CITC GLOBAL
Construction in the 21st Century

The Fourteenth International Conference on Construction in the 21st Century (CITC-14)
Rio de Janeiro, Brazil | **September 2-5, 2024**

Barriers to BIM Implementation in Sustainable Building Projects in Türkiye

Irmak Aksoy[1] and Emre Caner Akcay[1*]

[1] Atilim University, 06830 Ankara, Türkiye
*caner.akcay@atilim.edu.tr

Abstract
As the construction industry is a major contributor to greenhouse gas emissions, sustainable building projects play a vital role in mitigating its harmful environmental impact. Building energy analysis is particularly important for sustainable projects. Building Information Modeling (BIM), which enables comprehensive data management and analysis throughout the building lifecycle, has emerged as an indispensable tool at every stage of sustainable building projects. This study aims to investigate the barriers hindering the implementation of BIM in sustainable building projects in Türkiye. For this purpose, potential barriers were initially identified through literature searches in databases such as Scopus and Web of Science. Following the literature review, a structured questionnaire was designed to evaluate the significance of 18 identified barriers on the use of BIM technology in green buildings. The results indicate that significant impediments include financial barriers such as high licensing costs, the high costs of BIM experts, and high training costs. The findings highlight the critical need for support mechanisms to facilitate the broader adoption of BIM in sustainable construction practices.

Keywords
Barrier, Building Information Modeling, Sustainable Building Projects, Türkiye

1. Introduction

Over the past decade, carbon emissions, global warming, and climate change have emerged as pivotal issues in international policy discussions (Alsehrawy et *al.*, 2020). The construction sector is a significant contributor to greenhouse gas emissions, primarily due to its substantial energy consumption, waste generation, and various related processes (Labaran et *al.*, 2021). Buildings notably influence the environmental footprint of the construction sector (Veselka et *al.*, 2020), accounting for approximately 25% of CO_2 emissions and one-third of global energy usage (González-Torres et *al.*, 2022). Nonetheless, buildings present an opportunity to alleviate this environmental burden through measures aimed at reducing energy consumption (Nizam et *al.*, 2018). The concept of sustainable building has thus gained considerable traction, advocating for practices that minimize energy, water, and material usage, thereby promoting environmentally sustainable approaches (Zhang et *al.*, 2019). Global attention has been drawn to this concept, prompting the construction sector to transform in order to mitigate its environmental impact throughout the project life cycle (Zhang et *al.*, 2019; Ma and Wang, 2021).

For sustainable building projects, conducting an energy analysis typically necessitates the integration of data pertaining to the building's form, orientation, materials, and mechanical, electrical, and plumbing (MEP) systems (Mohanta and Das, 2022). Building Information Modeling (BIM) facilitates the digital management of project data and essential building design elements throughout a building's life cycle (Penttilä, 2006). BIM enables comprehensive analyses, including lighting analysis, construction and demolition waste analysis, and energy performance simulation, thereby supporting various stages of the project (Lu et *al.*, 2017). Unlike previous tools, BIM consolidates multiple models into a unified structure, enhancing precision and efficiency (Mohanta and Das, 2022). Given the more stringent requirements and standards of sustainable buildings compared to traditional ones, BIM proves to be an invaluable tool throughout the various stages of these projects (Cao et *al.*, 2022; Hwang et *al.*, 2018).

Despite BIM's widespread adoption in several countries, its implementation in sustainable building projects has not yet reached desired levels in certain regions. This study aims to elucidate the barriers impeding BIM implementation in sustainable building projects in Türkiye.

2. Research Background

2.1 Building Information Modeling (BIM) Implementation in Sustainable Buildings

BIM offers efficient and environmentally friendly solutions for energy performance analyses of buildings (Zhang et *al.*, 2019; Mohanta and Das, 2022; Lu et *al.*, 2017). Several researchers have investigated BIM's viability for sustainability analyses. For instance, Azhar and Brown (2009) examined BIM’s suitability for sustainability analyses, demonstrating that BIM can capture and coordinate information into a single integrated model, thereby streamlining the complex process of sustainable design. Jalaei and Jrade (2015) proposed a model that integrates the LEED system with BIM to provide comprehensive information regarding the sustainability of buildings. Najjar et al. (2017) combined BIM with Life Cycle Assessment (LCA) to evaluate the environmental impacts of building materials during the early design stages. Azhar et al. (2011) illustrated how designers can utilize BIM to achieve desired LEED certification. Liu et al. (2015) proposed a BIM-based approach for building design optimization, which assists designers in enhancing the sustainability of their designs.

2.2 Challenges of BIM Implementation in Sustainable Buildings

Although BIM is considered a promising technology for green building construction (Cao et *al.*, 2022), several barriers hinder its broader implementation. Zhang et *al.* (2019) identified four primary factors impeding BIM adoption in sustainable construction projects in China: “public participation”, “technology application”, “economic cost” and “application management”. Huang et *al.* (2021) identified six major obstacles to BIM's promotion of green buildings, including: “non-uniform BIM standards”, “inefficient information interaction between construction and BIM software”, “insufficient BIM technical training for employees”, “unreasonable government and enterprise management methods lacking rational top-level planning”, “high initial investment with unpredictable economic returns”, and “lack of policy guidance and guarantees”. Mohanta and Das (2022) identified 12 key challenges to BIM adoption in the Green Building Sector in India. Manzoor et *al.* (2021) explored barriers to BIM implementation in sustainable building projects in Malaysia. They reported the top five critical barriers as: “unavailability of standards and guidelines”, “lack of BIM training”, “lack of expertise”, “high cost”, and “lack of research and BIM implementation”. Kineber et *al.* (2023) examined the barriers to BIM implementation in sustainable construction projects in Egypt. They identified four categories of barriers, i.e., technology and business, training and people, cost and standards, and process and economic. Murti and Muslim (2023) explored barriers to BIM adoption in sustainable construction in Indonesia. They listed the top two barriers as “lack of demand from clients” and “perception of implementation as additional work”.

3. Methodology

The objective of this research is to identify and analyze the barriers to BIM implementation in sustainable building projects in Türkiye. Figure 1 shows the research methodology employed to achieve the study’s aims. The methodology consists of five sequential steps: literature review, questionnaire design, data collection, data analysis, and presentation of results.

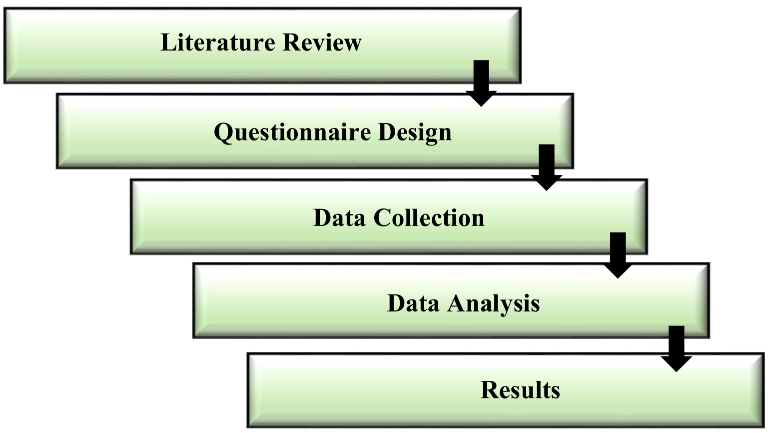

Fig. 1. Research Methodology

The first step was conducting an extensive literature review to identify potential barriers to BIM implementation in sustainable building projects. This step included a thorough analysis of existing research using the Scopus and Web of Science databases. The aim was to synthesize previous studies to create a list of potential barriers. Table 1 presents the barriers identified through this process.

Table 1. Barriers to BIM implementation for Sustainable Building Projects

Barrier ID	Barrier Name
B1	Lack of qualified BIM users
B2	Resistance of professionals to new technologies
B3	Lack of knowledge about BIM implementation in sustainable buildings
B4	Lack of sufficient experts in BIM and sustainable buildings
B5	Lack of BIM implementation guidelines and standards in sustainable buildings
B6	Copyright problems about data
B7	Difficulty of use in complex projects
B8	Lack of coordination among project stakeholders
B9	Lack of market demand
B10	Lack of government support
B11	Lack of demonstration projects to recommend BIM implementation in sustainable buildings
B12	Interoperability problems in Building Information Modeling (BIM)
B13	No specific BIM type (eQUEST, Autodesk Green Building Studio etc.) that conducts all sustainable analysis
B14	Unreliable estimation for the energy performance analysis of sustainable buildings
B15	The complexity of interface of the BIM software
B16	High training cost
B17	High licensing cost
B18	High cost of BIM experts

Following the literature review, a structured questionnaire was designed based on the identified barriers. Adopting a quantitative research approach, this study utilized closed-ended questions to collect data. The questionnaire comprised two sections: the first section collected general and demographic information from the participants, while the second section employed a 5-point Likert scale to evaluate the significance of the 18 identified barriers. The questionnaire was designed using Google Forms.

In the third step, the questionnaires were disseminated to the target population via email, accompanied by a link to the online questionnaire. Akcay (2023) mentioned the importance of selecting appropriate target respondents for effective data collection. Therefore, the target participants included representatives from both the public and private sectors with relevant experience in BIM and sustainable building projects. A total of 82 responses were initially collected. However, three responses were incomplete and subsequently excluded, resulting in 79 valid responses for further analysis.

To determine the significance of each barrier, the collected data were analyzed using the mean score ranking. The mean score for the significance of each barrier was calculated using the following formula:

$$\bar{S} = \frac{\sum S}{N} \quad (1)$$

where $\bar{S}$ represents the mean score of the significance of a barrier, $\sum S$ denotes the sum of each response value for the significance of a barrier (rated on a scale of 1 to 5), and N is the total number of valid responses.

The final step was presenting the results. The findings were analyzed to provide insights into the most significant barriers to BIM implementation for sustainable building projects in Türkiye.

4. Results and Discussion

4.1 Demographic Information

The demographic information of the respondents based on their profession, educational qualifications, and sectors of employment, as illustrated in the three pie charts, is presented in Figure 2.
Professionally, the majority of the respondents (51 of them) are civil engineers, comprising 64.56% of the sample. Architects constitute the second-largest group at 21.52% (17 respondents), followed by mechanical engineers at 11.39% (9 respondents). A minor proportion of respondents are energy systems engineers and industrial engineers, each accounting for 1.27% (1 respondent) of the survey population.
In terms of educational qualifications, the most prevalent degree among the respondents is a Bachelor of Science (B.Sc.), held by 59.49% (47 respondents) of the participants. This is followed by a Master of Science (M.Sc.) degree, held by 29.11% (23 respondents) of the respondents. Individuals with a Doctor of Philosophy (Ph.D.) degree represent 11.39% (9 respondents) of the sample.
In terms of employment sector, 66 (83.54%) respondents are employed in the private sector, while the remaining 13 (16.46%) are employed in the public sector.

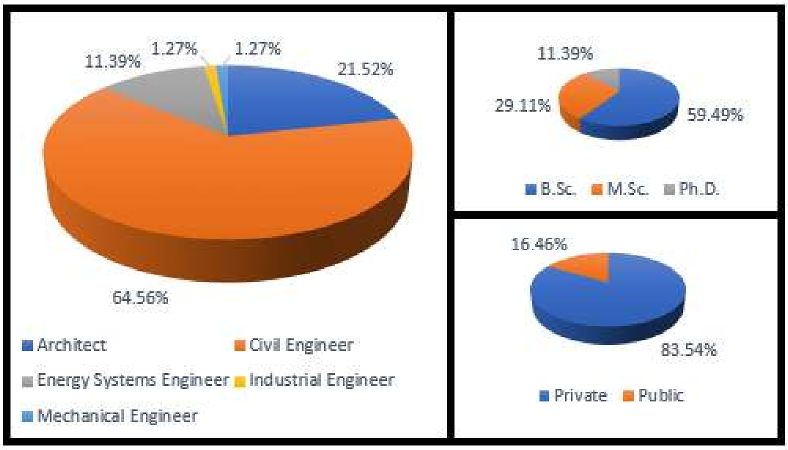

Fig. 2. Demographic information about respondents

4.2 Ranking of Barriers

The highest mean scores were observed for financial barriers, with "**High licensing cost (B17)"** scoring the highest at 4.58, followed by the "**High cost of BIM experts (B18)"** at 4.48, and "**High training cost (B16)"** at 4.39. These findings suggest that financial considerations are the most significant impediments to the widespread adoption of BIM in sustainable construction.
Conversely, barriers such as the "**Difficulty of use in complex projects (B7)"**, "**Copyright problems about data (B6)"**, and the "**Complexity of the interface of the BIM software (B15)"** were identified as the least significant, with scores of 2.29, 2.58, and 2.71 respectively. While these barriers are not negligible, they are perceived as less significant compared to the other barriers.
According to the results of the survey, there is a consensus regarding "**High licensing cost (B17)"** being the most significant barrier to BIM implementation in sustainable building projects. As mentioned by Zhou et *al.* (2019), one of the biggest obstacles to BIM implementation across industries is the prohibitively high cost of BIM software. The results of their study indicate that Singapore's experience of creating a BIM Fund that incorporates resources obtained from organizations and governments offers potential to boost these industries. Therefore, the same BIM Fund can also be established in Türkiye to increase the adoption of BIM in sustainable building projects.
Another critical barrier that experts agree on is "**High cost of BIM experts (B18)"**. Due to the limited number of experts in BIM technology and sustainable project, the fees for these experts are significantly high. To address this barrier, increasing the number of experts in BIM technology and sustainable projects through government incentives could be beneficial. In this direction, as offered by Manzoor et *al.* (2021), the curriculum of civil and architectural engineering can include BIM-related topics.

The third most important barrier is "**High training cost (B16)**". This barrier is closely linked to "**High licensing cost (B17)**" and "**High cost of BIM experts (B18)**" barriers. When the government provides the necessary incentives and there are a sufficient number of experts, training cost will be automatically reduced.

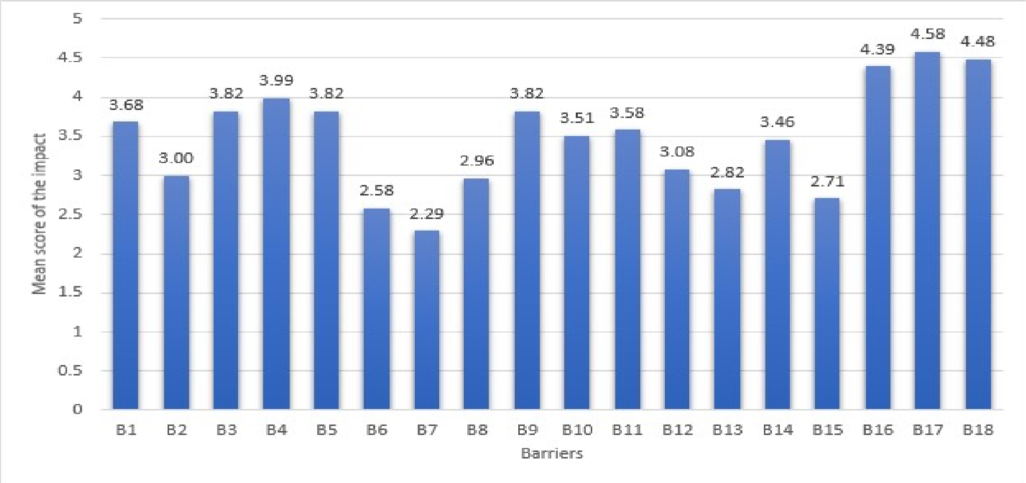

Fig. 3. Mean score ranking of the barriers

5. Conclusions

The aim of this study is to investigate the possible obstacles to the use of Building Information Modeling (BIM) technology in sustainable buildings within the Turkish construction industry. To this end, a questionnaire was created enlisting a total of 18 barriers identified through a comprehensive literature review. Mean score ranking was employed to analyze survey results, determining the significance of the barriers. The results highlight the financial barriers "**High licensing cost (B17)**", "**High cost of BIM experts (B18)**", and "**High training cost (B16)**" as the most significant impediments to BIM adoption for sustainable building projects in Türkiye. Government incentives are identified as crucial for overcoming these obstacles. Establishing BIM funds and enhancing the expertise in BIM technology and sustainable construction projects are recommended actions.

Future research could focus on methodologies that investigate the relationships between these barriers to develop more comprehensive and effective strategies for overcoming them. By addressing these obstacles, the Turkish construction industry can fully utilize the potential of BIM to achieve more sustainable and efficient building practices.

References

Akcay, E. C. (2023). Barriers to undertaking green building projects in developing countries: A Turkish perspective. *Buildings*, *13*(4), 841. https://doi.org/10.3390/buildings13040841

Alsehrawy, A., Tong, M., Callaghan, N., & Amoudi, O. (2020). A Critical Review of the Challenges and Barriers to an Effective Use of BIM in Green Building Assessment. *Proceedings of the Construction Digitalisation for Sustainable Development: Transformation through Innovation*, Hanoi, Vietnam.

Azhar, S., & Brown, J. (2009). Bim for sustainability analyses. *International Journal of Construction Education and Research*, *5*(4), 276–292. https://doi.org/10.1080/15578770903355657

Azhar, S., Carlton, W. A., Olsen, D., & Ahmad, I. (2011). Building Information Modeling for Sustainable Design and LEED® Rating Analysis. *Automation in Construction*, *20*(2), 217–224. https://doi.org/10.1016/j.autcon.2010.09.019

Cao, Y., Kamaruzzaman, S., & Aziz, N. (2022). Green Building Construction: A systematic review of Bim utilization. *Buildings*, *12*(8), 1205. https://doi.org/10.3390/buildings12081205

González-Torres, M., Pérez-Lombard, L., Coronel, J. F., Maestre, I. R., & Yan, D. (2022). A review on Buildings Energy Information: Trends, end-uses, fuels and drivers. *Energy Reports*, *8*, 626–637. https://doi.org/10.1016/j.egyr.2021.11.280

Huang, B., Lei, J., Ren, F., Chen, Y., Zhao, Q., Li, S., & Lin, Y. (2021). Contribution and obstacle analysis of applying BIM in promoting green buildings. *Journal of Cleaner Production*, *278*, 123946. https://doi.org/10.1016/j.jclepro.2020.123946

Hwang, B.-G., Shan, M., & Lye, J.-M. (2018). Adoption of sustainable construction for small contractors: Major barriers and best solutions. *Clean Technologies and Environmental Policy*, *20*(10), 2223–2237. https://doi.org/10.1007/s10098-018-1598-z

Jalaei, F., & Jrade, A. (2015). Integrating building information modeling (BIM) and LEED system at the conceptual design stage of Sustainable Buildings. *Sustainable Cities and Society*, *18*, 95–107. https://doi.org/10.1016/j.scs.2015.06.007

Kineber, A. F., Massoud, M. Mo., Hamed, M. M., Alhammadi, Y., & Al-Mhdawi, M. K. (2023). Impact of overcoming BIM implementation barriers on Sustainable Building Project Success: A PLS-SEM approach. *Buildings*, *13*(1), 178. https://doi.org/10.3390/buildings13010178

Labaran, Y. H., Mathur, V. S., & Farouq, M. M. (2021). The carbon footprint of construction industry: A review of direct and indirect emission. *Journal of Sustainable Construction Materials and Technologies*, *6*(3), 101–115. https://doi.org/10.29187/jscmt.2021.66

Liu, S., Meng, X., & Tam, C. (2015). Building information modeling based building design optimization for Sustainability. *Energy and Buildings*, *105*, 139–153. https://doi.org/10.1016/j.enbuild.2015.06.037

Lu, Y., Wu, Z., Chang, R., & Li, Y. (2017). Building Information Modeling (BIM) for Green Buildings: A Critical Review and future directions. *Automation in Construction*, *83*, 134–148. https://doi.org/10.1016/j.autcon.2017.08.024

Ma, H. C., & Wang, P. (2021). Research on Promoting the Sustainable Development of Green Building through BIM Application-From the perspective of the whole building lifecycle. *Turkish Journal of Computer and Mathematics Education*, *12*(11), 4091-4102.

Manzoor, B., Othman, I., Gardezi, S. S., Altan, H., & Abdalla, S. B. (2021). BIM-based research framework for Sustainable Building Projects: A Strategy for mitigating BIM implementation barriers. *Applied Sciences*, *11*(12), 5397. https://doi.org/10.3390/app11125397

Mohanta, A., & Das, S. (2022). Causal analysis of slow BIM adoption in eastern India with a special focus on Green Building Sector. *Journal of The Institution of Engineers (India): Series A*, *103*(1), 319–337. https://doi.org/10.1007/s40030-021-00561-w

Murti, C. K., & Muslim, F. (2023). Relationship between functions, drivers, barriers, and strategies of building information modelling (BIM) and sustainable construction criteria: Indonesia Construction Industry. *Sustainability*, *15*(6), 5526. https://doi.org/10.3390/su15065526

Najjar, M., Figueiredo, K., Palumbo, M., & Haddad, A. (2017). Integration of BIM and LCA: Evaluating the environmental impacts of building materials at an early stage of designing a typical office building. *Journal of Building Engineering*, *14*, 115–126. https://doi.org/10.1016/j.jobe.2017.10.005

Nizam, R. S., Zhang, C., & Tian, L. (2018). A BIM based tool for assessing embodied energy for buildings. *Energy and Buildings*, *170*, 1–14. https://doi.org/10.1016/j.enbuild.2018.03.067

Penttilä, H. (2006). Describing the changes in architectural information technology to understand design complexity and free-form architectural expression. ITcon Vol. 11, Special issue The Effects of CAD on Building Form and Design Quality, pg. 395-408, https://www.itcon.org/2006/29

Veselka, J., Nehasilová, M., Dvořáková, K., Ryklová, P., Volf, M., Růžička, J., & Lupíšek, A. (2020). Recommendations for developing a BIM for the purpose of LCA in Green Building Certifications. *Sustainability*, *12*(15), 6151. https://doi.org/10.3390/su12156151

Zhang, L., Chu, Z., He, Q., & Zhai, P. (2019). Investigating the constraints to buidling information modeling (BIM) applications for sustainable building projects: A Case of China. *Sustainability*, *11*(7), 1896. https://doi.org/10.3390/su11071896

Zhou, Y., Yang, Y., & Yang, J.-B. (2019). Barriers to BIM implementation strategies in China. *Engineering, Construction and Architectural Management*, *26*(3), 554–574. https://doi.org/10.1108/ecam-04-2018-0158