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Barriers, Potential Use, Competitiveness, and Implementation Framework of Building Information Modeling (BIM) in the Construction Industry of Pakistan

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ABSTRACT

The use of building information modeling (BIM) in construction industry is believed to help decision makers throughout the project. The building sector in Pakistan is trying to adopt BIM as a tool to enhance the efficiency of projects. However, its actual implementation is being hampered by a number of barriers. Therefore, the purpose of this study is to identify those barriers and propose a framework to ensure its implementation. Data was collected through a questionnaire. Forty-nine (49) responses were collected and data was then analyzed using ANOVA to identify any significant differences in the opinions of different experts. Mean score and relative importance indices of all variables were determined. It is found that the major barriers include lack of expert knowledge, outdated contractual system and use of traditional tools for drafting. Further, the potential use of BIM is found to cause a reduction in rework as well as tool flexibility to allow different people to work at the same time. Moreover, a framework for BIM implementation on building projects include adding clauses in contracts, enhancing the awareness among industry stakeholders, and providing training and financial support. So, the findings of the current study will be helpful to pave the way for technological advancements in building projects in Pakistan.

Keywords: Building information modeling (BIM), Potential benefits, Competitiveness, Barriers, Implementation framework.

INTRODUCTION

Building Information Modeling (BIM) involves creating 3D and more complex models to analyze a project's features and characteristics. BIM represents a significant advancement in the construction industry, promising numerous benefits, such as improved efficiency, better project management, clash detection, and enhanced collaboration among stakeholders (Adeyemi et al., 2024). It uses digital models to enable virtual construction of buildings before on-site work. BIM enables real-time coordination among stakeholders, resolving conflicts, accelerating solutions, and keeping projects on schedule and within budget.

Despite its potential, BIM adoption faces numerous barriers across different sectors and countries (El Hajj et al., 2023). In the realm of pre-fabricated construction, BIM adoption is hampered by a lack of research and development, the absence of standardized tools, and the predominance of domestic-oriented tools (Tan et al., 2019). These challenges impede the effective integration of BIM technologies into pre-fabricated construction workflows, resulting in inefficiencies and reduced potential for innovation. The integration of BIM in site health and safety management also faces significant challenges. These challenges encompass the cost and time required for training, cultural issues and lack of understanding of the connection between BIM and safety management (Nnaji & Karakhan, 2020; Swallow & Zulu, 2019). In renovation processes, BIM adoption is limited by financial constraints, lack of BIM skills and knowledge, software deficiencies, and poor renovation practices (Ahmed et al., 2024; Elagiry et al., 2019; Olugboyega, 2024). The scale of renovation work, inaccurate information about existing buildings, and lack of collaboration among project participants further compound these issues. Among sub-contractors and in facility management, high upfront cost of software, a lack of BIM knowledge and awareness, and scepticism about the value of BIM present major barriers (Fitriani et al., 2019; Jupp & Singh, 2014). Further, collaboration among BIM supply chain members is restrained by the absence of guidelines and standards, concerns over data ownership and privacy, and interoperability challenges throughout the project lifecycle (Oraee et al., 2019). On construction sites, BIM adoption is limited by technological versatility, performance issues, lack of capacity, and resistance to change (Boton et al., 2021). Globally, barriers to BIM adoption include insufficient government direction, legal issues, insufficient motivation and organizational issues (Andersson & Eidenskog, 2023; Jin et al., 2019; Takyi-Annan & Zhang, 2023).

In developing countries, BIM adoption faces major barriers, including lack of understanding of its benefits, resistance to moving away from traditional methods, non-availability of national mandate to drive adoption, inconsistent readiness among project teams, high costs of required software and hardware, and limited awareness of BIM standards (Hire et al., 2021). In Nigeria, top management support, cost of software and training, legal issues, lack of awareness, and weak expertise are significant barriers to BIM implementation (Olanrewaju et al., 2020; Sanni-Anibire et al., 2020). In Lebanon, Syria, Jordan, and North African countries, the limited governmental initiatives to promote BIM and the absence of mandatory BIM implementation have hindered its adoption (Olugboyega, 2024). Key challenges include limited stakeholder awareness and understanding of BIM, inadequate financial resources for implementation, insufficient technical infrastructure and IT support, resistance to departing from traditional methods, absence of standardized processes, interoperability issues among software platforms, and regulatory constraints (Ahmed et al., 2024; Khan et al., n.d.; Kineber et al., 2023). In Ghana, major barriers to BIM adoption include technical challenges, like software complexity and inadequate IT infrastructure (Takyi-Annan & Zhang, 2023). Significant barriers to 4D-BIM adoption in offshore projects include shortage of experienced users, organizational resistance to workflow changes, limited client demand, and inadequate governmental support (El-Habashy et al., 2023). The industry needs concerted efforts to develop standardized BIM tools and conduct extensive research to fully harness the benefits of BIM.

In this regard, most of the previous studies are conducted in developed countries to mitigate these barriers through effective strategies. Overcoming these barriers requires targeted strategies to educate stakeholders about the benefits of BIM in safety management and to provide necessary technical support. Further, these challenges can be addressed by improving BIM training, enhancing software capabilities, and fostering better collaboration among stakeholders to improve the renovation process (Tran & Nguyen, 2024). Therefore, to enhance BIM adoption, it is crucial to provide clear guidance, demonstrate the benefits of BIM, and align training with handover processes to ensure effective implementation. Developing comprehensive guidelines, improving interoperability, and enhancing BIM education are essential steps to foster better collaboration (Nikolic et al., 2021). In sustainable design and construction, major barriers include the absence of supportive sustainability analysis tools, the failure to implement open-source principles in software development, and the inadequacy of BIM data schemes (Olawumi, 2020; Saka & Chan, 2023). BIM can accurately take-off quantities of materials to order the materials in right quantities on sites to avoid any waste (Enshassi et al., 2018). Moreover, BIM can be integrated with automated fire alarm systems (Safayet et al., 2021). Considering the numerous benefits of BIM in construction sector, a framework for BIM adoption in construction industry is inevitable, offering structured guidelines and methodologies to ensure consistency, efficiency, and quality throughout project lifecycles (Al-Raqeb et al., 2024; Biancardo et al., 2023; Sah et al., 2024).

BIM is widely explored in developed countries, like the United States, China, and the UAE. Further, numerous researchers in Germany, the United Kingdom, Canada, the United States, Denmark, France, China, Brazil, South Korea, and the Middle East have also identified various barriers to BIM implementation (Al-Yami & Sanni-Anibire, 2021; Obi et al., 2021; Oraee et al., 2019; Porwal & Hewage, 2013; Tan et al., 2019). However, its adoption in developing countries, especially in Pakistan, is still very limited. In Pakistan, BIM adoption remains low, as only 11% of the industry has adopted BIM and it is primarily used for generating 3D models, which represents just a small fraction of BIM's capabilities (Bhatti et al., 2018; Chan et al., 2023; Farea et al., 2023; Farooq et al., 2020; Roohi et al., 2023). Moreover, the body of knowledge is still very limited to provide any guidelines for industry stakeholders to adopt BIM on construction projects in Pakistan. Since construction industry cultures and practices vary across the globe, essential efforts are needed to identify the barriers and their counter measures in the form of a framework for local construction industry. Therefore, this research aims at identifying the major barriers in the adoption of BIM, the awareness of local construction industry about the benefits and competitiveness of BIM, and developing a mitigation framework to integrate BIM with building projects to harness its benefits. The findings of the current research can also be used as a benchmark for other developing countries. The rest of this paper is organized as follows. Next, the methodology is outlined, then data-collection and analysis procedures are shown. The results of the current study are then provided and discussed. The conclusions and recommendations of this study are finally presented.

RESEARCH DESIGN AND METHODOLOGY

The flowchart of the current study is provided in Figure (1). The aim of the literature review was to develop a basic understanding regarding the subject of this work; i.e., BIM definition, its applications, benefits and barriers faced during BIM integration in the construction industry and in engineering universities. It was accomplished through the study of different journal papers and conference papers.

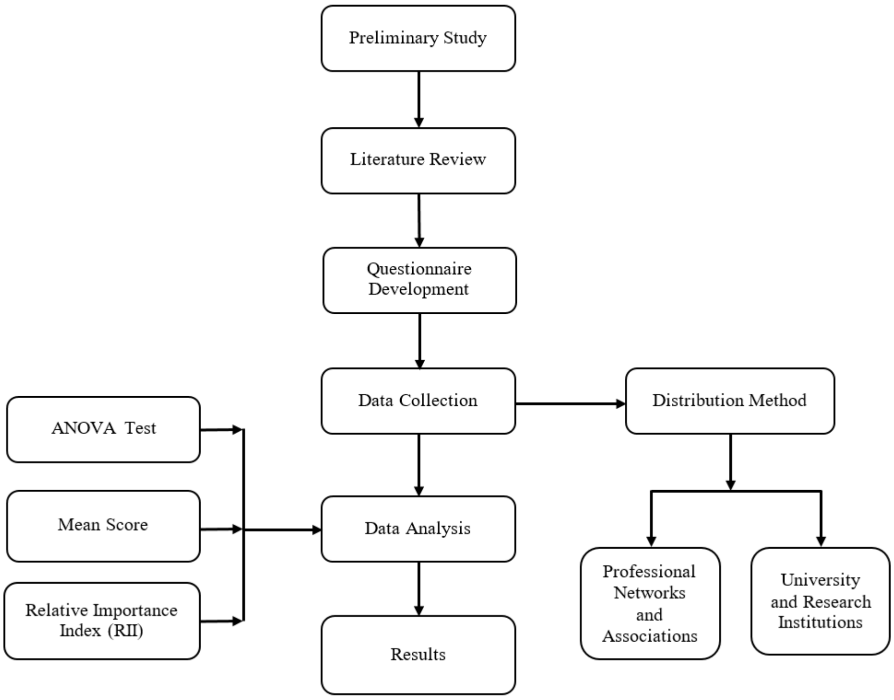

Figure (1): Flowchart of the research methodology

The current research is more about a theoretical framework, based on a literature review. A number of factors were taken and a questionnaire was developed to identify the barriers, potential benefits, competitiveness, and strategies to adopt BIM. The purpose of the survey was to find out how people understood BIM, what advantages people could see from using it, how it gives firms in the construction industry an advantage over competitors, what barriers exist to adopt BIM, and what kinds of implementation strategies might help promote BIM implementation on construction projects.

Data was collected from 49 experts from the construction industry. Firstly, the basic information of the respondents was collected and afterwards, their views on BIM and different aspects of it were questioned and the responses were recorded on a five-point Likert scale of 1-5 ranging from strongly disagree to strongly agree. MS Excel was used for data compilation and analysis, once the survey was completed.

ANOVA Test

The significance of the normal distribution cannot be overstated, as it underpins numerous statistical techniques, including t-tests, linear-regression analysis, discriminant analysis, and analysis of variance (ANOVA) (Mamat et al., 2020; Sah et al., 2024). ANOVA is a statistical method used to determine whether the means of two or more groups differ significantly. It evaluates the impact of one or more factors by comparing the means of different samples. ANOVA helps assess whether the results from surveys or experiments are statistically significant, essentially guiding whether to reject the null hypothesis and accept the alternative hypothesis. The null hypothesis in ANOVA assumes that all sample means are equal and that there are no significant differences among them, suggesting that the samples belong to the same population.

Mean Score

The mean score (MS) of the collected data was calculated by using Equation (1), where ‘s’ is the score given to each research variable by the respondents, ranging from 1 to 5, where “1” means “Strongly disagree” and “5” means “Strongly agree”; f is the frequency of responses to each rating (l-5), for each research variable; and N is the total number of responses (49) concerning the research variables.

$$MS = \sum \frac{f \times s}{N} \qquad (1 \leq \text{MS} \geq 5) \qquad (1)$$

Relative Importance index (RII)

Relative Importance Index (RII) was used to assess the perceptions of civil engineers and architects regarding the relative importance (Sah et al., 2024; Soundarya Priya & Anandh, 2024; Tibriz & Islam, n.d.). The RII was calculated by using Equations (2) and (3). The RII value ranges from 0 to 1, with the higher the RII value, the more significant the cause or impact. The relative importance index (RII) was used to compare the perceptions of stakeholders with each other and the overall in this study, and it was also used to measure the level of perceptions of construction industry stakeholders about the barriers, potential benefits, competitiveness, and implementation strategies for BIM adoption.

$$\text{Relative Importance Index (RII)} = \sum \frac{\boldsymbol{W}}{(\boldsymbol{A} \times \boldsymbol{N})} \qquad (2)$$

$$\textbf{RII} = \frac{(1n1+2n2+3n3+4n4+5n5)}{(\boldsymbol{A} \times \boldsymbol{N})} \qquad (3)$$

where **W** is the weighting given to each factor by the respondents (ranging from 1 to 5, with 1 being the least important and 5 being the most important). **A** is the highest weight (e.g. 5 if the scale is from 1 to 5). **N** is the total number of respondents.

RESULTS AND DISCUSSION

Statistical analysis was applied to ensure accurate and precise data analysis using MS Excel software. Different tests, such as ANOVA, Mean Score, and RII, were carried out on the collected data. The results of the tests are then used in order to suggest a framework to ease the adoption of BIM in the construction industry.

Responses Gathered

The questionnaire was distributed to 100 different experts from the field, but 57 responses were received, where 8 responses were invalid, as shown in Table 1. So, the total number of responses used for the analysis was 49. The respondents include Engineers/MEP Consultants (48.98%), Academia related (16.3%), Contractors/MEP Sub-contractors (10.2%), Architects/Designers (8.16%), Developers/Facility owners (6.12%), accountants (2.04%), and clients (2.04%), while 6.12% were other field related personnel.

Awareness of BIM

The data shows that the majority of the respondents (62%) are relatively new to BIM (0 to 5 years), while a significant minority (26%) have a moderate level of experience (5 to 10 years). Only a small percentage have extensive experience (10 to 15 years and >15 years) of BIM use on their projects, as shown in Figure (2). This means that the awareness of BIM in the construction industry of Pakistan is very weak. So, this shows that the realization of BIM to industry stakeholders is required. The awareness of BIM in other developing countries is also weak, because most of the people are reluctant to change (Babatunde et al., 2021). Further, barriers to adopt BIM and their counter measures in the form of strategies are inevitable to identify.

Table 1. Number of responses gathered

Responses	Sent	Received	Invalid	Valid	Response rate (%)
Online	100	57	8	49	49

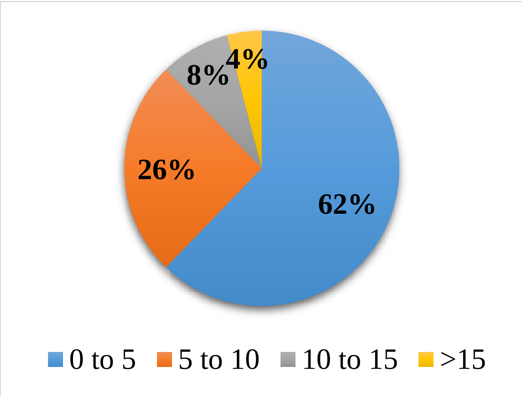

Figure (2): Respondents' awareness about BIM

Potential Benefits of BIM

The rankings of different potential benefits of BIM as research variables have been compared based on their RII values, as shown in Figure (3). The top two benefits include reducing rework in building performance and facilitating collaboration among architecture, engineering, and construction (AEC) professionals, both with high RII values around 0.86 and 0.8, respectively. This means that BIM can detect clashes early on in the project and helps take corrective measures timely, instead dismantling the executed work due to any clash with other utilities in the project. Similar results were found in other studies around the globe (Akhmetzhanova et al., 2022; Hasannejad et al., 2023). Further, it allows industry stakeholders to work on the same models at the same time, but at different locations. It is one of the major advantages which BIM provides as compared to other traditional methods of drafting and building design tools. If one of the stakeholders makes any change in the model, it can be visualized by other stakeholders at the same time. So, any kind of clash can easily be detected and informed to all stakeholders. This attribute of BIM makes it unique from other tools which are currently being used by the construction industry in Pakistan.

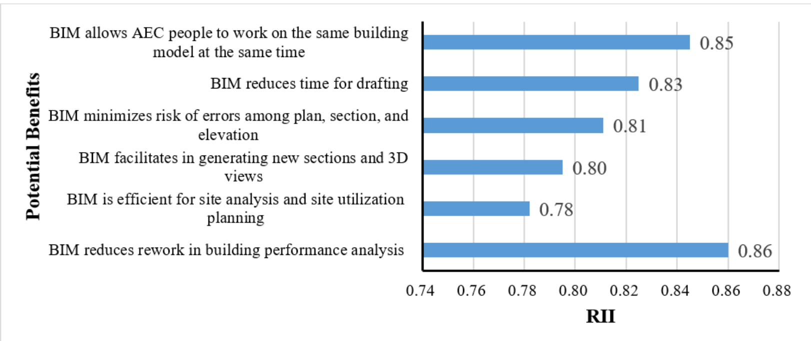

Figure (3): Ranking of potential benefits of BIM

At number 3 in the ranking of potential benefits is the BIM ability to perform tasks in less time as compared to other tools. This is due to the better collaboration and timely decision making by key stakeholders. In another study conducted by Martins et al. (2022), the same results of BIM were reported, where it was found that BIM could perform drafting tasks in less time as compared to other drafting tools. Other significant benefits of BIM include reductions in errors and discrepancies. Further, efficiency in site analysis and utilization is rated moderately important (RII ~ 0.76). This feature of BIM is also very important, because it helps plan the site in a much better manner and maximize the utilization in terms of services. Site analysis and utilization of BIM in site planning has been found a key feature in another study conducted by Avendano et al. (2022).

Competitiveness of BIM

Figure (4) shows the competitiveness of BIM in construction management, ranked with respect to RII. The highest-rated factors are early clash detection (RII ~ 0.82) and integrating request for information with change orders (RII ~ 0.80). As discussed earlier, that clash detection feature is one of the key features, significantly increasing BIM competency over the other tools which have been used in the construction sector. It allows to see which services or utilities overlap with each other, so that timely decisions at the design stage can be made. Further, BIM ability to integrate information for the projects with any kind of change order is also a significant attribute. Similar results were also reported in another study conducted by Porwal et al. (2023). BIM can also improve the budgeting, estimation and scheduling capabilities for better management of project activities. This is due to the BIM capability to estimate the quantity of each material more accurately as compared to other traditional methods of estimation. So, accurate estimation means an accurate budget as well. In the same manner, project activities can be planned more precisely when the quantities are accurately known. So, BIM helps improve cost- and time-management practices in projects (ElMenshawy & Marzouk, 2021).

Enhancing the construction process, providing strategic advantages, and increasing productivity are also highly valued (RII ~ 0.79-0.80). Productivity in construction projects is also one of the major areas of concern for industry stakeholders. BIM can also help improve the productivity of construction activities by providing accurate quantities of all resources; i.e., manpower requirements, machinery and materials (Ghasemi Poor Sabet & Chong, 2020). In addition, BIM can be helpful in improving quality on construction sites by better quality assurance and quality control practices (Porwal et al., 2023). Moderately important benefits include facilitating mobile access, defining construction phases, and ensuring safety management (RII ~ 0.77 - 0.78). Helping with timely project delivery and increasing the ability to meet project demands have the lowest RII values (RII ~ 0.73 - 0.76), but are still considered beneficial. Further, BIM is capable of improving risk management practices on construction sites by early detection of any kind of discrepancies (Alirezaei et al., 2022). Lastly, lean construction is rated as the lowest factor which can be assisted by BIM application in construction projects. So, BIM competencies include a number of features if it is applied in true spirit.

Barriers to BIM Adoption

In terms of barriers to BIM adoption, as shown in Figure 5, it is found that the existing contractual system does not support to adopt BIM in construction projects. There is a number of reasons for that, such as client's poor awareness about BIM technology and resistance to change from traditional methods (Nast & Rekve, 2023). Secondly, most of the designers are used to draft by using traditional methods for drafting, such as the use of AutoCAD. Therefore, they do not seek to consider other new technologies in their design practices. This shows a serious concern about local industry's poor behaviour about the adoption of latest technologies in their construction practices (El Hajj et al., 2023). It means that the current behaviour of industry stakeholders about BIM adoption is very poor and need to change. Therefore, there is an immense need to develop counter measures to resolve this issue.

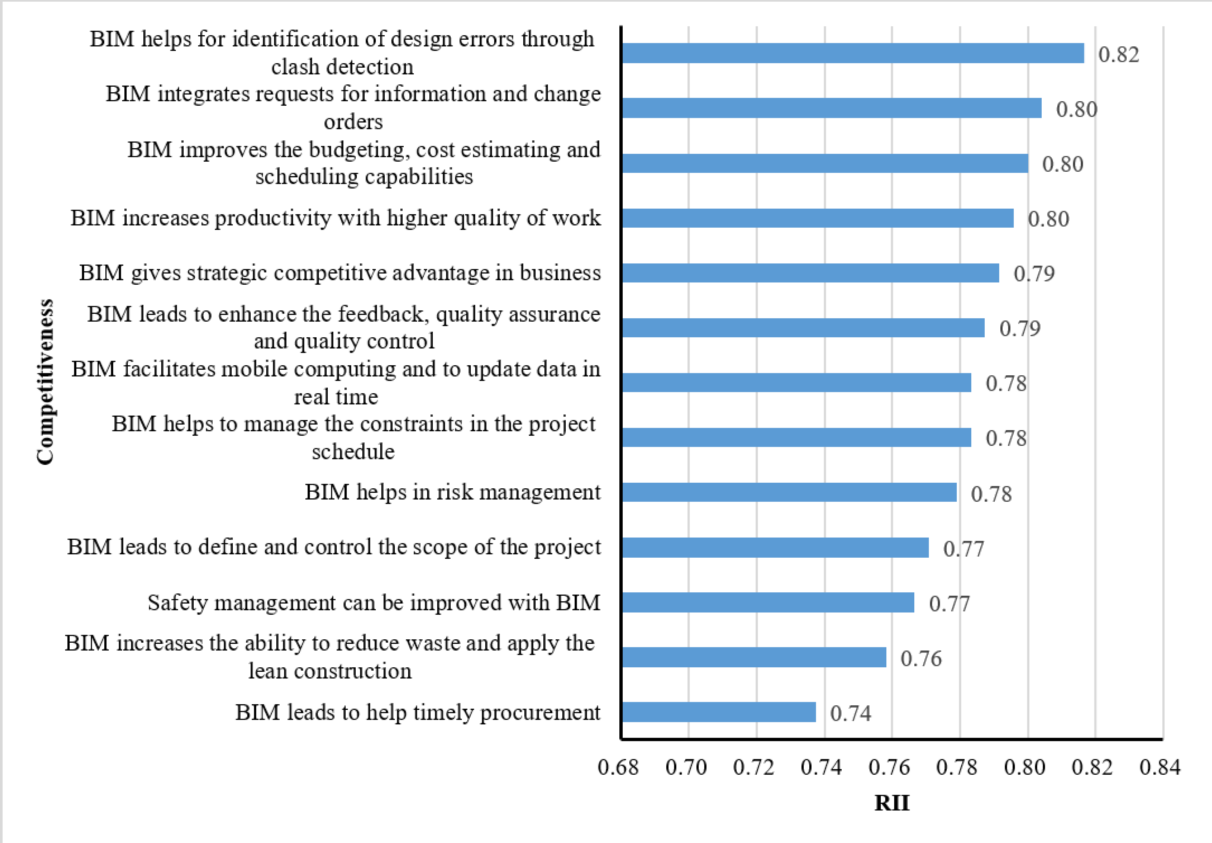

Figure (4): Ranking of competitiveness of BIM in construction industry

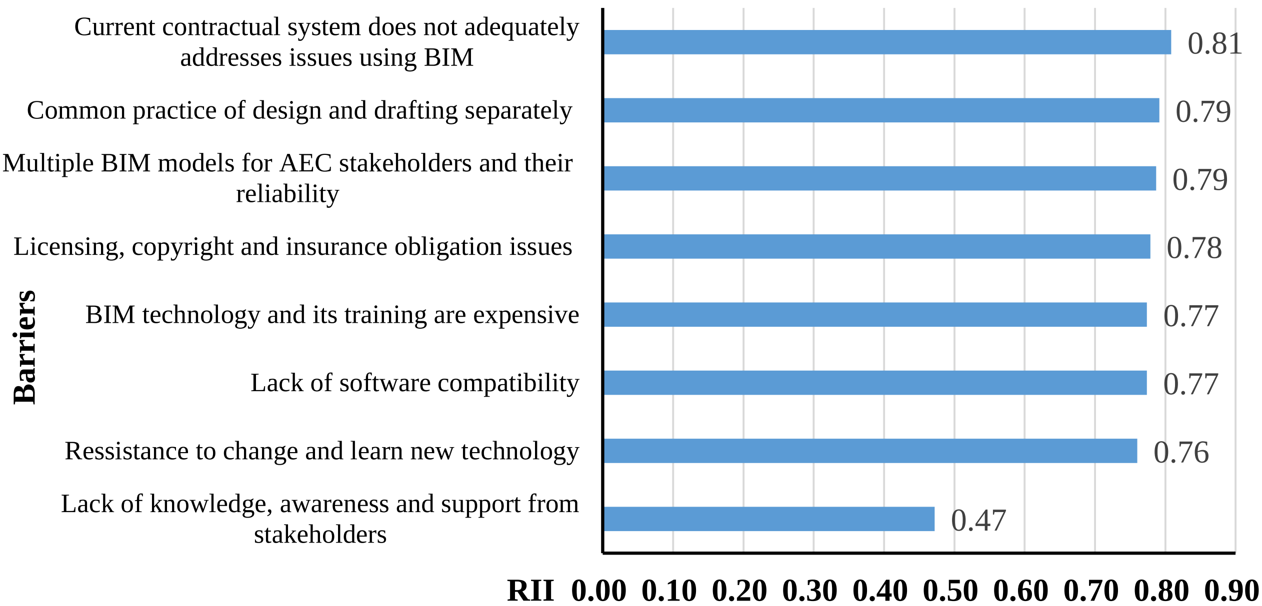

Figure (5): Ranking of barriers to BIM adoption

Another barrier is the reliability and confidence of stakeholders regarding multiple models of BIM. It is very important that stakeholders must realize the potential benefits of BIM to promote its adoption in the construction sector. Licensing issues and software compatibility also hinder BIM adoption in the local sector. Further, formal training to educate designers and other stakeholders to use BIM in their projects is rigorously required. It will build more confidence among stakeholders about BIM utilization (Shojaei et al., 2023). Lastly, the resistance to change and to adopting latest technologies is mainly linked with poor behavior of local industry to choose BIM as an option in construction projects. This issue can be addressed through effective BIM implementation strategies (Durdyev et al., 2021). Therefore, there is a need to develop effective strategies to promote the culture of BIM adoption in building projects in the construction sector of Pakistan.

Framework for BIM Implementation

A framework has been outlined to guide the implementation of BIM at various stages within Pakistan's construction sector, taking into account BIM's potential, barriers, and competitiveness, as illustrated in Figure (6). This framework was developed based on survey results and a review of relevant literature. It is part of an ongoing research initiative aimed at enhancing the performance of individuals and organizations in the construction industry through improved engineering practices and knowledge sharing. The framework provides the measures/strategies that must be taken to implement BIM in the local construction sector. These strategies are divided into three major domains; at the governmental, industrial and organizational levels.

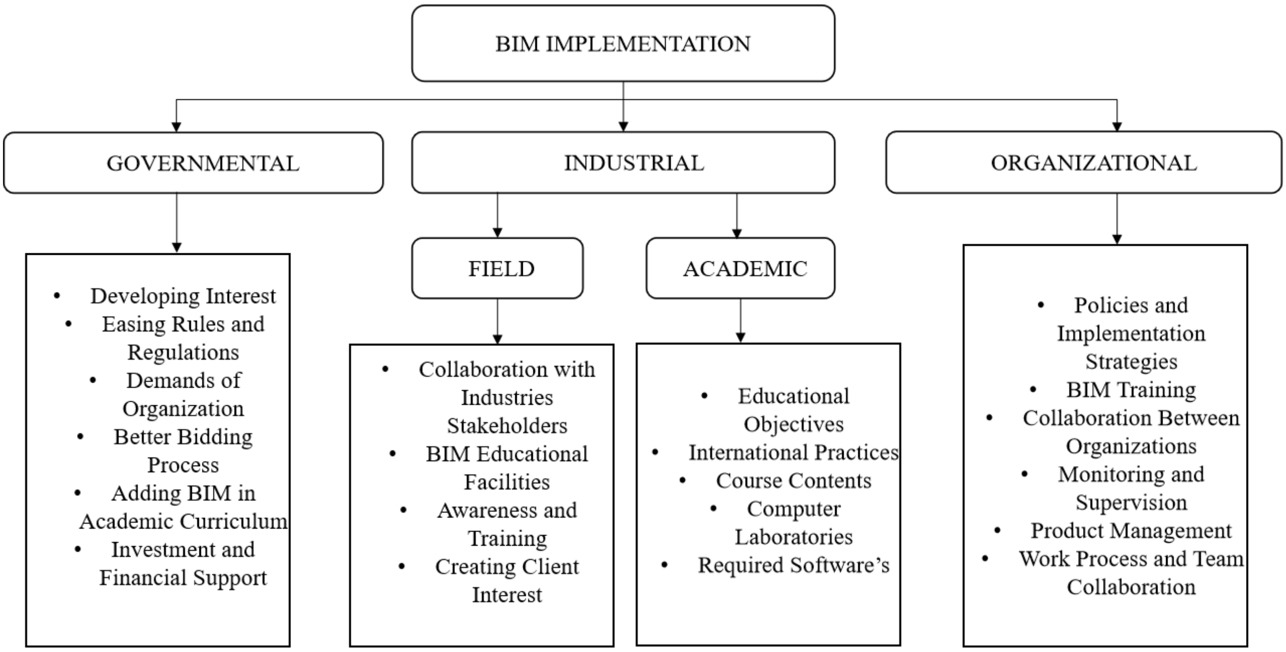

Figure (6): BIM implementation framework

At the governmental level, major strategies which can help improve BIM implementation include developing the interest of stakeholders through incentives, formulating rules and regulations though contractual requirements, addition of BIM in the BS curricula of engineering institutes, and governmental financial support by in purchasing the license of BIM for different institutes. Similar strategies were proposed by other studies as well (Ghaffarianhoseini et al., 2017; Yang & Lu, 2023). Next is the organizational level, where implementation of policies developed by governments must be ensured. The same strategy was proposed by another study (Olugboyega, 2024). Then, organizations must start regular training workshops to build in-house capabilities about BIM. Further, proper supervision and monitoring are also very important for BIM implementation in the construction sector. Lastly, the team collaboration to use BIM in their projects is also very important.

At the industrial level, both academia and field are equally important, because once engineers are familiar with BIM at the BS level, it will encourage and ease the way to adopt BIM in their projects. It is necessary that educational institutes provide the required infrastructure, like labs, software and hardware to practice BIM during their education. Further, BIM should be formally taught in academia as a regular course content. It will develop more interest of students to learn it (Besné et al., 2021). Then comes the field practices, where collaboration, training and developing awareness among different industry stakeholders are very necessary to adopt BIM in their projects. So, this framework addresses the major barriers which are hindering the adoption of BIM and promotes the latest technologies in the construction of building projects.

CONCLUSIONS

The objective of this study was to investigate the potential benefits, competitiveness, barriers and strategies to adopting BIM in the building sector of a developing country. Key findings of the current study include:

- Potential benefits of BIM are identified as flexibility of BIM to allow multiple stakeholders to work on the same model at the same time with a reduction in drafting time.
- In terms of competitiveness, the current study found that BIM can identify clashes among different stakeholders of a building project during the design stage and integrate project information with change orders effectively.
- Further, major barriers to BIM adoption include poor contractual system, where using BIM for design is not asked, as well as resistance to change the use of traditional tools for drafting.
- In the end, a framework is proposed which guides the industry stakeholders how to implement BIM in the construction sector of a developing country. The proposed framework demands efforts at the governmental, industrial and organizational levels to implement BIM effectively.

Recommendations

The following general recommendations could be taken into account in light of the findings of this research work:

- The government should promote BIM adoption as a collaborative tool in the built environment sector. Governmental departments should be educated about the benefits of model-based deliverables.
- In future, case studies must be conducted to implement BIM throughout the project lifecycle to determine its effectiveness.

Statements and Declarations

- The authors have no relevant financial or non-financial interests to disclose.
- The authors have no competing interests to declare that are relevant to the content of this article.
- All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.
- The authors have no financial or proprietary interests in any material discussed in this article.

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Conflict of Interests

The authors declare no potential of known conflict of interests with respect to the research, authorship, and/or publication of this article.

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