIM in the construction industry is a product of a lack of BIM standards and awareness, leading to resistance to change in the construction sector. Therefore, UAE continues to lag in adopting and implementing BIM as a strategy for enhanced performance and efficiency.

Due to the existence of several implementation barriers (Venkatachalam, 2017), the adoption of BIM in the United Arab Emirates (UAE) and other developing countries lags where BIM adoption appears to be gradual in the UAE with some of the large projects has implemented.

2.3 Barriers to Implement Building Information Modelling in The Construction Industry

Building Information Modelling is a process that presents many challenges and opportunities in the AEC industry. Observably, there are several barriers to the method of implementing Building Information Modelling. Most of these barriers have been successfully managed over the years due to the development of interconnected technologies. However, there are some issues that arise when dealing with BIM preventing its full implementation in the industry. Contract and legitimate barriers, security and economic issues, management system, and cultural issues are the most significant challenges to putting this technology into effective practice. Building Information Modelling technology is a radical innovation in the construction industry that virtually designs projects and manages them in their whole building lifecycle.

The construction industry is among the biggest economic sectors in the whole world which make building information modeling one of the greatest forms of technology to plan. The five most significant barriers to implementing building information modeling are the lack of awareness, high cost of buying the software, learning curve, training expenses, and social resistance to change. The main aim of building information modeling is to build a complete project virtually before the actual project structure begins physically to detect any potential conflicts, problems, and risks. Besides, it analyses the process and techniques of construction and the socio-economic issues during the early planning stage of the project. This paper will focus on the social, technological, and financial barriers to implementing building information modeling in the construction industry.

2.3.1 Social Barriers

The habitual and social resistance to change is a very natural factor in all living organisms (Charef et al. 2019). This resistance to change is mainly due to the fact of trying to keep everyone involved in the concerned matter unaffected such as shareholders in construction projects (Ahmed, 2019). Another most substantial factor is the old-style method of construction where most of the involved individuals are used and adapted to the old-style method of construction and they've been practicing it for a long period of time which made them skillful and quick with it (Gao et al. 2019). Therefore, replacing this traditional method is not an easy task for the shareholders, and also it is unacceptable for every person (Chan et al. 2019). According to Matthews et al., 2015, lack of training and education is another social barrier to the effective implementation of building information modeling in the construction industry since most people lack BIM knowledge from either the firm or education. Yin et al. 2019, observed that the lack of training from different construction firms is mostly contributed by the challenging software constant development and high cost of training. In essence, building information modeling software costs put a large obstacle to the implementation of the software (Aranda-Mena 2020).Moreover, according to Charef (2019), the barriers preventing the implementation of building information modeling technology include employees' fear of making changes, reluctance, and habits.

2.3.2 Technological Barriers

Building Information Modelling is utilized vaguely with inappropriate certifications and practices (Bueno et al. 2018). The inadequate use of the technology in the construction industry shows the existing shortage of building project experts skilled in construction practices and collaborative design (Sacks et al. 2018). Besides, the lack of preparedness to boost qualifications in the field of building information modeling technology and a low level of consciousness of the importance of introducing a virtual environment to the plan are other obstacles to implementing the software (Dixit et al. 2019). In addition, the machinery used in the construction industry is only in English which causes a great problem for the elderly participants in the process of construction (Bueno et al. 2018). Another issue lies in the computer hardware in medium and small-sized companies where in most cases the hardware can be insufficient and outdated to produce multi-dimensional models. (Charef et al. 2019) state that lack of management team commitment, lack of readiness to collaborate with other experts, and lack of agreement to higher compensations for building information modeling coordinators result in a lack of professionals. In consequence, these issues become barriers that delay the implementation of building information modeling in construction enterprises (Antwi-Afari et al. 2018). Moreover, productivity applications and operating systems need constant updates (Aranda-Mena et al. 2020) which requires the companies to constantly update their software and hardware systems and devices.

Financial Barriers
According to Saieg et al. 2018, the extremely high cost of software and training for workers are two of the major barriers to the implementation of building information modeling in the construction industry. Such costs are the ones that companies suffer from at the beginning of the investment. The low costs of construction and project documentation do not cover the prices allocated to implement the building information modeling technology. Moreover, no subsidies or co-financing are meant for the implementation of the building information modeling environment that would let medium and small-sized companies implement and begin to model in the computer-generated cloud (Sacks et al. 2018). The cost factor is one of the major contributors to preventing the implementation of building information modeling since more work should be done to improve the knowledge on building information modeling and related training since lack of training and education is a social barrier to the effective implementation of building information modeling in the construction industry. Most people lack building information knowledge from either the firm or education. In the technological category, the machinery used in the construction industry is only in English which causes a great problem for the elderly participants in the construction sector.

2.4 The Benefits of Successful BIM Implementation in Sustainable Construction Project
There have been several attempts to develop methods to calculate and quantify the benefits of BIM and related information system adoption in the construction industry, but existing methods of analysis lack industry acceptance and fail to provide a principal framework methodology that can measure comparable data across multiple projects. Building Information Modelling (BIM) implementation in construction projects can enhance the quality of the information provided for making critical design decisions regarding a building's environmental impact. Based on (Olawumi & Chan 2018), BIM capability serves application and process:

The application is a software that provides information-rich 3D models and associated structured data that help in analyzing the construction projects using Revit, ArchiCAD, Tekla Structures, or other BIM software.
The process is the procedure that enables other knowledge areas such as construction project management, scheduling, and planning, cost estimation and control, construction safety, and sustainability parameters to be embedded in BIM software to provide a single source of information for project stakeholders. BIM is vital for construction stakeholders and organizations in managing project data and provides considerable value to construction projects throughout the lifecycle stages.

Santos (Santos et al. 2019) pointed out that the increased adoption of BIM in the construction industry contributes to model-based cost estimation, thus mitigating risks and reducing construction costs. Ireland's National BIM Council reported that successful implementation of BIM in the construction sector would cut down the cost of construction projects by at least 20%, translating into economic gain. Agreeably, Amuda-Yusuf (2018) affirms that the effective implementation of BIM increases the reliability of a construction project, allowing for adequate cost-saving planning. Besides during the early stages of project development, feasibility studies, and planning stages, BIM allows for the fullest control of the compliance with regulations, having easy access to different types of manufacturer's data allows the project team to make a fast decision on the basis of true data that becomes embedded in the model-based of real-life information. ((Olawumi & Chan 2018) highlighted that the success of BIM implementation in construction projects is measured from a social perspective.

To this extent, the effective implementation of BIM would improve collaboration and coordination of construction projects with different stakeholders through improved communications, resulting in higher quality projects. Furthermore, in the operation stage, BIM ensures that high standards of sustainability are maintained by making all the data concerning replacements, refurbishments, and renewals available. The social benefit of BIM is that all stakeholders can take advantage of a digital document that they can all share at the same time which will help in eliminating the chance of undesired surprises over the years of usage. Affirmatively, (Wang et al. 2021) mentioned that BIM leads to construction projects delivering common reasonable measures in economic terms. Thus, the economic needs of the stakeholders are met, translating to business solutions and economic development. The contribution of BIM to a sustainable built environment contributes to the micro-level representation of buildings, reflecting the economic needs and priorities of a given locality and contributing to the economic growth at all levels of a country (Wang et al. 2019). In contrast, Khahro et al. (2021) argue that assessing the contribution of BIM on the economic growth level is a complex concept involving analysis of cost and carbon emission to ensure that a building does not deprive other sectors of resources. BIM benefits environmental, social and economic aspects of sustainability.

It brings productivity up because no time is wasted digging through scattered pieces of information needed for decision making.

BIM could support various aspects of sustainable/green buildings during their lifecycle, as shown in Figure 1. Current research studies suggest that the benefits of implementing BIM in the lifecycle process can be classified into three phases. First, BIM data can be exchanged among multi-disciplinary users with different analysis tools for sustainability. For instance, a BIM model can integrate the information necessary for green building design, automate the design evaluation processes and facilitate simple updates on the building model on a common but distributed platform. Second, BIM applications can provide visual information related to building performance and process and thus enable project participants, such as designers, contractors, and owners to make more environmental-friendly decisions. For instance, a BIM-based energy consumption assessment of a building was designed to provide a graphical visualization of energy performance indices (Schlueter & Thesseling 2009). Third, BIM could enhance the communication and collaboration of various stakeholders associated with green design, construction, and operation (Grilo & Jardim-Goncalves 2010). This integrated platform offers a new paradigm for all stakeholders who are working on the same project for a shared vision (Azhar et al. 2012) which will strengthen the ties among all project parties who, in the building and construction industry, had previously experienced fragmented relations.

2.5 Building Information Modelling and Sustainable Development Goals

Mésároš et al. (2021) argued that the sustainability of projects is a critical subject of discussion in the construction sector. This observation explains the increased pressure on the construction industry to contribute to the achievement of sustainable development goals (SDGs). According to Fei et al. (2021), the construction industry is involved in mega projects directly impacting communities and the environment, emphasizing the need for the sector to remain socio-economically sustainable. Notably, Shaikh et al. (2017) pointed out that BIM as a tool in the construction industry can redefine the sector and lead it to sustainable development through sustainable designs incorporating socio-economic factors. Similarly, Goubran and Cucuzzella (2019) pointed out that BIM contributes to the integration of SDGs and the development plan of the construction industry, making it vital in minimizing the challenges in the sector and contributing to the achievement of the SDGs. Arguably, Fei et al. (2021) asserted that BIM allows the construction industry to translate its goals into business solutions, contributing to the achievement of the SDGs. In contrast, Khahro et al. (2021) argued that achieving SDGs is a collaborative approach bringing together different sectors and stakeholders, including the government, for reliability, affordability, and sustainability.

Summary

Based on the extracted data, a survey was designed for the data collection. The data consists of the main three barriers of integrating BIM in sustainable construction projects, and nine sub criteria, which are sub barriers divided under the technological, financial, and social barriers.

3. Methods

3.1 Analytical Hierarchy Process

AHP is considered a multicriteria decision-making (MCDM) tool which is used to prioritize selected criteria. It is a linear weighing technique developed by Saaty in 1977 to weigh both qualitative and quantitative criteria. AHP is structured in four phases, first structuring the decision problem, second measurement and data collection, third setting the normalized weights, and fourth getting the final problem (Tam & Tummala 2001). In addition, AHP is a hierarchal structure that helps in getting the importance of each criterion related to different sub-criteria related to it. It uses a 1-9 scale to denote the relative importance where 1 indicates "equally important" and 9 indicates "extremely important". The AHP scale was developed in 1980 by Saaty and it is shown in table 1. In this study 9 barriers were selected and grouped under three categories which are (1) social aspect, (2) technological aspect, and (3) financial aspect. Respectively, this study followed a three-level AHP analysis.

Table 1. Saaty 1980 AHP pairwise comparison importance scale.

Numerical Value	Definition
1	Factor i and j are equally important
3	Factor i is weak and important
5	Factor i is moderate important
7	Factor i is a strong important
9	Factor i is absolute/extreme important
2,4,6,8	Intermediate values between the two adjacent values
Reciprocal	If the important rate of factor i to j is Pxy, then the important rate of factor j to i is Pyx = 1/Px

4. Data Collection

After identifying the critical social, economic, and technological barriers and challenges facing the successful implementation of BIM in the UAE sustainable construction industry from the literature review, a pairwise comparison questionnaire was prepared to serve the goal of the analytical hierarchy process, which is prioritizing the selected barriers. Data collection tools is an online conducted survey that was distributed among various participants in the UAE construction industry. 30 representative responses were gathered and analyzed for this study.

5. Results and Discussion

5.1 Demographics Results

The questionnaire targeted subject of experts (a total of 25 respondents) from different job position levels; 8% entry level, 40% analyst, 48% managerial level, and 4% c-suite level, as shown in figure 1, such as project managers and directors, construction managers, design managers and engineers, resident engineers, project planning and control managers and engineers, as indicated in figure 2.

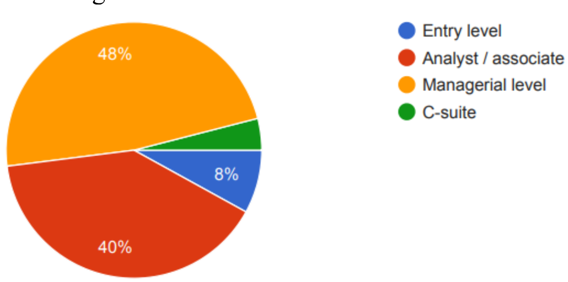

Figure 1. Participant's positions

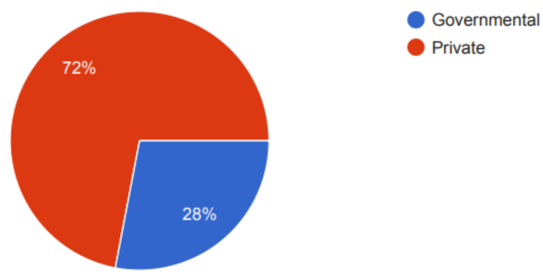

Figure 2. Participant's organization

BIM managers and engineers in both private and governmental sectors the former with 72% and the latter with 28% of the responses with years of experience range from less than 5 years (20%), from 5 up to 10 years (52%) and from 11 to 20 years (28%), as reflected in figure 3. In addition to this, 68% of the respondents mentioned that they knew about Building information modeling (BIM) where 28% of them come from the contractor and client firms, 20% from construction management firms, 16% from consultant/engineering firms, and 8% from subcontractor companies, as reflected in figures 4 and figure 5.

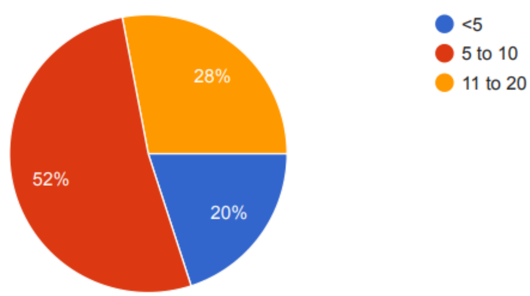

Figure 3. Years of experience

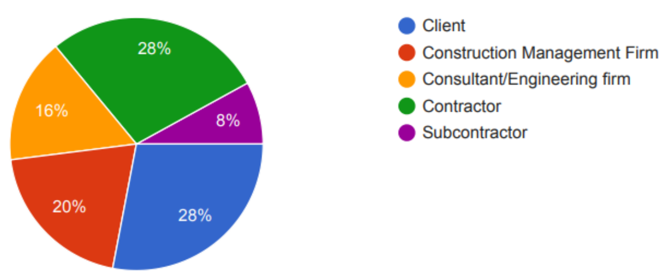

Figure 4. Organization type

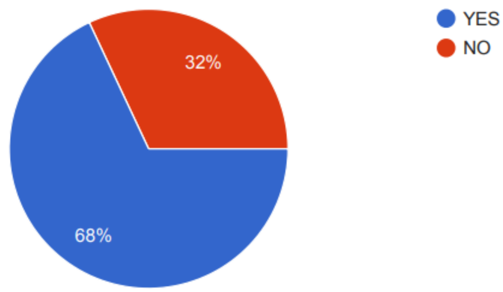

Figure 5. Previous BIM knowledge

5.2 Barriers Ranking and Weights

The AHP analysis was used to prioritize the selected barriers (social, technological, and financial). A pairwise comparison matrix was done for the three main criteria and then the sub-criteria under each main criteria against each other for all the 25 response results based on Saaty's scale. Among the main criteria, the technological aspect ranked the first weighing 50%, followed by the financial aspect at 34%, and lastly social aspect at 16%, figure 7. Regarding the weights for the sub-criteria, under the technological aspect, lack of preparedness ranked the first weighing 45%. For the financial aspect, the high cost of software ranked first weighing 42%. The obtained weights from AHP for all the sub-criteria are listed in Table 2 demonstrating the overall global weights and ranking.

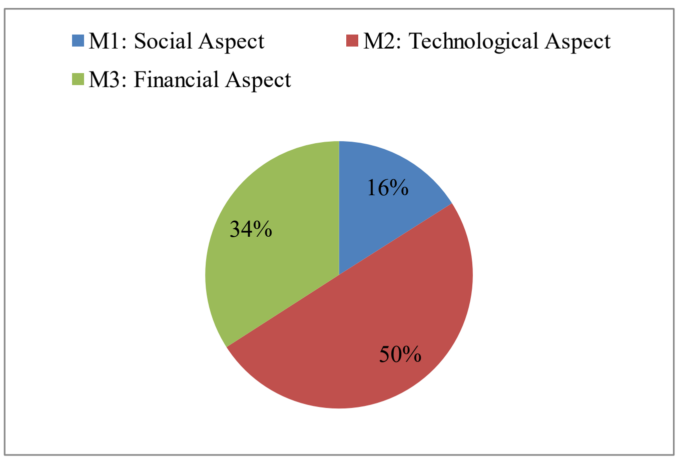

Figure 6. Main impacting criteria

Table 2. Weights and ranking of BIM barriers

Criteria	Weight	Rank	Sub-criteria	Local Weight	Global Weight	Rank
Social Aspect	0.1600288	3	Resistance to change	0.430604412	0.068909095	7
			Old-style method of constructing	0.170650329	0.027308962	9
			Lack of training and education	0.398745259	0.063810714	8

Technological Aspect	0.4991088	1	Lack of preparedness	0.448332815	0.223766861	1
			Software difficulties	0.267824657	0.133673648	4
			Low level of consciousness of the importance of introducing a virtual environment	0.283842528	0.141668308	3
Financial Aspect	0.3408624	2	High cost of software	0.420233474	0.143241796	2
			High cost of training	0.261358772	0.089087382	6
			Lack of subsidies or co-financing for the implementation	0.318407754	0.108533235	5

As the purpose of this paper is to investigate the challenges and barriers faced by the construction industry in implementing BIM in sustainable construction practices in UAE, this research findings will allow the decision-makers to focus on addressing the critical problems. Thus, the survey results show that a sample size of 25 respondents who have already worked in the field of BIM indicated that the highest challenge that they're facing in implementing BIM is the technological aspect which is reasonable and expected due mainly to the lack of preparedness in the market to improve the qualifications in this field, a low level of consciousness of the importance of introducing a virtual environment and the difficulties that come with dealing with this software, as indicated in figure 7. Therefore, these technological barriers ranked among the top in preventing the successful implementation of BIM in sustainable construction management which is supported in their discussions.

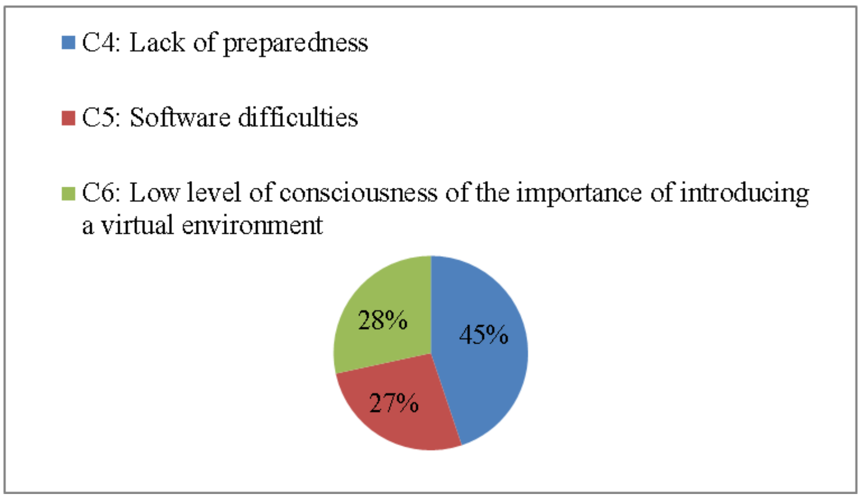

Figure 7. Technological aspect

While the financial aspect ranked second; it's considered as important to the respondents since the sub-criterion of the high cost of software is the 2nd highest ranked within the sub-criteria due to the initial cost of buying such software and building the necessary IT infrastructure to run them, illustrated clearly in figure 8. Nonetheless, these types of software will need ongoing updates due to the constant technological development which will require the IT systems to be updated in the concerned company to keep up with these software updates, all this leads to high expenditures confirm.

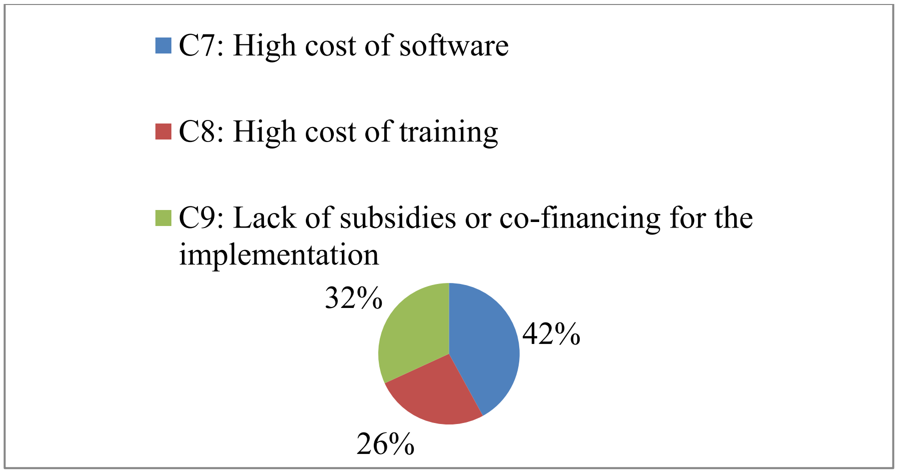

Figure 8. Financial aspect

The last ranked barrier seen by the respondents is the social aspect which makes sense as people always try to maintain the status quo and avoid any new changes which may cause unknown risks and problems, figure 9. However, people do have the potential to embrace new changes if they are equipped with what can make them cope with the new status such as education, training, and the proper digital infrastructure, that's why this barrier was ranked the least affecting one which confirms with what explained.

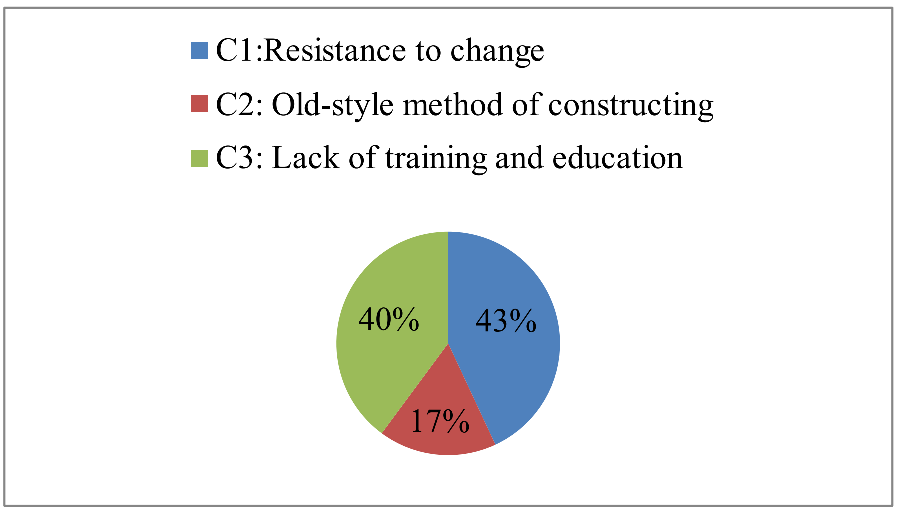

Figure 9. Social aspect

Conclusion

This research study investigated and examined the social, economic, and technological barriers and challenges facing the successful implementation of BIM in the UAE sustainable construction industry where the technological aspect was found to be the most affecting barrier with three of its sub-criteria were found to be among the top influencing barriers of all the sub-criteria. This study also explored the benefits of successful BIM implementation in sustainable practices in construction projects. The findings of this research study will facilitate the BIM adoption and integration in sustainable construction projects, allowing the decision-makers to focus on addressing the critical problems and barriers outlined in the study.

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