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BIM implementation in project management practices for sustainable development: Partial Least square approach

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ABSTRACT

As an emerging area with far-reaching implications for project management practices, Despite the growing global adoption of Building Information Modelling (BIM), its implementation in the Pakistani construction sector faces significant challenges, particularly in relation to conflict and risk management, communication, and technical safety practices. The primary objective of this study is to identify and evaluate the key factors influencing BIM adoption in Pakistan, with a specific focus on understanding the roles of conflict and risk management, communication, technical safety management, and resource management in successful BIM implementation. The research used a combined pilot survey with 90 contributors, a prime questionnaire with 125 contributors, an exploratory factor analysis (EFA), and a structural equation modelling (SEM) approach has been used to do in depth statistical analysis. The results indicated the highest relation among planning and technical safety management and BIM implementation with path impact value of 0.613 followed by conflict and risk management with path value 272. According to the findings, every contributes appreciably to BIM's usefulness in construction and project management. This examination contributes to the development of BIM research.

1. Introduction

Construction has a significant impact on the economic and infrastructure growth of a country. Approximately 4.5 % of the nation's financial system has been derived from this sector annually. Numerous sectors are reliant on the success of this enterprise, which provides employment for a significant number of jobless [1]. Obstacles that the construction sector has encountered include project delays, cost overruns, and ineffective management. A paradigm shifts and revolutionary approach, BIM has surfaced in response to these challenging circumstances and to enhance the efficiency of production undertakings. BIM is a digital representation of the tangible and functional characteristics of a structure, which can be utilized in its design, construction, continuous refurbishment, and operation. It enhances documentation management, communication, and collaboration from inception to conclusion [2]. Internationally, BIM has been acquiring traction in the building sector, and Pakistan is no different.

BIM is an advanced computer-aided method used to represent and manage the physical and functional attributes of a structure or any other industrial project [3]. This model documents every facet of the task, encompassing strategizing, construction, maintenance, and utilization. Achieving success in the planning, execution, and completion of a construction project is the domain of undertaking management [4]. This category encompasses responsibilities such as funds and time management, resource distribution, risk assessment, and quality control.

There are multiple justifications for the critical nature of the Pakistani production region's implementation of BIM in its mission control procedures. In recent years, performance gains have assumed a greater significance in the construction sector of Pakistan [5]. Construction projects often surpass their allocated budgets and schedules. Construction projects in Pakistan were, on average, 35.4 % late in 2019, according to statistics from the Construction Industry Development Board

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(CIDB) [6]. By standardizing processes and reducing duplication of effort, businesses may save a lot of money and time by switching to BIM. The success of a project depends on the teamwork of many people, including the architects, engineers, contractors, and clients [7,8]. BIM makes better study of environmental implications, material use, and energy efficiency possible, which may lead to more eco-friendly building methods [8,9].

Even though BIM is becoming more critical in the building sector, there needs to be more study in the Pakistani construction sector. Although there have been studies on BIM deployment internationally, the specific features and difficulties of the Pakistani building industry call for regional studies [9,10]. Existing studies have often focused on the software and hardware components of BIM and its advantages throughout the design and building processes. However, a dearth of studies evaluate the full extent to which BIM has been integrated into Pakistani project management practices throughout the whole spectrum of the construction project life cycle [11,12].

This study aims to assess how well BIM has been incorporated into project management procedures used in Pakistan's construction industry. This study examines the impact of BIM adoption on project management with an emphasis on critical performance metrics, including stakeholder participation, cost control, and project time. The benefits and drawbacks of applying BIM in this context will also be covered in the paper. The results of this study will have a significant impact on Pakistan's building industry both now and in the future. Experts in the field, decision-makers, and interested parties may find this research valuable since it will pinpoint the factors that influence the integration of intelligent BIM into project management practices. This would improve project performance and the competitiveness of Pakistan's construction industry by empowering them to make well-informed decisions on training and BIM generating investments.

2. Literature review

The increasing importance of BIM is evident in the proliferation of published research concerning its implementation in project management practices within the manufacturing sector of Pakistan. Numerous studies have investigated the impact of BIM on the efficiency of construction projects in Pakistan. Prior research has demonstrated that BIM can also substantially decrease project delays and increase overall efficiency [13]. In Pakistan's industrial sector, where delays have traditionally been a big issue, BIM can increase the effectiveness of stakeholder efforts, which would help them make better decisions and solve problems [14]. This demonstrates how crucial it is to employ BIM to solve those issues. Studies have indicated that, in spite of all of its advantages, incorporating BIM into Pakistan's construction sector can be challenging. Previous studies have highlighted the importance of qualified experts, and the shortage of skilled personnel has hindered the application of BIM [15]. This result is consistent with most BIM adoption studies, which suggests that human error is the most significant predictor of BIM adoption [16]. There is an urgent need for BIM-trained workers in Pakistan's building industry right now [17]. Adoption of BIM is greatly aided by laws and government efforts [18]. The Construction Industry Transformation Plan (CITP) of the government of Pakistan has been a major factor in the implementation of BIM [19]. Research indicates that government initiatives that promote investment in BIM technology are beneficial to the building sector [20]. It's encouraging that the Pakistani government wants to see BIM used extensively nationwide. A critical literature assessment, however, indicated more research evaluating the efficacy of these rules and their direct influence on project management practices.

BIM increases information exchange and collaboration by giving stakeholders a centralized platform to better coordinate their efforts. Early mistake detection before the building phase is also made possible by its visual nature and collision detecting features. 4D BIM modelling enables sophisticated sequencing and scheduling to maximize deadlines and reduce delays—a problem that has long dogged Pakistan's industry [21]. The data-rich BIM model offers helpful insights for monitoring performance and productivity. Nonetheless, polls have regularly shown that the lack of knowledgeable BIM users is a significant obstacle, surpassing both financial and technological constraints [22]. Scholars advise funding professional and academic training initiatives to foster regional BIM competence. Incentives and regulations from the government are also recommended to boost demand and hasten adoption. Even though the literature offers a generally consistent perspective, some of its drawbacks include the fact that it mostly relies on expert opinions and surveys, with little empirical evidence showing how BIM actually affects project performance. There are few insights unique to developing nations like Pakistan. It should be the goal of future research to measure the advantages of BIM, evaluate suggested training courses, and customise adoption tactics for regional settings. The overwhelming body of research affirms the benefits of BIM and emphasizes the necessity of developing knowledgeable users in order to fully tap into its potential shown in Table 1. Priorities for sustainable growth include workforce development programs and targeted policies. The building all of its benefits, a number of studies have shown that integrating BIM in Pakistan's building industry can be difficult [23]. The implementation of BIM has been hampered by a recognized shortage of skilled workers, and prior research has emphasized the significance of qualified professionals. This result is in line with the majority of research on BIM adoption, which indicates that the most important predictor of BIM adoption is human error. The implementation of BIM in Pakistan has been the subject of several research. Lack of experience, inadequate training, and industry veterans' aversion to change were ranked as the top three obstacles in a study. These cultural and human elements were judged to be more important than financial or technical constraints. Comparable results were found in another study, which identified the main obstacles as the absence of trained BIM users, low customer demand, and a deficiency in the nation's training infrastructure.

Researchers suggest long-term training programs as a means of overcoming these obstacles, both in academic settings and for the professional advancement of seasoned construction experts. Government regulations and incentives may also encourage adoption by raising demand and improving the financial viability of BIM investment. However, the most important element for successful implementation in Pakistan is thought to be building local knowledge. Government policies and programs greatly aid the adoption of BIM. The Pakistani government's Construction Industry Transformation Plan (CITP) has been essential in pushing BIM forward in the country. Investing in BIM technology has been demonstrated in studies to be a result of government policies encouraging the building sector [30,31]. It's encouraging that the Pakistani government wants to see BIM used extensively nationwide. A critical literature assessment, however, indicated more research evaluating the efficacy of these rules and their direct influence on project management practices. To successfully manage a project, all relevant parties must work together effectively [31,32]. BIM's collaborative features have the potential to revolutionize the building sector. Researchers in Pakistan stressed the value of BIM in facilitating teamwork. BIM's ability to promote real-time data interchange and team collaboration was highlighted [30,33].

However, in-depth examinations of the complexities and unique obstacles of stakeholder engagement in the Pakistani context still need to be included in the existing literature. Internationally, sustainable construction practices have also become the norm in the production sector of Pakistan. BIM provides resources for analyzing energy efficiency, fabric consumption, and environmental impacts. Research has indicated that BIM may have utility in the context of selling environmental duties in the Pakistani construction industry. Nevertheless, a significant gap exists in the academic literature as further research is required to fully comprehend the long-term environmental and sustainability impacts of BIM implementation.

Table 1
Comprehensive analysis of key factors related to BIM implementation for project management in Pakistan based on a review of relevant studies.

Factors Related to Literature	Main Findings	Supporting Evidence	References	Research Methods Used	Sample Size & Location	Implications and Recommendations	Limitations and Gaps
BIM improves collaboration and information sharing	BIM provides a centralized platform for coordination and reduces miscommunication	• Case studies, surveys, interviews demonstrate information sharing benefits	[24]	Case studies, surveys, interviews	Kaner: 6 projects Riaz: 54 responses in Pakistan	Suggests BIM implementation can improve coordination through better information sharing	Limited real-world data from Pakistani projects
BIM enables early clash detection and error identification	Clash detection in BIM identifies errors prior to construction	• Simulations and experiments show BIM error checking capabilities	[25]	Experiments, simulations	Edirisinghe: 3 case studies Ouertani: Simulation study	Highlights value of early error finding with BIM before construction starts	Experimental studies may lack realism
BIM allows advanced scheduling and sequencing	4D BIM optimizes schedules and minimizes project delays	• Literature reviews demonstrate scheduling benefits of 4D BIM	[26]	Literature reviews, surveys	Ali: 15 papers reviewed Farooqui: 62 responses in Pakistan	Indicates 4D BIM scheduling should be used to reduce delays	Survey data subjective; Lacks empirical project performance data
BIM provides data for analytics and insights	Rich BIM data enables advanced analytics for productivity, performance tracking, etc.	• Case studies and interviews reveal useful BIM analytics capabilities	[13]	Case studies, expert interviews	Abid: 7 interviews Kaner: 6 projects	Highlights BIM analytics as underutilized opportunity	Minimal examples demonstrating actual impact on productivity
Lack of trained personnel is a barrier to BIM adoption	Shortage of expertise is a top challenge to BIM implementation	• Multiple surveys find lack of skilled users impedes adoption	[27]	Surveys, interviews	50–100 responses each	Indicates critical need for BIM training and skilled workforce development	Self-reported data subject to biases
Training programs needed to develop BIM expertise	Investments should be made in academic and professional BIM training programs	• Expert recommendations based on literature reviews	[28]	Literature reviews, expert opinions	N/A	Highlights priority of BIM training programs for construction industry	Lacks data on efficacy of proposed training programs
Government support can incentivize BIM adoption	Policies and incentives can accelerate BIM adoption	• Case studies find government mandates drive implementation	[29]	Case studies, interviews	Kaner: 6 projects Riaz: 11 experts	Implies targeted policies could spur greater BIM adoption	Minimal examples from developing country contexts

Source: Developed doing the review of previous related works.

3. BIM from various research perspective

Building information modeling (BIM) will be an inclusion of a platform to discuss technological integration with construction management [34]. The review takes off from integrating both with an interdisciplinary approach and further steps in methodologies to underscore the BIM for sustainable management practices in projects worldwide and within the boundaries of Pakistan.

- Interdisciplinary Research and Methodological Innovations

This is related to focus on substantial contributions in interdisciplinary research on how BIM interacts with other areas, such as economics, environmental science, and information technology. For instance, economists have tried to quantify the impacts that BIM may have in reducing life cycle costs for building projects [35], while environmental scientists have tried to understand the impacts of BIM towards waste minimization and resource optimization [13]. Its methodological innovations, particularly related to analytics of the data and simulation techniques, inform the latest findings in predictive modeling and risk assessment with BIM [21]. This research is highly necessary, not only to understand the full spectrum of BIM applicability and benefits but also to develop a new way of promoting evidence-based practice across the construction industry.

- Global Insights and Comparative Analyses

Furthermore, the review brings forward comparative analyses, which use a set of examples to manifest the use of BIM in different regulatory and economic contexts. For example, Scandinavian studies highlighted the use of BIM extension under an advanced condition of government mandating in public projects [35]. Juxtaposed against such instances are the slower rates of adoption in most developing economies, often on account of infrastructural and educational barriers [36]. This would bring a global perspective that may be a reason for the low adoption of BIM in Pakistan and means of mitigating the same.

- Technological Advancements: Beyond Basic BIM

Recent literature considers advanced integrations BIM is looking at beyond the most basic BIM applications. In addition to these are the likes of the cloud computing, artificial intelligence, and augmented reality applications [37]. Each of these adds to BIM's abilities in real-time data management, automated design decision-making, these synergies will accrue to the Pakistani construction industry, particularly in terms of providing solutions to the typical problems related to project completion delays and cost overruns.

- Regional Studies and Comparative Analyses

The use of BIM in Pakistan has emerged as a very recent phenomenon; hence its implementation remains sporadically influenced by economic, technological, and regulatory challenges. Comparative studies in other South Asian countries mirror the same patterns as described here, in that case, following the economic growth trajectories of these countries [3839]. This literature review section focuses on the studies that have taken up the case of Pakistan alone, such as the one regarding the regulatory and technological barriers in BIM integration [40]. The development of BIM in this region brings out the place of management practices that are commensurate in harnessing BIM for realization of development goals in an ecologically sound manner. Other related studies relevant to the Asian and Middle East markets on the investigation of organizational and technological barriers to implementing BIM [41]. As such, therefore, such studies remain key in the sense that they provide a comparative framework through which unique challenges that are poised to Pakistan are understood. These papers often deliberate on the role of government policies and institutional frameworks that have either encouraged or discouraged the process of technology adoption, with lessons to be applied in the Pakistani context.

- Sustainability and Green Building Practices

With sustainability in focus, the research review brings into perspective how BIM sustains the practices of green buildings further reviewed with mainstream such as "Sustainable Buildings" presenting BIM as technology for higher energy efficiency and better trackability of materials [42]. These are two aspects that carry special importance to a country like Pakistan, where urban development has to be managed in such a way that growth is in balance with environmental sustainability. From the literature review, effective use of BIM can ensure more sustainable urban infrastructures up to global standards of sustainability like LEED or BREEAM. This purpose is to take into consideration the BIM role in environmental, economic, and social sustainability [43]. Perhaps this is the only reason why there has been much reliance on case studies and data analytics to drive the point home on how BIM can be put into good use, significantly lowering the levels of waste and energy consumption during construction. For example, a *meta*-analysis provided adds to the lifecycle assessment of building projects managed through BIM with an indication of substantial improvements in resource efficiency [44].

- Key Theoretical and Empirical Contributions

The use of BIM in project management has well-documented challenges and best practices through many global contexts. A good example is the comprehensive works by Sacks et al. (2018), which give a general overview of standardization of BIM exhaustively and the implications for project workflows, with a call on industry consensus for standards in BIM protocols shown in Table 2. This is further elaborated in the research from automation in construction, who give a quantitative estimation of BIM contributions to the reduction of carbon in construction projects, one of the main parameters in sustainable development [45].

Despite the breadth of literature, there remains a distinct gap in studies utilizing Partial Least Squares (PLS) approaches to explore the structural relationships within BIM implementation strategies in emerging markets. This gap is particularly pronounced in the context of Pakistan, where empirical research on BIM's economic and environmental impacts is nascent. This study seeks to fill this gap by employing a PLS approach to rigorously analyze how BIM can enhance project management practices towards achieving sustainable development goals.

4. Methodology and research design

This investigation employed a mixed-method approach, which included a literature review, to identify twenty-eight critical success factors for BIM project management. Thereafter, twelve interviews were conducted with Pakistani construction industry experts who were experts in BIM and construction management. To further refine the survey, an online pilot study was conducted, and the results were analyzed using exploratory factor analysis (EFA). The final degree employed Structural

Table 2
Research related to BIM implementation from regional perspective.

Section Title	Research Focus	Technological Aspects	Geographical Context	Key Findings	Reference
Interdisciplinary Research and Methodological Innovations	Economic impact of BIM	Economic analysis	Global	Reduces lifecycle costs	[46]
Interdisciplinary Research and Methodological Innovations	Environmental benefits of BIM	Environmental analysis	Global	Minimizes waste, optimizes resource use	[15]
Interdisciplinary Research and Methodological Innovations	Predictive modeling and risk assessment	Data analytics, simulation	Global	New insights into BIM applications	[47]
Global Insights and Comparative Analyses	BIM adoption in public sector projects	Government mandates	Scandinavia	Advanced BIM usage	
Global Insights and Comparative Analyses	BIM adoption rates in developing economies	Educational barriers	Developing economies	Challenges in BIM adoption	[48]
Technological Advancements: Beyond Basic BIM	Integration of IoT, AI, and AR with BIM	IoT, AI, AR	Global	Enhances BIM capabilities	[42]
Technological Advancements: Beyond Basic BIM	Capabilities in real-time data management	Automated design, virtual walkthroughs	Global	Improves project efficiency	[49]
Regional Studies and Comparative Analyses	BIM adoption trends in South Asia	Comparative studies	South Asia	Illustrates economic growth and BIM adoption	[50,51,52]
Regional Studies and Comparative Analyses	Technological hurdles in BIM integration	Regulatory analysis	Pakistan	Discusses regulatory and technological hurdles	[53,6]
Sustainability and Green Building Practices	Support for green building practices	LEED, BREEAM standards	Global	Achieves higher energy efficiency	[54]
Key Theoretical and Empirical Contributions	BIM standardization and workflow implications	Quantitative analysis	Pakistan	Emphasizes need for consensus on BIM protocols	[55]
Specific Gaps and Research Opportunities	Lifecycle assessment of BIM projects	Meta-analysis	Global	Shows improvements in resource efficiency	[56]
Technological Advancements: Beyond Basic BIM	Advanced BIM integrations	IoT, AI, AR	Global	Augmented reality in project management	[57,58]
Sustainability and Green Building Practices	BIM and sustainability	Green certifications	Global	Environmental sustainability focus	[7]
Key Theoretical and Empirical Contributions	BIM protocols and impacts	Standardization studies	Pakistan	Reduction in carbon footprint	[59]
Regional Studies and Comparative Analyses	Comparative regional studies	Economic and technological comparisons	South Asia	Comparative studies in adoption trends	[60]
Interdisciplinary Research and Methodological Innovations	Interdisciplinary methodological impacts	Methodologies in interdisciplinary research	Global	Innovations in economic and environmental impacts	[42]
Global Insights and Comparative Analyses	Comparative international insights	Regulatory impacts and economic contexts	Scandinavia	Public sector projects and government roles	[37]

Source: Detailed literature review of various studies.

Equation Modelling (SEM) to examine the correlations between significant achievement variables. By employing this comprehensive approach, the study was capable of conducting an in-depth analysis of BIM's utilization in construction project management in Pakistan. A flowchart of this study is presented in Fig. 1.

4.1. Identification of factors

A systematic search was conducted on Scopus using the keywords "BIM" OR "Building Information Modeling" AND "Critical Success Factors" OR "Key Success Factors" AND implement* OR adopt* OR challenges OR barriers OR issues AND "Case Study" OR survey OR interviews. This returned 38 relevant documents. Further analysis shows the top contributing countries were Malaysia with 8 documents, China with 6, United Kingdom with 6, United States with 4, and Australia, Taiwan, and Turkey each with 3 documents as shown in Fig. 2. The distribution indicates research interest in BIM success factors spans developed and developing country contexts. Reviewing the 38 articles shows a prevalence of survey research methods, with over 20 papers reporting questionnaire results. Other common approaches were case studies, interviews, and literature reviews. Sample sizes ranged from 15 to over 300 respondents across construction stakeholders like clients, consultants, and contractors. In terms of findings, the most frequently cited critical success factors were management support, training and education, user/staff expertise, communication and collaboration, and top-down policies and standards. Challenges like resistance to change,

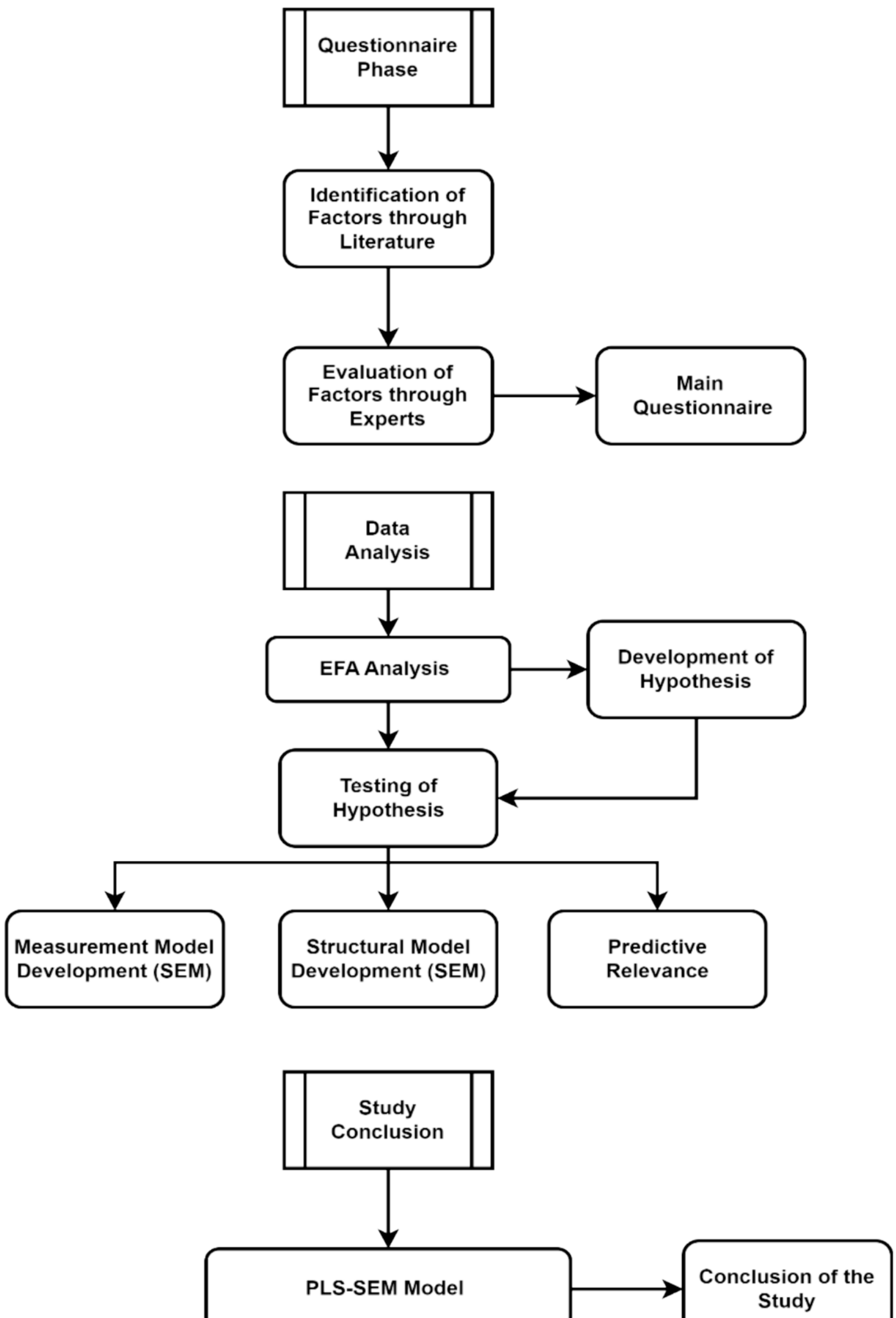

Fig. 1. Flowchart of research method ().
Source: flowchart is drawn by using MS Visio

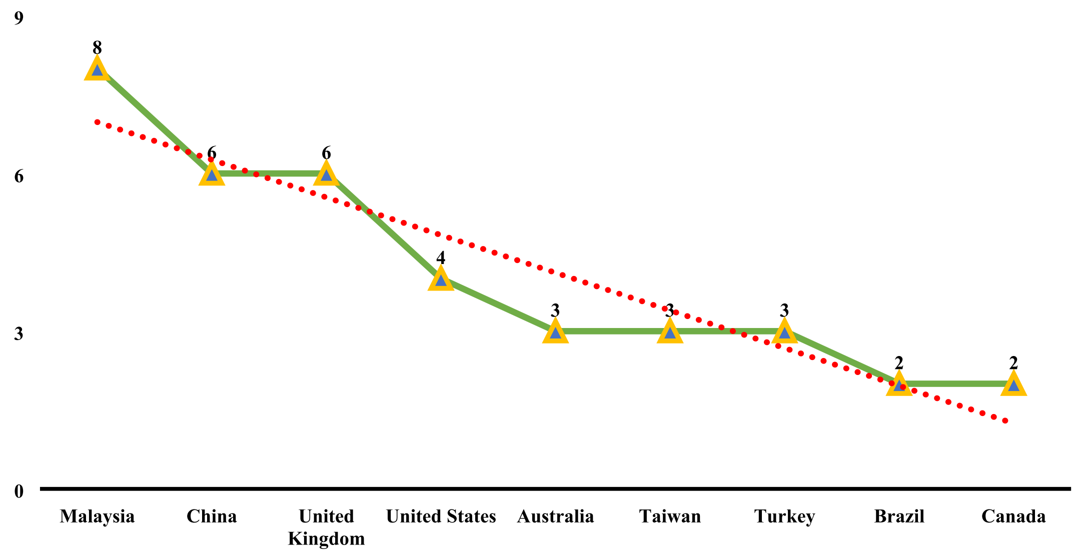

Fig. 2. Documents by Countries ().
Source: this graph is drawn by authors through in detailed review of previous work based on counties perspective on MS excel

lack of BIM understanding, and cost concerns were also commonly identified. Together, these 38 documents provide useful insights into BIM implementation issues in Pakistan and other developing regions. The research spans nearly 15 years, providing both current and historical perspectives. Through surveys and firsthand accounts, consistent success factors and barriers emerge around people, processes, and policies. Although the sample is moderately sized, the multiple research approaches and respondent diversity lends validity. Nonetheless, more empirical research on actual BIM project performance could further substantiate the findings.

Further analysis of keywords related to BIM implementation success factors was conducted using VOS Viewer. The visualization and clustering of terms provides additional insights. The top keyword occurrences centered around "architectural design", "building information model/modeling", "construction industry", "critical success factors", "factor analysis", and "surveys" as shown in Fig. 3. This affirms construction and design as key application areas of BIM, with architectural integration being a priority. The prominence of "building information model/modeling" highlights that research specifically focuses on BIM rather than broader information management. Survey methods also

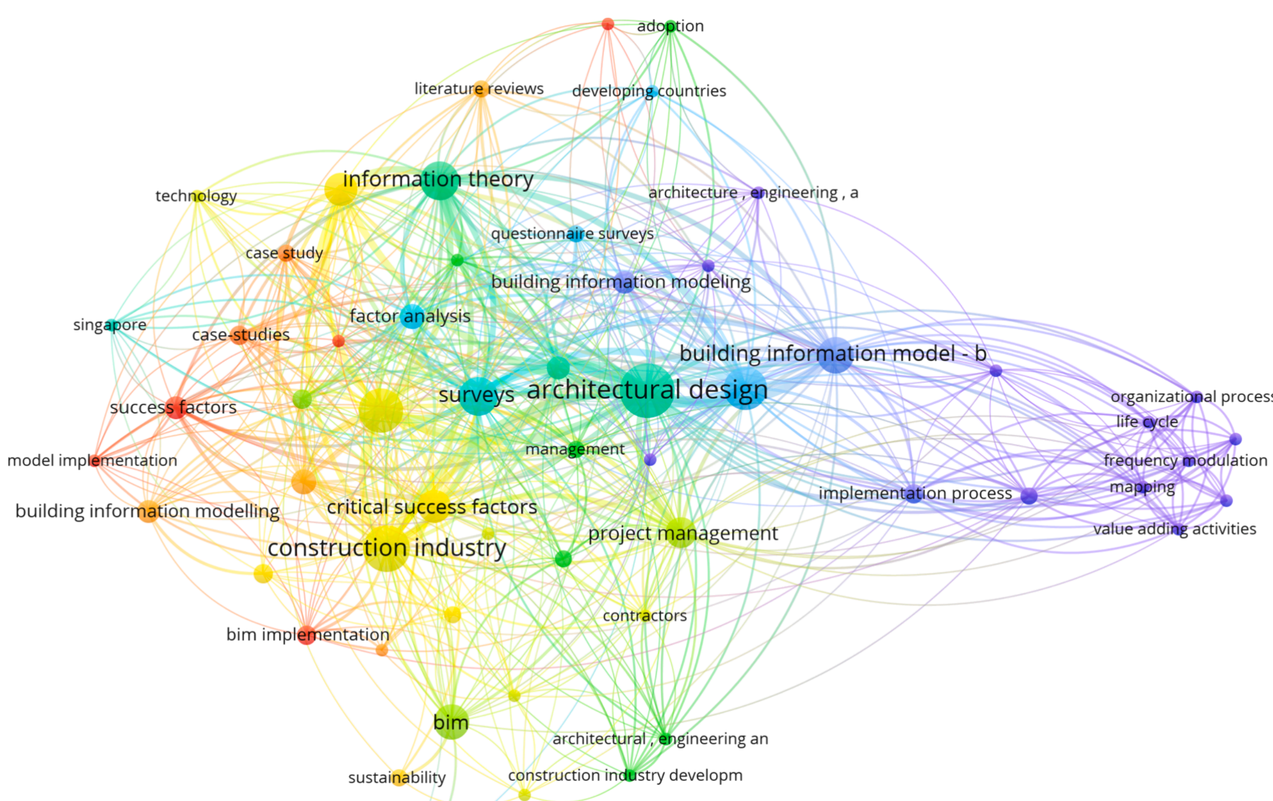

Fig. 3. Keywords Visualization through VOS Viewer ().
Source: VOSVIEWER free version is used by authors to developed research network diagram

feature strongly, aligning with the prevalence identified in the Scopus literature review. The strong presence of “critical success factors” and “factor analysis” underscores the emphasis on identifying key enablers, barriers, and considerations for BIM adoption. Terms clustering closely to these nodes include “information theory”, “design methodology” and “project management”, showing the connection to information flows, processes, and management.

Table 3 shows the list of identified factors from literature. Additionally, the network visualization reveals “BIM” clustering near “construction” and “project management”, while “building information modeling/modelling” is closer to architectural and design terms. This suggests BIM is viewed from both technology and process perspectives.

4.2. Expert validation

Interviews were instrumental in the polishing of survey instruments to collect quantitative data during follow-up with the mixed-method research approach employed. The method used during this study involved a total of 12 interviews with construction industry professionals from Pakistan to ensure that the 28 questions prepared for the main survey instrument were relevant and covered the required area.

Principally, these interviews were conducted to affirm and refine the survey items that could really reflect the real reflection of complexities and nuances in BIM implementation in the Pakistani paradigm. Interview also helped identify any possible ambiguity or bias in the questions and give a view of practical aspects of BIM use that might be derived from the literature review only.

The selection of the interviewees through purposive sampling was intended to get full and in-depth qualitative viewpoints from individuals who are fully aware and actively involved in the adoption of BIM in the construction industry of Pakistan.

The selection of interviewees was targeted in terms of the number of years of experience in the construction field and had a bias towards the roles that interact with and influence the adoption and implementation of BIM. It consisted of roles such as project manager, BIM coordinator, and construction manager.

They were identified under an assumption that they had some expertise in BIM, which would enable them to answer the questions posted in the questionnaire. Such expertise was usually confirmed from their professional engagements, the participation of their firms in BIM projects, and from their participation in industry panels and dialogues on BIM.

Significant effort was put into contacting a very diversified group, which included expert representatives of the different construction firms (large-scale vs. small-scale) and those who contribute differently within those firms to achieve a broad spectrum of experiences and perspectives in implementing BIM.

Semi-structured was the first, and the rest followed, guided by the emerging patterns. This made it possible to have two types of questions targeting experts: open answers, where the respondent explains freely from experience and perception. Interviews were done through face-to-face or video conference, based on the availability of the interviewees, and each one was approximately 45 to 60 min in duration.

The feedback from this interview was very crucial in finalizing the survey questionnaire, ensuring that full and effective capturing of the key factors influencing the implementation of BIM, as experienced by practitioners in the field, would be undertaken.

The interviews also followed good ethical research conduct, such as the obtaining of informed consent by the respective interviewees before undertaking any interview. There was keen and tight following of confidentiality, in such a manner that no names of the interviewees were incorporated, and after the compilation of the study results, all anonymized data were destroyed.

Table 3
Success factors of BIM.

Sr. #	VARIABLES	References
BIM1	BIM 3D models illustrate project elements.	Interview
BIM2	Detection of collisions prevents spatial conflicts.	Interview
BIM3	Simulations identify construction sequences with significant risk.	[21,61]
BIM4	Planning reduces congestion and dangers.	[62,63]
BIM5	Integrated emergency response protocols into BIM.	[21,64]
BIM6	4D BIM depicts the progression of construction over time.	Interview
BIM7	The allocation of resources matches talents to duties.	Interview
BIM8	Immersive Virtual Reality (VR) training for safety practice.	Interview
BIM9	Integration of data improves risk assessment.	[65,66]
BIM10	Communication among stakeholders improves.	[66,67]
BIM11	Collaboration facilitates decisions centered on safety.	Interview
BIM12	Accurate models facilitate emergency planning.	Interview
BIM13	The properties of materials inform safety measures.	Interview
BIM14	Environmental data improves risk assessment.	[65,66]
BIM15	Incident records from the past inform safety strategies.	[68,69]
BIM16	BIM-communicated safety protocols that are transparent.	[64,65]
BIM17	Virtual reality tours enable pre-site safety instruction.	[66,67]
BIM18	Before construction, design defects are addressed.	Interview
BIM19	Planning in sequence reduces concurrent hazards.	[21,65]
BIM20	Documented safety features in post-construction BIM.	[61,64]
BIM21	BIM models emphasize evacuation routes.	Interview
BM22	The placement of the safety apparatus was optimized.	[70,71]
BIM23	Routine safety exercises in a virtual environment.	[67,72]
BIM24	Planned site logistics for secure transportation.	[62,68]
BIM25	Monitoring of construction hazards in real-time.	[66,73]
BIM26	Safety standards are updated in a BIM environment.	[65,66]
BIM27	Integrating regulatory compliance into BIM workflows.	[64,65]
BIM28	BIM is used to keep track of and manage hazardous materials.	Interview

Source: Detailed literature review.

4.3. Data collection

This study’s data was gathered using a two-stage survey procedure. Initially, a pilot survey was conducted with 90 individuals drawn via a stratified sample process from the larger Pakistani construction sector community. After that, a more extensive questionnaire survey was carried out, with 125 randomly drawn from the same community [64,65]. Both polls used a 5-point Likert scale, with extremes including “strongly disagree” and “strongly agree.” The rigorous sampling strategy used here guaranteed a diversified and representative data set to conclude the variables affecting the use of BIM in project management within the Pakistani construction industry.

4.4. Data analysis

4.4.1. Exploratory factor analysis (EFA)

The pilot survey data, which included the 28 BIM implementation elements in project management, was analyzed using exploratory factor analysis (EFA). Using this data analysis method, the underlying structures or components responsible for most of the observed variation in the dataset may be identified and extracted. The adequacy of the facts was verified (KMO) and Bartlett’s tests. Eigenvalues and a scree plot, on the other hand, were employed to approximate the initial variety of retained factors. A varimax rotation is implemented to enhance the recognition of the component matrix after factor extraction. This approach assisted in clarifying the interrelationships among the various components of BIM implementation.

4.4.2. Structure Equation modelling (SEM)

Subsequently, this investigation transitioned to employing Structural Equation Modelling (SEM) on the primary survey questionnaire data. The interrelationships among the chosen constructs had been thoroughly examined through the application of SEM evaluation. Thorough analyses of discriminant and convergent validity were conducted to ensure that the version effectively assessed the constructs and that they could be differentiated.

5. Results and analysis

5.1. Exploratory factor analysis (EFA)

Kaiser-Meyer-Olkin (KMO) test results are shown in Table 4. This test evaluates the sufficiency of the sample for factor analysis. The KMO score of 0.893 shows that the dataset is sufficient, suggesting that it may be used effectively in a factor analysis [21,68]. These findings demonstrate the dataset's viability for future research and factor extraction.

The factor analysis eigenvalues and loadings are shown in Table 5. When first calculated, eigenvalues show how much variation can be attributed to each factor. The most significant initial eigenvalue, 13.933, is found in Component 1, explaining 49.760 % of the variation, while the lowest, 3.613, is found in Component 2, explaining 12.902 %. These two factors may explain the bulk of the variation. After applying a varimax rotation, the variance distribution may be seen in the sums of squares of the loadings [62,74]. Component 1 accounts for 35.128 % of the remaining variation, whereas Component 2 accounts for 16.529 %. Fig. 2 presents the scree plot of the calculated eigenvalues in EFA analysis.

Principal Components Analysis using Varimax rotation and Kaiser Normalisation yields a rotated component matrix, which is shown in Table 6. The matrix displays the relative importance of each aspect in BIM implementation to the determined subsystems. BIM factors such as BIM21, BIM22, BIM20, and others have significant loadings in Component 1, highlighting their importance in this component. High loadings for factors like BIM3, BIM4, and BIM1 in Component 2 indicate a close relationship between these variables and this component. Differential loadings for different BIM variables are shown in Components 3 and 4. Fig. 4 is showing the scree plot for all variables according to the loading criteria. These findings aid in developing new concepts and provide the groundwork for a methodical examination of the effects of BIM deployment in Pakistani building project management.

Table 7 show construct names reflect the underlying nature and qualities of the elements used in their creation. The names were chosen to represent the primary characteristics and themes in the factor analysis [62,69]. The "Planning and Technical Safety Management" framework encompasses elements fundamental to BIM implementation, such as project planning, technical management, and safety precautions. A fundamental theme of "Conflict and Risk Management" is the importance of aspects related to identifying conflicts and evaluating risks. Conceptually, "Resource and Facility Management" refers to resource distribution and physical placement issues. Finally, the "Communication and Safety Practises Accomplishment" construct includes indicators of successful communication and the implementation of safety procedures.

Following the findings from EFA, six research hypotheses, as indicated in the hypothesized framework of Fig. 5, were devised as follows.

- H1: Conflict and risk management positively impact BIM implementation for project management in the construction industry.
- H2: Communication and safety practices positively impact BIM implementation for project management in the construction industry.
- H3: Planning and technical safety management positively impact BIM implementation for project management in the construction industry.
- H4: Resource and facility management positively impact BIM implementation for project management in the construction industry.

Table 4
KMO and Bartlett's test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.893
Bartlett Tests of the Sphericity	Appro. Chi-Squares	2475.856
	Df.	378.00
	Sig	0.0000

Source: SPSS 26 is used to perform tests.

5.2. Demographics

The demographics of the survey respondents show that they represent a wide range of professionals from the building trade. A wide age range is represented among the respondents, although those between the ages of 26 and 35 make up the biggest group (40 %). With 55 % having master's degrees and 35 % PhDs, the majority of responders are highly educated professionals shown in Fig. 6. A wide range of expertise is represented in this sample; 45 % are BIM professionals, 35 % are project managers, 20 % are civil engineers, and 0 % are safety engineers. This demographic mix is ideal for thoroughly examining BIM's use in project management because of the wide range of experience and insight its members bring to the table.

5.3. Structure Equation modelling (SEM)

5.3.1. Measurement model

For each of the 28 BIM implementation criteria, Table 8 displays descriptive data, such as the mean, sample size (N), and standard deviation (Std. Deviation) of the survey results. The standard deviations are relatively small, with the means fluctuating between 2.47 and 3.77 [62,63]. Differences in participants' levels of agreement or disagreement may be inferred from the standard deviations of their replies [21,61]. These numbers provide light on the median and range of opinions, giving us a foundation for learning how Pakistani construction industry players see BIM's effects on project management.

Table 9 shows the reliability and validity statistics of the model for the selected variables. Factor loadings, composite reliability, and average variance retrieved are shown in the table, respectively, for each construct. Strong construct validity is shown by factor loadings ranging from 0.729 to 0.910 in the "Planning and Technical Safety Management" construct. Additionally, supported by the AVE and composite dependability, the construct is credible [66,73]. Factor loadings between 0.729 and 0.873 for the "Conflict and Risk Management" construct indicate high construct validity. The factor loadings of 0.860 and 0.890 for "Resource and Facility Management" and an acceptable AVE show high construct validity. Factor loadings of 0.907 and 0.914 and a high CR and AVE support the reliability and validity of the "Communication and Safety Practises Accomplishment" construct.

The square root of the AVE values for each construct, which results from using the Fornell-Larcker criteria, is shown on Table 10′s diagonal. Outside-of-the-normal distribution values indicate correlations between the constructs. The conditions are met if the correlation between two constructs is less than the AVE for that construct squared [21,69]. When the square root of AVE for each component is higher than the correlations between the constructs, the research exhibits discriminant validity [62,63]. This demonstrates that many management principles, including Resource and Facility Management (RAFM), Planning and Technical Safety Management (PTSM), Communication and Safety Practices Accomplishment (CSPA), and Conflict and Risk Management (CARM), do not overlap.

Discriminant validity may be evaluated using the HTMT data shown in Table 11. Discriminant validity is typically accepted for HTMT levels below 0.85. All values in this study are significantly less than 0.85, demonstrating high discriminant validity between the constructs. Correlations between the constructs are much less than one, as seen in the table, proving that they are entirely separate and unrelated [9,11].

Relationships between the 28 BIM implementation factors and the four identified constructs (conflict management, risk management,

Table 5
Observed Eigenvalues and loadings.

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	13.933	49.760	49.760	9.836	35.128	35.128
2	3.613	12.902	62.662	4.628	16.529	51.657
3	1.466	5.237	67.899	3.296	11.773	63.430
4	1.283	4.583	72.482	2.535	9.052	72.482
5	1.055	3.767	76.250			
6	0.805	2.874	79.124			
7	0.697	2.489	81.613			
8	0.639	2.280	83.893			
9	0.539	1.924	85.817			
10	0.486	1.736	87.553			
11	0.464	1.658	89.211			
12	0.374	1.337	90.548			
13	0.332	1.187	91.735			
14	0.301	1.075	92.810			
15	0.270	0.965	93.775			
16	0.251	0.897	94.672			
17	0.218	0.777	95.449			
18	0.184	0.658	96.107			
19	0.174	0.622	96.730			
20	0.163	0.580	97.310			
21	0.143	0.512	97.822			
22	0.125	0.445	98.267			
23	0.113	0.404	98.671			
24	0.099	0.352	99.023			
25	0.088	0.314	99.337			
26	0.074	0.265	99.602			
27	0.063	0.224	99.826			
28	0.049	0.174	100.000			

Source: SPSS 26 is used to perform tests.

Table 6
Rotated component matrix.

Rotated Component Matrix	Component			
	1	2	3	4
BIM21	0.875			
BIM22	0.866			
BIM20	0.863			
BIM23	0.861			
BIM24	0.860			
BIM19	0.819			
BIM17	0.778			
BIM18	0.758			
BIM25	0.753			
BIM26	0.745			
BIM27	0.713			
BIM16	0.712			
BIM28	0.657			
BIM15	0.633		0.526	
BIM13	0.595			
BIM3		0.871		
BIM4		0.796		
BIM1		0.760		
BIM11		0.723		
BIM2		0.714		
BIM5		0.705		
BIM7			0.741	
BIM9			0.698	
BIM14	0.526		0.532	
BIM6			0.511	0.502
BIM8				0.739
BIM10				0.703
BIM12				

Source: SPSS 26 is used to perform tests.

communication, safety practises, and planning and technical safety management) are shown in Table 12 as cross-loadings. Each factor's strength of association with the constructs is represented by a value in the table. These cross-loadings support the reliability of the proposed factor-to-construct linkages by demonstrating that each BIM factor is most strongly connected to the construct with which it is theoretically associated [11,75].

5.3.2. *Structure path analysis*

Table 13 shows strong route coefficients and statistically significant results that highlight the influence of specific constructions on BIM deployment in construction project management. Conflict and Risk Management (CARM) 's favorable and considerable effect on BIM adoption is seen in its path coefficient of 0.272. A T-statistic of 12.36 and a P-value of 0 lend even more weight to this finding. With a path coefficient of 0.155, a T-statistic of 8.12, and a P-value of 0, Communication and Safety Practices Accomplishment (CSPA) is shown to affect BIM adoption positively. With a path coefficient of 0.617, Planning and Technical Safety Management (PTSM) has a significant and beneficial influence on BIM adoption. A t-statistic of 20.247 and a significance level of 0 both emphasize the importance of this factor. Finally, Resource and Facility Management (RAFM) positively impacts BIM adoption, as shown by the 0.165 path coefficient. This relevance is further supported by the fact that the T-statistic is 8.461 and the P-value is 0 [31,75]. Fig. 7 presents the structure model with path significance, and Fig. 8 indicates the model t-stat. Path coefficient is also included in both figures, indicating a significant relationship.

The outcomes of the model's predictive relevance study are shown in Table 14. The study determines the model's predictive value for BIM deployment. 2576.000 squares can be attributed to the observed variables, and 1332.856 squares can be attributed to the errors [76]. The predictive significance, or Q2, is determined by taking the ratio of SSO to SSE and subtracting 1. The model's ability to explain and predict BIM results is highlighted by the Q2 value of 0.483, demonstrating a relatively significant predictive relevance for BIM Implementation in the construction sector.

6. Analysis and discussion

BIM has been successfully implemented in the project management

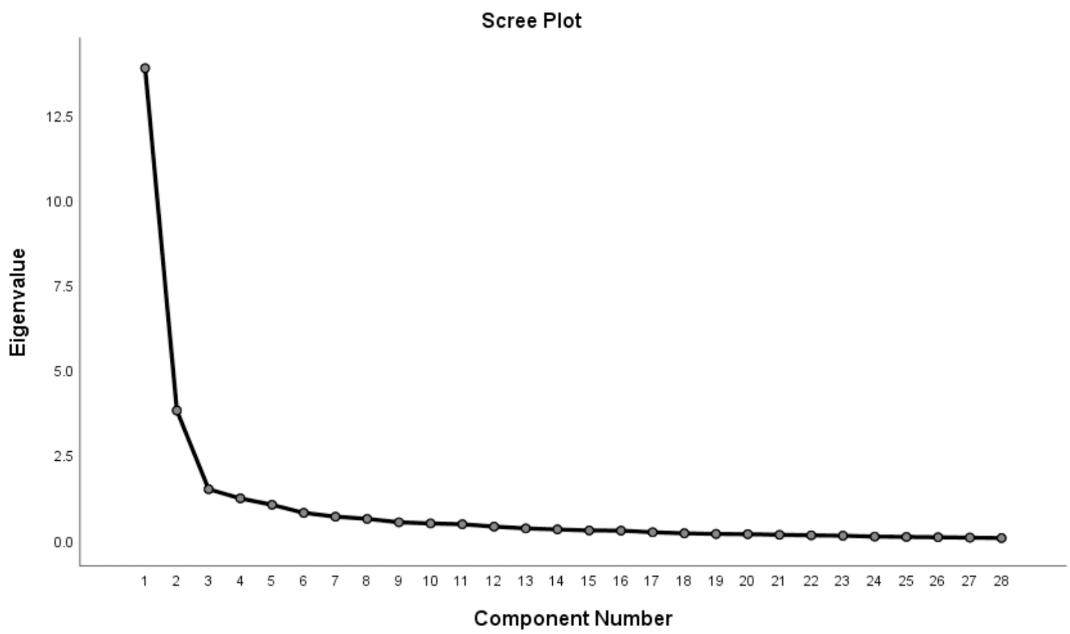

Fig. 4. Scree plot ().
Source: SPSS 26 is used to perform test

Table 7
Challenges with named constructs.

Construct	Code
Planning and Technical Safety Management	BIM21
	BIM22
	BIM20
	BIM23
	BIM24
	BIM19
	BIM17
	BIM18
	BIM25
	BIM26
	BIM27
	BIM16
	BIM28
	BIM13
Conflict and Risk Management	BIM3
	BIM4
	BIM1
	BIM11
	BIM2
	BIM5
Resource and Facility Management	BIM7
	BIM9
Communication and Safety Practices accomplishment	BIM8
	BIM10

Source: SPSS 26 is used to perform tests.

practises of the Pakistani construction sector, and this research sheds light on how it was done. These findings provide a vital vantage point on the significance of the effect of specific structures on BIM deployment. The path coefficient of 0.272 shows that Conflict and Risk Management (CARM) is a significant factor influencing BIM adoption favorably. This is in line with other studies highlighting the significance of risk management in building projects [77]. Still, its unique addition focuses on the effects of BIM in Pakistan. Planning and Technical Safety Management's (PTSM) high path coefficient of 0.617 demonstrates the importance of PTSM in facilitating BIM adoption. The significance of PTSM in project management is well-established; nevertheless, the novel component of this research is its connection to the adoption of BIM in the Pakistani context [59].

Accomplishment in Communication and Safety Practices (CSPA) also emerges as a significant factor in BIM adoption, with a path value of 0.155. While the importance of communication in construction management is well-known, this research sheds new light on the topic by examining it in the context of BIM adoption [78].

With a path coefficient of 0.165, Resource and Facility Management (RAFM) positively affects BIM adoption. This relates to earlier studies that have stressed the significance of resource management, but this time, it's in the context of BIM adoption [79]. The study's original contribution is that it is the first to examine the use of BIM in Pakistan's construction sector. This study enhances our understanding of the role that BIM plays in optimizing project control practices in the construction industry of Pakistan by identifying the significant factors that significantly influence BIM implementation.

Building Information Modeling (BIM) is one such emerging innovation that has now been considered pivotal for the construction sector. Through its implementation, a changed and enhanced level of management and operational efficiency of projects within the sector can be noticed [6]. This paper would, therefore, help provide essential insight regarding the deployment of BIM in Pakistan, a region in which rapid infrastructure development is needed but is challenged due to inefficiencies such as delays and budget overruns.

This research is of particular importance with relation to the use of Building Information Modeling (BIM) in the construction sector of Pakistan, where surely it has a large contribution to the national economy and at the same time has a multiplier effect on socio-economic development [5]. Construction contributes around 4.5 % to the GDP of Pakistan and, therefore, underlines its role in employment generation and infrastructural growth [50]. The only barrier that comes in its way is the inefficiencies like delays and cost overruns that can be prevented through BIM.

The construction industry in Pakistan operates in a complex social, economic, and cultural environment, which has had an impact on the adoption of BIM [59]. Equally compelling in the adoption of BIM are the high rates of unemployment in the country and that most of the workforce in this sector is informal. This underlines an urgent need to push the construction workers at an increased level of professionalism to gain a good grip on the skills and knowledge that BIM needs. On the other side, however, BIM does hold significant potential for productivity

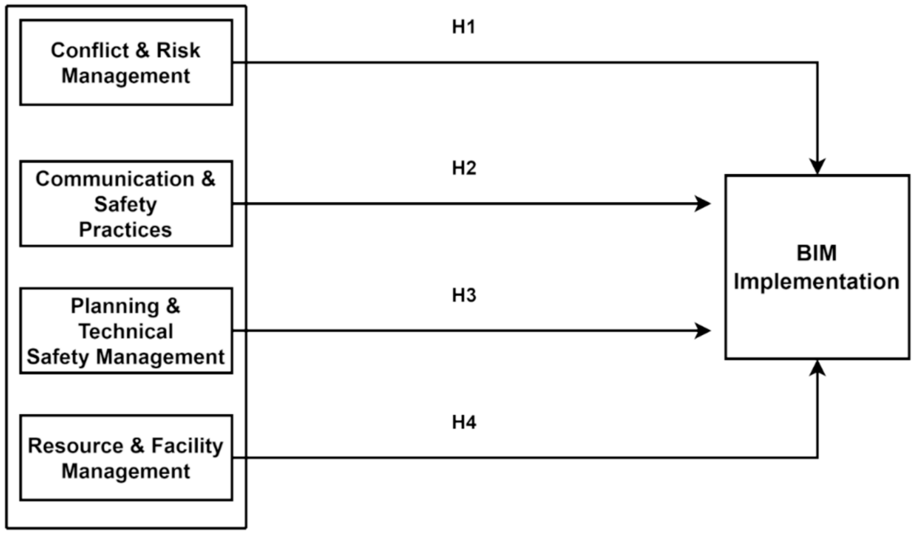

Fig. 5. Hypothesized framework ().
Source: the hypothesis diagram is drawn by authors using Io draw online tool

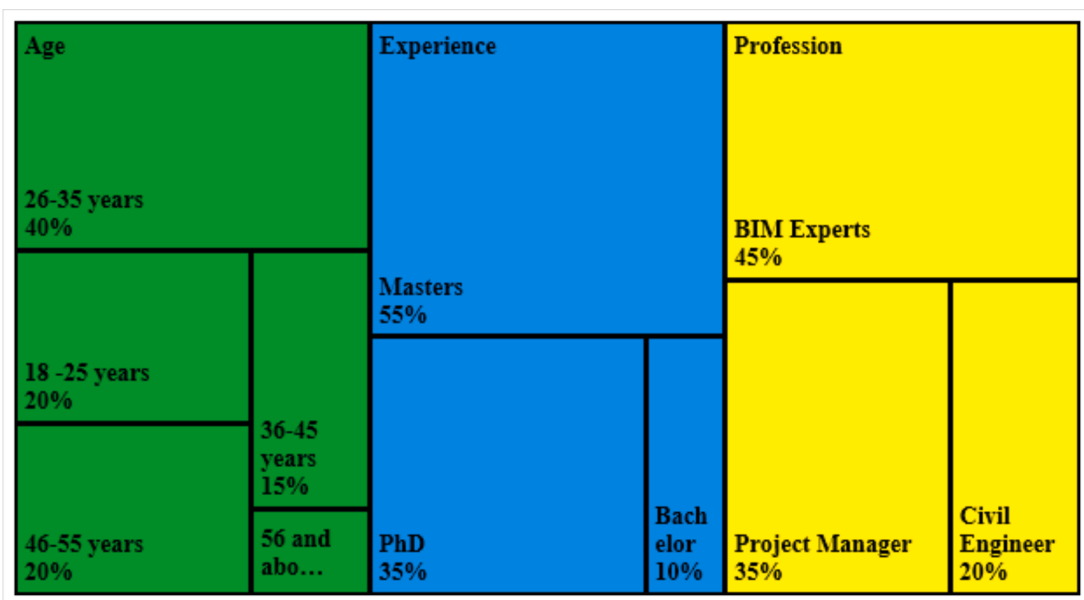

Fig. 6. Demographics ().
Source: MS Excel is used to draw the diagram on collected data of respondents

improvements that might allow better project results and thus mean more stable employment opportunities.

The resistance to change of management practices and technology adoption is strongly noticed as part of the culture within the construction industry in Pakistan [55]. This attitude normally results in a very slow process of adopting novelties like BIM. If the actual benefit of transparency and accountability of the project is the focus point for which Building Information Modeling is being introduced, this will, to some extent, attract the project stakeholders having a traditional tendency against new methodologies conservatively.

This would also be very relevant to environmental consideration, keeping in view the poor conditions of the changing climate and how it directly affects Pakistan, and literally each material and construction methodology [5]. This would, therefore, be quite relevant with the potential of BIM in improving the efficiency of resources and waste reduction, which perfectly fits within the country's agenda of sustainable development. The deciding factor of the adoption in most cases is likely to be the adopted model, because the adopted model is capable of simulating various impacts on the environment before the actual implementation of the model.

These findings compare with regional studies, in which findings of common adoption barriers, such as lack of trained personnel and technological infrastructure, have been found in other South Asian countries [52]. However, the situation in Pakistan presents some challenges and opportunities that are unique to BIM regulation and the economic environment. In other words, the recognition of the important contribution of digital technologies by the Pakistani government to the construction sector is just beginning, and the process of policy implementation is following the countries that have put a stronger institutional setup in place for BIM adoption [21]. Understanding of these similarities and differences would be important in helping to customize the implementation strategies of BIM, which are informed not only by the best practices from all over the world but also by the local realities. Pakistan's policymakers and industry leadership do need to

Table 8
Descriptive statistics.

	Mean	N	Std. Deviation
BIM1	3.07	125	1.265
BIM2	3.03	125	1.199
BIM3	2.49	125	1.191
BIM4	2.87	125	1.311
BIM5	2.76	125	1.409
BIM6	3.12	125	1.221
BIM7	2.99	125	1.245
BIM8	3.77	125	1.259
BIM9	3.05	125	1.161
BIM10	3.41	125	1.336
BIM11	3.10	125	1.241
BIM12	3.09	125	1.201
BIM13	3.34	125	1.278
BIM14	3.29	125	1.322
BIM15	2.99	125	1.395
BIM16	2.84	125	1.260
BIM17	2.79	125	1.322
BIM18	2.75	125	1.246
BIM19	2.90	125	1.375
BIM20	3.17	125	1.480
BIM21	3.01	125	1.371
BIM22	3.09	125	1.380
BIM23	3.12	125	1.582
BIM24	3.09	125	1.388
BIM25	3.02	125	1.367
BIM26	3.04	125	1.414
BIM27	2.47	125	1.402
BIM28	3.24	125	1.425

Source: SPSS 26 is used to perform tests.

Table 9
Model reliability and validity statistics.

Construct	Code	Loadings	CA	CR	AVE
Planning and Technical Safety Management	BIM21	0.900	0.964	0.966	0.72
	BIM22	0.875	–	–	–
	BIM20	0.910	–	–	–
	BIM23	0.894	–	–	–
	BIM24	0.874	–	–	–
	BIM19	0.908	–	–	–
	BIM17	0.845	–	–	–
	BIM18	0.840	–	–	–
	BIM25	0.823	–	–	–
	BIM26	0.804	–	–	–
	BIM27	0.729	–	–	–
	BIM16	0.759	–	–	–
	BIM28	Deleted	–	–	–
	BIM13	Deleted	–	–	–
Conflict and Risk Management	BIM3	0.729	0.905	0.914	0.676
	BIM4	0.873	–	–	–
	BIM1	0.804	–	–	–
	BIM11	0.799	–	–	–
	BIM2	0.853	–	–	–
	BIM5	0.828	–	–	–
Resource and Facility Management	BIM7	0.860	0.700	0.701	0.766
	BIM9	0.890	–	–	–
Communication and Safety Practices accomplishment	BIM8	0.914	0.794	0.794	0.829
	BIM10	0.907	–	–	–

Source: Smart PLS 4 is used to perform tests.

Table 10
Fornell Larker criteria results.

Constructs	CARM	CSPA	PTSM	RAM
CARM-Conflict & Risk Management	0.822			
CSPA-Communication & Safety Practices accomplishment	0.505	0.91		
PTSM-Planning & Technical Safety Management	0.459	0.514	0.849	
RAFM-Resource & Facility Management	0.583	0.555	0.525	0.875

Source: Smart PLS 4 is used to perform tests.

Table 11
HTMT statistics.

Constructs	CARM	CSPA	PTSM	RAM
CARM-Conflict & Risk Management				
CSPA-Communication & Safety Practices accomplishment	0.589			
PTSM-Planning & Technical Safety Management	0.471	0.582		
RAFM-Resource & Facility Management	0.719	0.749	0.638	

Source: Smart PLS 4 is used to perform tests.

Table 12
Cross ladings.

Variables	CARM-Conflict & Risk Management	CSPA-Communication & Safety Practices accomplishment	PTSM-Planning & Technical Safety Management	RAFM-Resource & Facility Management
BIM1	**0.804**	0.439	0.438	0.391
BIM2	**0.853**	0.441	0.526	0.537
BIM11	**0.799**	0.472	0.348	0.417
BIM3	**0.773**	0.299	0.157	0.312
BIM4	**0.873**	0.427	0.351	0.537
BIM5	**0.828**	0.38	0.352	0.629
BIM8	0.403	**0.914**	0.514	0.479
BIM10	0.518	**0.907**	0.421	0.533
BIM16	0.363	0.327	**0.759**	0.394
BIM17	0.434	0.406	**0.845**	0.372
BIM18	0.458	0.438	**0.84**	0.509
BIM19	0.486	0.48	**0.908**	0.577
BIM20	0.369	0.541	**0.91**	0.418
BIM21	0.348	0.525	**0.9**	0.4
BIM22	0.397	0.494	**0.875**	0.336
BIM23	0.338	0.534	**0.894**	0.429
BIM24	0.281	0.415	**0.874**	0.379
BIM25	0.432	0.419	**0.823**	0.541
BIM26	0.395	0.376	**0.804**	0.591
BIM27	0.362	0.23	**0.729**	0.38
BIM7	0.477	0.487	0.422	**0.86**
BIM9	0.541	0.485	0.493	**0.89**

Source: Smart PLS 4 is used to perform tests.

consider such factors in devising frameworks for the adoption of BIM that takes heed of the universal and industry-specific aspects of the Pakistani construction industry.

The contribution is invaluable, particularly in the construction sector of Pakistan, which has been rife with inefficiency, hence the need of the utmost nature for strong mechanisms of schedule and budget implementation [5]. BIM carries in it the promise of operational efficiencies and development trajectories that are safer, if not more economically sustainable.

Linking these findings to the problems and operational realities of the Pakistani construction industry, research is therefore filling a critical void within the literature and providing a customized blueprint of how BIM can be leveraged within emerging markets. Strategies will provide evidence of the potential BIM could deliver to the sector for improved competitiveness and sustainability to the stakeholders, including policy and industry leadership.

In order to enhance BIM implementation, it is recommended that managers in the Pakistani construction sector give priority to the aforementioned structures, as indicated by the findings. In addition to stable planning and technical safety management, effective strategies for resolving conflicts and risks, efficient resource, and facility management, and streamlined communication and safety practices are required for the successful implementation of BIM. While this study offers valuable insights, it is important to acknowledge its limitations and future ramifications, which are elaborated. The scope of the study is limited to the Pakistani context, which restricts generalizability. It is preferable to have a more comprehensive and diverse dataset in order to

Table 13
Path relationship analysis results.

Hypothesis	Relation	(O)	(M)	SD	T statistics	P values	Status
H-1	CARM –> BIM Implementation	0.272	0.272	0.022	12.36	0.000	Acknowledged
H-2	CSPA-> BIM Implementation	0.155	0.155	0.019	8.12	0.000	Acknowledged
H-3	PTSM-> BIM Implementation	0.617	0.616	0.03	20.24	0.000	Acknowledged
H-4	RAFM-> BIM Implementation	0.165	0.164	0.02	8.46	0.000	Acknowledged

(O) = Original sample; (M) = Sample mean; SD=Standard deviation; CARM=Conflict & Risk Management; CSPA=Communication & Safety Practices Accomplishment; PTSM=Planning & Technical Safety Management; RAFM=Resource & Facility Management.
Source: Smart PLS 4 is used to perform tests.

enhance the representation of the general population in future research. Additionally, the research focuses solely on the impact of specific components on BIM implementation; therefore, it is possible to explore the interrelationships of additional variables. Ongoing research is imperative for businesses to adapt to the constantly evolving dynamics of the market.

7. Implications

The findings from this study not only validate the utility of BIM in improving project management within the Pakistani construction sector but also offer new theoretical and conceptual insights into its implementation challenges and benefits. This discussion aims to elaborate on how these findings enhance our understanding of BIM and contribute to the theoretical framework of construction management in emerging markets.

1. Theoretical contributions

- Integration of BIM and Project Management Theory

This study bridges the gap between BIM technology and traditional project management theories by demonstrating how BIM's capabilities can enhance project planning, risk management, and communication strategies. By quantitatively establishing the correlation between BIM implementation and improved project outcomes in terms of safety and technical management, the study substantiates theoretical propositions that advocate for the integration of digital tools in construction project management frameworks.

- Adaptation of Technology Acceptance Models

The findings contribute to the adaptation of technology acceptance models in construction management by identifying critical factors that influence BIM adoption in Pakistan. These include technical, organizational, and cultural barriers, providing a comprehensive understanding that can be used to modify existing models to better suit the construction sector's specifics.

2. Conceptual contributions

- Development of a Contextual Framework:

This research contributes to the development of a contextual framework for BIM implementation that considers the unique challenges of the Pakistani construction industry, such as limited technological infrastructure and resistance to new processes. By doing so, it enriches the conceptual understanding of how BIM can be effectively integrated into project management practices under diverse operational conditions.

- Enriching BIM Implementation Strategies:

The study further enriches the conceptual landscape by proposing tailored BIM implementation strategies that address both generic and context-specific challenges. It highlights the importance of targeted training programs, government incentives, and a phased adoption approach, which are essential for overcoming the identified barriers.

3. Implications for practice and policy

- Practical Guidelines for BIM Adoption:

Based on the study's findings, we propose practical guidelines for the phased implementation of BIM in the Pakistani construction sector. These guidelines emphasize the need for initial pilot projects, stakeholder engagement through workshops, and the development of localized BIM standards to ensure alignment with global practices while catering to local needs.

4. Policy Recommendations

The study's insights are critical for policymakers who are tasked with fostering technology adoption in the construction industry. Recommendations include enhancing IT infrastructure, subsidizing BIM training programs, and creating a regulatory environment that encourages digital innovation in construction practices.

By focusing on these theoretical and conceptual contributions, the discussion section of the manuscript will not only contextualize the findings within the broader literature of BIM implementation but also highlight their implications for improving construction management practices in emerging markets like Pakistan. This approach should meet the reviewer's expectations for a meaningful discussion that advances the understanding of BIM's role in construction management.

8. Conclusion

In conclusion, this research set out to learn how various factors in the Pakistani construction industry's project management practices react to BIM. The primary goal was to clarify the complex interplay between conflict and risk management, communication and the achievement of safe work practices, planning and technical safety management, and resource and facility management in successfully deploying BIM. The results of this study show how these factors are crucial in shaping BIM adoption in Pakistan. After careful examination, it was found that each element adds considerably to BIM's usefulness in building project management. These findings address a significant need in the literature by providing a novel and locally relevant viewpoint on BIM adoption in Pakistan. This research adds to the current body of knowledge by providing a fresh and narrow perspective on the variables influencing the adoption of BIM in the Pakistani construction industry.

Overall, the study added to the existing knowledge base some vital factors affecting the adoption of Building Information Modeling (BIM) in the construction industry of Pakistan. By considering in detail the interrelations that BIM maintains with the respective practices of project management, it becomes really possible to address their interest to the possibility that BIM use can lead to a very remarkable increase in efficiency and safety in the construction project. Not without its limitations, the present research will discuss them in the next section.

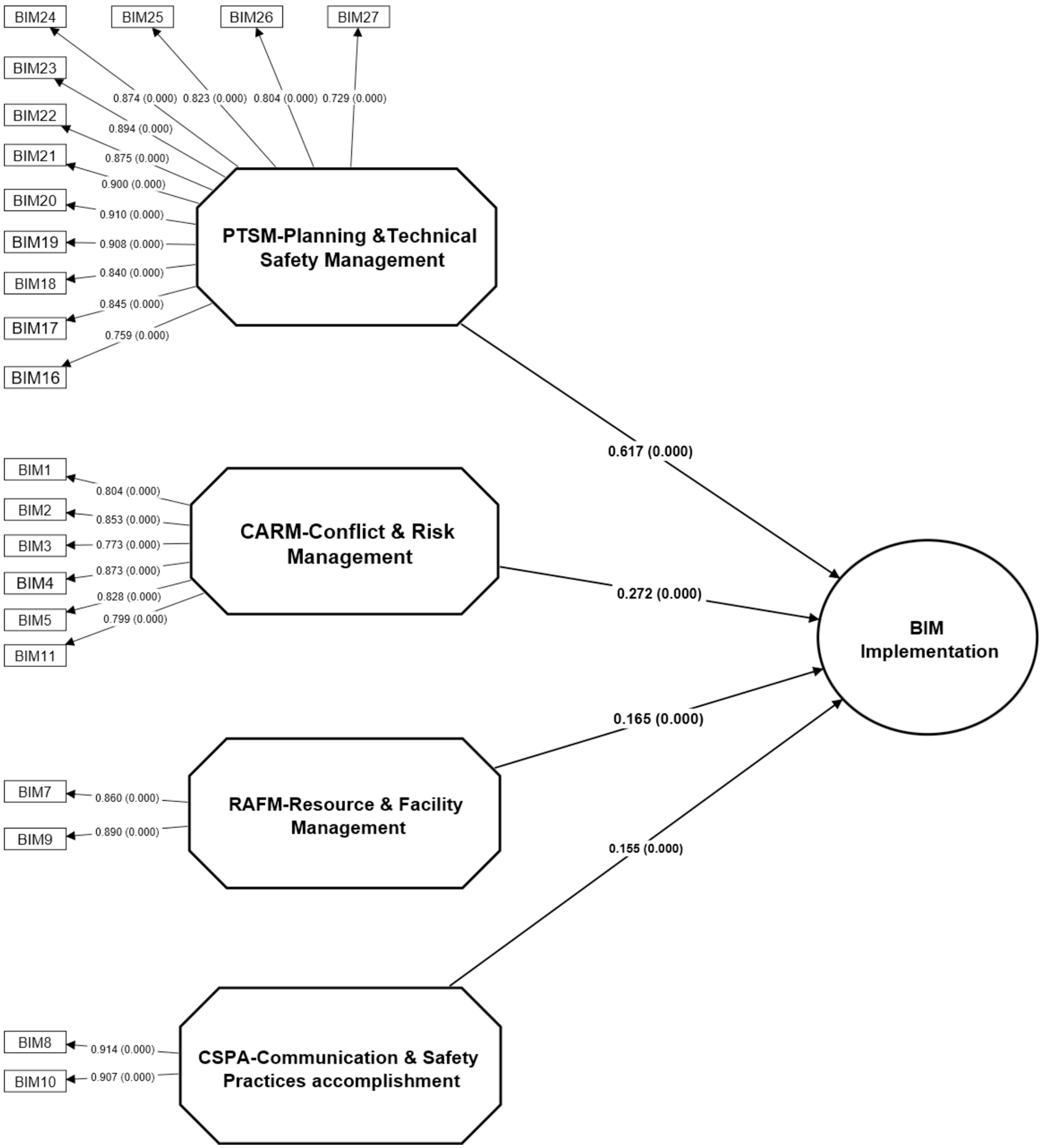

Fig. 7. Model path coefficients and significance ().
Source: Smart PLS 4 is used to perform test and generate the output diagram which is the model of the study

8.1. Limitations of the current Study

Since the research took a sample from a specific segment of the Pakistani construction industry, the findings are not generalizable to any other part of Pakistan or, for that matter, to other countries. This may limit the scope of demographic and geographic diversity within the sample and therefore may have limitations in how generalizable the findings would be.

From the fact that research focuses on technological deployment, the study may be biased to the technological solution and thus need to account for those non-technological organizational culture or economic conditions, which might have far more implications for the adoption of BIM.

The cross-sectional nature of the study allows no cause of inferences from the data. As the process of BIM implementation is a dynamism, relying upon and between the changing technologies and policies, an

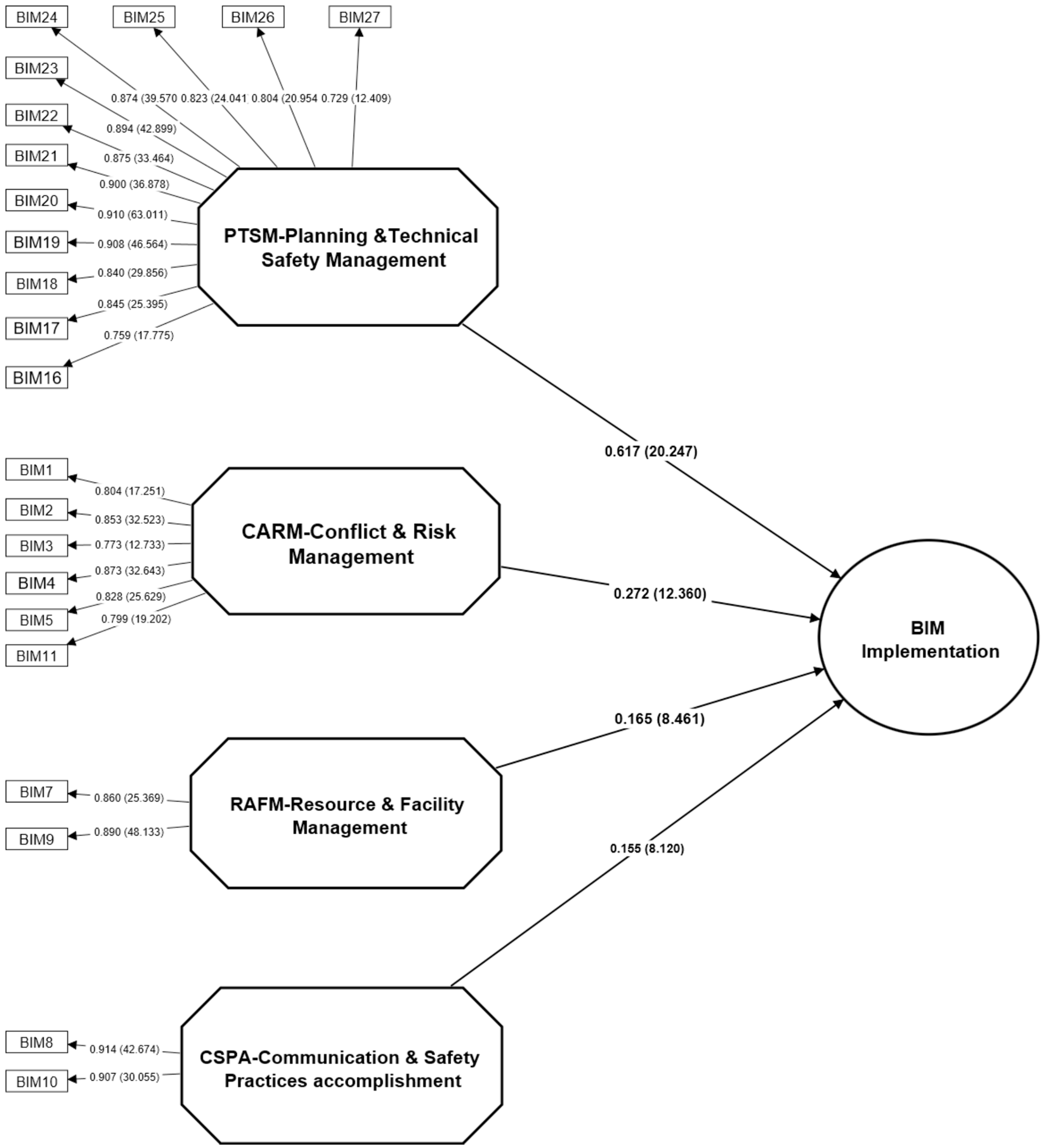

Fig. 8. Model t-stat and path coefficient ().
Source: Smart PLS 4 is used to perform test and drawn diagram is output of software

Table 14
Model predictive relevance.

Relevant Construct	(SSO)	(SSE)	Q^2 (=1- (SSO)/(SSE))
BIM Implementation Construct	2576.000	1332.856	0.48

Source: Smart PLS 4 is used to perform tests.

approach which is longitudinal would prove more insightful for the impacts over a time period.

8.2. *Directions for future research*

Future research should target aspects of BIM adoption to a larger and more varied group geographically and demographically in order to strengthen the generalizability of the results to practice. Another area of further research may explore the differences in BIM adoption toward different types of construction projects, such as residential versus commercial or public versus private.

It will require longitudinal studies that would give some understanding of long-lasting effects of BIM adoption and sustainability. It is at this point that one may find tracking changes over time to be key: longitudinal studies could give the evolving implementation challenges and benefits developed by industry practice and technologies as sources of insight.

This is further research extended to how BIM converges with other upcoming technologies, such as Artificial Intelligence (AI) and the Internet of Things (IoT). In this respect, it would be equally interesting to establish how synergies of different technologies could further help construction project management.

It is recommended to carry out further detailed research on the economic and cultural impacts of BIM implementation. Understanding these could help in drawing BIM strategies in a way that they conform more specifically to requirements and prevailing conditions of developing countries, like Pakistan.

Further research, therefore, is recommended to assess the impact such policy and regulatory frameworks have on BIM adoption. It would assess the effectiveness of current policies and propose new frameworks that would provide better help for the adoption of BIM technologies.

In one way or the other, the study will fill the gap that exists, but it will also contribute to the existing body of knowledge and encourage the growing exploration and development in the area of the construction industry within BIM. Such efforts contribute to the overall objective of improving construction project management practice with advanced technologies.

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CRediT authorship contribution statement

Muhammad Sajjad: Writing – review & editing, Writing – original draft, Visualization, Validation. **Anfeng Hu:** Supervision, Resources, Project administration. **Dorin RADU:** Funding acquisition, Formal analysis, Data curation, Conceptualization. **Ahsan Waqar:** Writing – review & editing, Writing – original draft, Visualization, Conceptualization. **Hamad R. Almujibah:** Writing – original draft, Software, Project administration. **Abdul Mateen:** Writing – review & editing, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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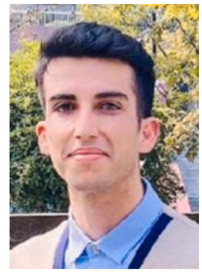

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