Building Information Modeling (BIM) for Sustainable AEC Projects: A Review of Current Practices and Future Directions

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ABSTRACT

The research analyzed Building Information Modeling (BIM) for sustainable Architecture, Engineering and Construction (AEC) projects in Pakistan, primarily focusing on energy efficiency and sustainability. The study documented the current level of BIM technologies and practices adopted in Pakistan construction and analyzed the level of BIM practices in construction firms and the results of sustainable building outcomes. For the comprehensive review, the BIM practices study survey designed for 85 AEC professionals, 15 completed project case studies, and stakeholder expert interviews was conducted across Lahore, Karachi, and Islamabad. BIM use in Pakistan is still in its infancy. Of the firms surveyed, 23 percent use BIM for conducting sustainability assessments. This research documented lack of technical knowledge, expensive software, weak government policies, and reluctance from old-school builders to adopt digital BIM as the most urgent barriers. Still, BIM for energy design strategic plans assisted project teams in improving predictive energy performance design, reducing materials waste by 18 to 25 percent, and improving stakeholder coordination. This research mapped the future of BIM use in the Pakistan AEC sector and proposed a step-by-step structural approach, training and policy setting for BIM use to be mandatory in government AEC projects. Strategically implementing Building Information Modeling (BIM) technology in Pakistan's construction industry has the potential to reshape the industry and enhance environmentally sustainable design decisions based on real-time data analytics. This will play a vital role in fulfilling the country's commitments to climate change and energy savings.

Keywords: *Building Information Modeling (BIM), Architecture, Engineering, Construction, energy, efficiency, sustainability.*

INTRODUCTION

The global construction industry is at a turning point where traditional forms of construction must change in response to environmental challenges and sustainability issues (Spassova 2022). Building Information Modeling has become a game-changing digital technology that alters how construction, architecture, and engineering design, plan, implement, and manage projects across their lifecycles (Ullah, Akram et al.). This advanced technology allows practitioners to design intelligent 3D models containing all relevant information on the components, materials, costs, and performance of the various parts of a structure. The addition of BIM to construction workflows is more than integration on a digital level; it is the beginning of a new collaborative approach to construction where workflows are integrated in a single, real-time collaborative environment and decisions are made through a closed-loop system in real-time. This system is able to improve the performance of a project in various aspects, including cost, time, quality, and environmental sustainability (Tanhadoust, Dabbaghisouraki et al. 2025).

The construction sector plays an important role in the economy of Pakistan and the economy. In light of burgeoning urbanization, a fast-growing population, and rising energy demands, the sector is under pressure to adopt new construction approaches to fulfill the needs of high resource buildings, those that waste less energy, and those that operate resource efficiently over their building life (Rahman and Khan 2025). In Pakistan's construction and architectural industry, the predominant building method is 2D drawings integrated with poor systems of design communication. This 'design' approach results in the production of buildings with poor performance and an excessive waste of building materials. Legally, buildings are not equipped with the energy systems that satisfy the design intent. This unfortunate state of affairs decouples the expected energy performance of a building, leading to a myriad of socio environmental ramifications and a significant financial burden to the owner (Sultan, Khan et al. 2025).

Using global evidence, we understand that Building Information Modeling (BIM) technologies improves the outcomes of sustainable buildings considerably due to precise energy simulations, efficient material usage, increased coordination of diverse stakeholders, and empowered decision-making at various levels of the project (Kusi, Boateng et al. 2025). Enhanced BIM systems provide the opportunity to designers to examine numerous design options, assess the possible consequences for the environment, and choose the most sustainable options in the context of efficiency, cost, and sustainability prior to the actual construction. While the benefits of BIM are considerable, and the technology is widely available in developed construction markets, the AEC sector in Pakistan has adopted BIM at much slower pace, with adoption still significantly lower than many other countries. This gap offers the sector the opportunity to modernize and become competitive in the global marketplace (Chen, Wang et al. 2023).

The limited understanding of BIM adoption within Pakistan's construction sector impacts strategic planning and policy formulation. Countries abroad have researched and documented the construction sector's use of BIM technologies, capabilities, and implementation techniques, but the unique socioeconomic, regulatory, and construction sector characteristics of Pakistan warrant research of its own (Akram, Nadeem et al. 2025). Assessing the state of BIM adoption and its diffusion barriers, along with documented success stories of its implementation, is crucial to building technologically advanced, context-appropriate frameworks to drive adoption. Additionally, documenting empirically the influence of BIM on the sustainable outcomes of construction within Pakistan would assist in building stakeholder knowledge and confidence in the technology, training, and organizational change investments (Sohail 2024).

The study explores the implementation of Building Information Modeling (BIM) on sustainable architecture, engineering, and construction (AEC) projects in the major urban centers of Pakistan. It evaluates the various levels of adoption, usage, and the different barriers, both technical and non-technical, organizational readiness, and the impacts of the level of sustainability of the completed projects. Having construction professionals, completed projects, and industry experts as references became the basis of the study and looks at the overall state of the construction industry in Pakistan in regard to its BIM implementation and the potential ways to move forward into deeper and broader application of BIM in sustainable construction. It serves the dual purpose of assisting in the gap of scholarly literature on the diffusion of construction technologies in developing countries and BIM for industry players (Bhatti, ul Haq et al. 2025).

This research is important not only because of Pakistan's engagement in addressing climate change but also because the construction industry is a major consumer of energy and a significant emitter of carbon in Pakistan. The climate change mitigation strategy must also incorporate energy-efficient buildings because a large part of energy demand is driven by buildings and their operational efficiencies. Thus, the operational cost benefits to owners and occupants is an added incentive. BIM technology has the potential to strengthen energy-efficient design, aid in the integration of other renewable energy technologies, perform sustainability assessments on construction projects, and support green construction lifecycle analyses. Hence, it becomes facilitating technology for Pakistan's construction industry. Therefore, it is important to understand BIM's construction and design technologies within the Pakistan context. The implications, in this case, will not only be relevant to the success of the specific projects but also to the success of the projects on a national scale in Pakistan to achieve national development and target climate goals.

Research Objectives

1. To evaluate the extent to which BIM is currently adopted and implemented, particularly in energy-efficient and sustainable building outcomes, in Pakistan's major urban centers' construction industry, particularly in the Architecture, Engineering, and Construction sectors.
2. To examine the technical, economic, organizational, and policy dimensions of the barriers to the construction industry in Pakistan related to the sustainable use of BIM.
3. To create a detailed framework that includes practical recommendations for fast-tracking the adoption of BIM technology in the AEC sector of Pakistan. This would include capacity-building initiatives, policy recommendations, and steps pertaining to the transformation of the sector to adopt environmentally sustainable construction practices.

Research Questions

1. How widely adopted is BIM within Pakistan's Architecture, Engineering, and Construction sector, and how many firms are employing BIM tools for sustainability and energy efficiency within building projects?
2. What are the main barriers to the widespread implementation of BIM in Pakistan's construction industry, and how do these barriers differ among various stakeholders, project types, and organizational contexts?
3. What are the most effective methods for implementing BIM within Pakistan's construction industry, and what policy, educational, and industry framework changes are required to improve sustainability within the built environment?

Significance Of The Study

The construction industry in Pakistan has yet to embrace BIM technology fully. Thus, BIM's implementation across the AEC sector in Pakistan has left a significant gap in the sustainable construction literature. The study's implementation of evidence-based BIM practices and the construction of a sustainable technology roadmap for the industry will assist construction stakeholders in focusing their efforts on sustainable construction. Sustainable technologies can be applied and practiced within the building sector in Pakistan. The in-depth analysis of the AEC sector in Pakistan will serve as a guiding framework for policy formulation and strategy integration across various stakeholders. Adopted diffusion frameworks target specific gaps within Pakistan's construction industry. They ensure maximum project efficiency and positive positioning for the construction industry's value chain. It aids in project delivery that's sustainable and efficient in execution. It addresses the construction industry's literature and diffusion and supports other suggested literature on optimization of state-of-the-art sustainable practices. It furthers Pakistan's socio-economic goals of energy efficiency and climate change mitigation. The impact of this research is reduced socio-economic vulnerability and improved socio-economic development for the built environment.

LITERATURE REVIEW

Since the 1970s, the developments of the Building Information Modeling (BIM) conceptual framework have been building the foundations of what would become a more complex digital and integrated construction practice used worldwide today. Beyond the graphics produced in three-dimensional visualization software, the academic literature identifies BIM as a digital construction document integrated process of 3D model representations of functional and static building elements that serves as a knowledge base repository throughout the life cycle of a facility (Chen, Wang et al. 2023). Literature illustrates that BIM profoundly streamlines collaborative work of the architects, engineers, contractors, and owners through integration of design, sequencing of construction, and operational considerations in a unified system. Such collaboration minimizes the risk of the fragmentation of the flow of information that has historically been a key challenge in construction projects. Each discipline worked separately in their own inconsistent documentation systems that contained contradictory information resulting in expensive construction phase errors and costly rework (Revolti, Gualtieri et al. 2024).

Scholars have examined the sustainability dimensions of BIM while the construction industry tries to deal with environmental responsibilities and energy efficiency (Akram, Mubin et al. 2024). Some of these studies emphasize BIM's support to the designer in the 'sustainable design' process including energy modeling, daylighting, analyzing materials, lifecycle assessment, and more. Given the importance of certain design decisions on overall building performance, researchers confirm that evaluating sustainability during the early design phases, rather than applying post-design completion retrofits, offers much more positive environmental results (Waqar, Othman et al. 2023). The ability of BIM platforms to rapidly generate and test design alternatives together with immediate energy and environmental impact analysis is the key to this early integration. The literature shows that BIM sustainability analysis projects achieve significantly lower energy used in the building, lower carbon footprint of materials used in construction, and better indoor environmental quality compared to buildings designed without BIM (Alvur, Anaç et al. 2024).

The advantages of BIM across different types of projects and buildings are documented within various international case studies. Evidence from developed construction markets, including the United States, the United Kingdom, Singapore, and Scandinavian countries indicates that BIM use is associated with decrease in construction duration, construction cost, change orders, and quality of work. According to studies that estimate the effect of BIM on construction waste, wastes worth 15% to 30% of the project cost are eliminated, on-site construction conflicts are resolved before they manifest, and the overall duration of construction is reduced by 10% to 20% as a result of improved project coordination. These reductions in construction waste and the associated environmental impacts material waste to be disposed, construction waste, waste to be transported, and the emissions from transportation are significant. Moreover, BIM-designed buildings use less energy during the post-occupancy phase than conventional buildings, suggesting that the energy consumption simulation tools offered in BIM are reliable (Alshorafa and Ergen 2021).

In some parts of the world, documented benefits of BIM adoption hold true, but the literature shows quite the opposite to be the case in developing countries such as Pakistan. Research focusing on the diffusion of construction technologies in emerging markets points to several barriers to the adoption of BIM. They can be technical, such as costly software and the expensive and complex hardware requirements and learning curves that software users face, or they may be organizational, like professional culture resistance to change, poorly designed training, and the absence of consistent BIM operational procedures within and across project teams. Literature indicates that fully successful adoption of BIM transcends merely acquitting the requisite technologies to encompass changes to the very structures and cultures of the adopting firm, their operational workflows, and the teamwork relationships of all those involved in a project (Akram, Thaheem et al. 2022).

The importance of government policy in accelerating the adoption of BIM technologies is a significant focus within the scholarly community. Research on the diffusion of BIM technologies in countries such as Singapore, the United Kingdom, and Norway, highlights the adoption of BIM for public sector projects as a major reason for rapid adoption. These policies create a pull that motivates the private sector to develop the necessary capabilities and helps create a critical mass of trained personnel. Documentation describes how government leadership in the form of procurement policy, project funding for training, the establishment of national BIM standards, and public infrastructure demonstration projects, technology adoption in the sector is substantially accelerated. In contrast, studies of voluntary adoption markets show persistent gaps in adoption and diffusion. This is particularly evident in small and medium-sized enterprises that do not have the resources to make stand-alone technology investments (Jiang, Wu et al. 2022).

Research focusing on construction practices in Pakistan and comparable developing economies demonstrates considerable gaps in sustainable building delivery compared to international best practices (Akram, Mubin et al. 2025). Several studies note the predominance use of traditional construction methods in Pakistan, which is exacerbated by limited technological integration, fragmented approaches to project delivery, and minimal lifecycle performance, sustainability, and holistic considerations. Several research studies focus on professional skill gaps, inadequate educational programs lacking exposure to cutting-edge technologies, and industry structures where lowest-cost bidding is the norm, thereby excluding value-based procurement which incentivizes creativity and innovation. Combined, these elements create an environment in which the adoption of BIM technologies faces additional difficulties that are very different from those in developed economies, requiring the development of specific approaches to BIM that focus on industry strengths and contextual challenges of limited resources and low capability, within the developing world construction environment (Iqbal, Ma et al. 2021).

RESEARCH METHODOLOGY

The researchers adopted mixed-method research design for studying the AEC sector in Pakistan. For the primary data collection, the researchers used a structured questionnaire survey directed at 85 construction professionals across the 3 primary cities of Lahore, Karachi, and Islamabad. These professionals included architects, engineers, project managers, and contractors, all of whom were active in the design and construction of buildings. The researchers also undertook detailed case study analyses of 15 completed construction projects which incorporated varying degrees of BIM technologies. In addition to the project BIM documentation, they also reviewed energy performance and sustainability documentation. Furthermore, semi structured interviews with BIM professionals, government representatives, and construction executives were conducted to understand qualitative aspects of barriers to adoption and integration. For the quantitative adoption and disengagement BIM survey, usage correlation with sustainable building outcomes, the researchers employed statistical techniques. Qualitative interview narratives were subjected to thematic analysis whereby the policy, software, and technical skill gaps were identified as recurring challenges. The case studies were able to demonstrate in comparative terms the influence of BIM on stakeholder coordination, material waste, and energy efficiency. This mixed approach facilitated an understanding of the contemporary BIM practices while ensuring the findings validation across different sources, which in turn, provided solid groundwork for the design of the proposed construction industry's BIM implementation framework in Pakistan.

RESULTS AND DATA ANALYSIS

Quantitative Analysis

Table 1: BIM Adoption Rates Among Pakistani AEC Firms

BIM Adoption Status	Number of Firms	Percentage
Full BIM Implementation	8	9.4%
Partial BIM Use	27	31.8%
Limited/Experimental Use	30	35.3%
No BIM Adoption	20	23.5%
Total	**85**	**100%**

The survey results revealed that BIM adoption in Pakistan's construction sector remained relatively limited, with only 9.4 percent of firms reporting full BIM implementation across their projects. The largest proportion of respondents, comprising 35.3 percent, indicated limited or experimental use of BIM technologies, suggesting awareness of the technology but incomplete integration into standard workflows. Partial BIM use was reported by 31.8 percent of firms, typically involving specific project phases or particular applications rather than comprehensive implementation. Notably, 23.5 percent of surveyed firms had not adopted BIM at all, continuing to rely entirely on traditional two-dimensional drafting and conventional project delivery methods, indicating substantial room for growth in technology diffusion.

Table 2: BIM Applications In Current Practice

BIM Application Area	Number Using	Percentage	Effectiveness Rating (1-5)
3D Visualization	58	68.2%	4.2
Clash Detection	42	49.4%	4.5
Quantity Takeoff	38	44.7%	3.8
Energy Analysis	20	23.5%	3.9
Sustainability Assessment	20	23.5%	3.7
4D Scheduling	15	17.6%	3.5
5D Cost Estimation	12	14.1%	3.4
Facility Management	6	7.1%	3.2

Analysis of specific BIM applications demonstrated that Pakistani firms primarily utilized BIM for visualization purposes, with 68.2 percent employing three-dimensional modeling capabilities. Clash detection emerged as the second most common application at 49.4 percent, receiving the highest effectiveness rating of 4.5, indicating strong user satisfaction with coordination benefits. Energy analysis and sustainability assessment, critical for the research focus, were utilized by only 23.5 percent of firms despite their importance for sustainable building outcomes. Advanced applications including four-dimensional scheduling, five-dimensional cost estimation, and facility management integration showed notably lower adoption rates, suggesting that firms were primarily exploiting BIM's basic capabilities rather than its comprehensive potential for project lifecycle management.

Table 3: Barriers To BIM Implementation

Barrier Category	Mean Severity Score (1-5)	Rank	Percentage Citing as Major Barrier
High Software Costs	4.6	1	78.8%
Lack of Technical Skills	4.5	2	76.5%
Insufficient Training Programs	4.3	3	71.8%
Resistance to Change	4.2	4	68.2%
Lack of Government Mandates	4.1	5	65.9%

Client Awareness/Demand	3.9	6	58.8%
Hardware Requirements	3.8	7	54.1%
Lack of Industry Standards	3.7	8	51.8%
Interoperability Issues	3.5	9	45.9%
Legal/Contractual Concerns	3.3	10	38.8%

The barrier analysis identified high software costs as the most significant obstacle to BIM adoption, with a mean severity score of 4.6 and recognition by 78.8 percent of respondents as a major impediment. Lack of technical skills ranked second with a score of 4.5, reflecting widespread concerns about workforce readiness for BIM implementation. Insufficient training programs closely followed at 4.3, indicating inadequate educational infrastructure for capacity building. Resistance to change from established professionals scored 4.2, highlighting cultural and organizational challenges beyond purely technical considerations. The absence of government mandates requiring BIM use received a severity score of 4.1, suggesting that policy intervention could substantially accelerate adoption by creating market incentives and establishing industry expectations for technology implementation.

Table 4: Reported Benefits From BIM Implementation

Benefit Category	Mean Benefit Score (1-5)	Percentage Reporting Benefit
Improved Visualization	4.4	86.2%
Enhanced Coordination	4.3	83.1%
Error Reduction	4.2	80.0%
Better Client Communication	4.1	76.9%
Material Waste Reduction	3.9	70.8%
Time Savings	3.8	66.2%
Cost Reduction	3.7	63.1%
Energy Efficiency	3.6	56.9%
Sustainability Improvement	3.5	52.3%

Firms that implemented BIM reported substantial benefits across multiple performance dimensions, with improved visualization receiving the highest benefit score of 4.4 and recognition from 86.2 percent of users. Enhanced coordination among project teams scored 4.3, demonstrating BIM's value in facilitating collaboration and reducing conflicts. Error reduction achieved a score of 4.2, validating BIM's capacity to identify and resolve design inconsistencies before construction commenced. Material waste reduction, directly relevant to sustainability objectives, received a benefit score of 3.9 with 70.8 percent reporting this advantage. However, energy efficiency and sustainability improvement received comparatively lower scores of 3.6 and 3.5 respectively, suggesting that firms had not fully exploited BIM's potential for environmental performance optimization despite these capabilities being available within the technology.

Table 5: Project Performance Metrics - BIM vs Non-BIM Projects

Performance Metric	BIM Projects (Mean)	Non-BIM Projects (Mean)	Improvement
Design Time (weeks)	14.2	18.7	24.1% reduction
Construction Duration (weeks)	42.3	48.9	13.5% reduction
Budget Variance (%)	5.8%	12.3%	52.8% improvement
Change Orders (number)	8.4	15.7	46.5% reduction
Material Waste (%)	6.2%	8.7%	28.7% reduction
Design Conflicts (number)	12.3	28.6	57.0% reduction
Client Satisfaction (1-10)	8.4	7.1	18.3% improvement

Energy Performance vs Design	94.2%	78.6%	19.8% improvement

Comparative analysis of project performance between BIM-enabled and conventional projects revealed substantial advantages across all measured dimensions. BIM projects demonstrated 24.1 percent reduction in design time, allowing faster project initiation while maintaining or improving design quality. Construction duration decreased by 13.5 percent, translating to earlier project completion and reduced carrying costs. Budget variance improved dramatically, with BIM projects showing only 5.8 percent deviation compared to 12.3 percent for non-BIM projects, representing 52.8 percent improvement in cost predictability. Material waste reduction of 28.7 percent directly contributed to both cost savings and environmental benefits. The 57 percent reduction in design conflicts demonstrated BIM's clash detection capabilities preventing costly on-site problems. Energy performance alignment with design intent improved by 19.8 percent, indicating that BIM-designed buildings achieved closer conformance to predicted energy consumption levels.

Table 6: Organizational Readiness For BIM Implementation

Readiness Factor	High Readiness (%)	Medium Readiness (%)	Low Readiness (%)	Mean Score (1-5)
Management Support	32.9%	41.2%	25.9%	3.2
Financial Resources	24.7%	38.8%	36.5%	2.9
Technical Expertise	18.8%	35.3%	45.9%	2.6
Training Infrastructure	15.3%	32.9%	51.8%	2.4
Process Documentation	21.2%	36.5%	42.3%	2.7
Collaborative Culture	28.2%	43.5%	28.3%	3.0
Technology Infrastructure	25.9%	40.0%	34.1%	2.9
Change Management Capacity	20.0%	38.8%	41.2%	2.7

Organizational readiness assessment revealed significant deficiencies across most factors necessary for successful BIM implementation. Management support scored highest with a mean of 3.2, suggesting leadership awareness of BIM's importance, yet only 32.9 percent of organizations demonstrated high readiness in this dimension. Technical expertise showed particularly low readiness, with 45.9 percent of firms in the low category and a mean score of only 2.6, confirming the critical skills gap identified in barrier analysis. Training infrastructure received the lowest score at 2.4, with 51.8 percent showing low readiness, indicating inadequate mechanisms for workforce capability development. Financial resources and technology infrastructure both scored 2.9, reflecting capital constraints limiting investment capacity. The moderate collaborative culture score of 3.0 suggested some foundation for the teamwork essential to BIM success, though substantial development remained necessary.

QUALITATIVE ANALYSIS

Theme 1: Technical Knowledge Gap As Primary Implementation Barrier

Every interview respondent noted lack of sufficient knowledge as the most basic barrier to BIM utilization in the construction industry. Senior architects described how enthusiasm around BIM use waned within organizations once the extent of the training needed to make the use of BIM meaningful, was realized. One project manager described how companies would obtain costly BIM software and licenses, yet, without the needed staff training, the software would be so poorly deployed that the licenses would be abandoned and attempts BIM utilization discontinued. The lack of BIM training in higher education was also noted, and the graduates described as entering the workforce with BIM knowledge so limited that organizations were needed to place supplementary training to lower that knowledge gap. Respondents described the lack of knowledge in sophisticated sections of BIM, particularly energy simulation, parametric modeling, and other advanced data analytic techniques, leaving practitioners only competent in basic 3D modeling and absent the tools for advanced sustainability assessments. Numerous interviewees suggested extensive training for both graduates and in other professional areas to create a substantial base of BIM competent practitioners that would allow the industry to reach the BIM adoption.

Theme 2: Economic Constraints And Return on Investment Concerns

Financial factors were described as the most significant barriers in the use of BIM technology, specifically for the small and medium-sized businesses which make up the majority of the construction firms in Pakistan. Respondents described the significant initial costs of BIM as including software purchase, hardware upgrades, training, and the cost of lost productivity during the transition. Small firms considered the capital costs so high compared to the value of construction projects and profit margins, that they would not adopt BIM technology even for the benefits. Bigger firms in the construction industry described the problem of ROI calculations as a major barrier, especially in Pakistan, where the businesses in construction compete primarily on the price for bids, and pay little attention to the value of technology or quality. A few respondents stated that the business case for BIM technology would be easier to justify if there were published case studies of construction projects in Pakistan that proved financial returns. Interview respondents highlighted the negative impact of cost and project volatility on firms adopting new technology when concerns of financial survival were the main focus of business strategy.

Theme 3: Policy Vacuum And Lack Of Government Leadership

Inadequate and unsupportive government policies and mandates consistently emerged as a central barrier to BIM diffusion. Compared to Pakistan, respondents cited instances in other countries, where government requirements of BIM on public projects were a cornerstone of industry-adoption. There was consensus, that due to the scale of public construction, the public sector ought to stipulate mandatory BIM requirements, which would create immediate demand and incentivize the development of industry capabilities. Interview respondents noted that because of a lack of policy, which in turn led to a lack of standards, frameworks, and protocols, uncertainty was created around BIM, and this uncertainty was a key deterrent to investment due to interoperability and compatibility concerns. Policy neglect was described as the primary reason for inaction on responsive investments. Delegates from professional associations argued for policy positions on national BIM standards, funding of training practices, and the integration of demonstration projects. Interview participants remarked that policies regulating BIM are yet to be developed, which include frameworks of the associated liability, IP, and ownership of data and consequently, prudent clients and contractors have shunned progressive practices. As a responsive policy development, with mandates and the investment of political capital to build capacity, was consistently seen as the primary accelerator to BIM adoption.

Theme 4: Generational And Cultural Resistance To Digital Transformation

The concept of different generations and interests as hurdles within the context of digital adoption focuses on the qualitative aspects of Building Information Modeling (BIM) and the dissimilarity in attitudes across generations pertaining to the use of new technologies. There appear to be substantial qualitative as well as quantitative differences within the construction BIM cohort. There seemed to be a qualitative difference not only between the construction cohort and the architectural BIM cohort but also between younger and senior construction professionals. While younger construction professionals were keen to use new methodologies and adopt BIM on construction projects, senior participants were keen to use older methodologies and technologies. Senior participants, in particular, seemed to be stuck in a particular mindset, and having a successful career made them reluctant to pivot towards new methodologies or technologies, BIM in particular. Participants seemed to suggest a top-down approach regarding construction projects and organizational structures, as having successful careers in senior positions in the construction industry made senior professionals reluctant to embrace BIM, thus adding to the inertia.

Theme 5: Client Awareness And Demand Deficiencies

A lack of client appreciation of BIM's value proposition was described as a significant obstacle to adoption. Clients' indifference, and even opposition, to the implementation of BIM was described as a disincentive to pursue implementation. In the private sector, clients focused on first-cost over the lifetime value of a project and so did not request BIM or value the benefits enough to pay the price, so that offering BIM created a marginal competitive advantage. Some respondents observed that clients who did not understand BIM could not assess value innovative, BIM-driven proposals, and the differences in results from defaulting to traditional methods. Several interviewees recounted instances in which clients rejected BIM proposals, disregarding explained lifecycle benefits, because of perceived extra cost or complexity. A particularly conservative approach was noted in the public sector, where clients adhering to traditional procurement methods continue to execute BIM processes and workflows. Participants described the need for client education, as well as for the showed use of BIM in new industry initiatives and awareness campaign.

Theme 6: Sustainability Integration Opportunities And Gaps

Sustainability capabilities of BIM motivated the focus of the research, but insight gatherings showed stark discrepancies between theoretical potentials and real-life implementations within the Pakistani projects. Interviewees justified BIM's energy and environmental impact assessment potentials, but most BIM practicing organizations do not use it. The interviewees noted the absence of energy performance criteria on clients' briefs, no green labels for accountability, the soft competency of some specialized sustainability software, and the race to finish a design being the reason for excessive performance trade-offs. Many respondents noted the contrast to sustainability assessments as regular use in the BIM cycle for international projects as a result of legislative, certification, and client-driven requirements. Respondents were confident that compliance with emerging green building codes with active carbon control, within a context of rising energy costs, will make energy efficiency and environmental performance trade-offs more compelling. Optimistic interviewees appreciate BIM as a potential driver for Pakistan's sustainable construction while underlining the need for focused implementation of sustainability, targeted education, policy levers to create market pull, and embedding the environmental priorities into normalized practices.

DISCUSSION

There is data describing Pakistan's construction industry position relative to adoption of building information modeling (BIM). There is considerable understanding of the technology's possible value, but its breadth and depth of use is shallow. Sustainability assessments by 23.5 percent of the respondents represents the development of the capability to use BIM, but it is far from sufficient given the Pakistan's challenges and its international commitments on climate. There is a gap between BIMs capacity and its current use for solving urgent problems of the country. Most likely the opportunities to unleash the benefits of the technology fall somewhere within the socio-economic barriers that are articulated in the literature, and wherein interventions are articulated in a silo. The documented benefits of BIM are proof that investments to overcome socio-economic barriers to adoption will yield substantial value. Improvements in BIM enabled projects have documented benefits of 18 to 25 percent reductions in material waste and waste energy management. These benchmarks could apply to industry-wide expectations.

The combination of quantitative survey data, qualitative data from interviews, and information from case studies all point to priority intervention areas with a high degree of confidence. Nevertheless, the development of master's level technical skills remains a fundamental building block. Architectural and engineering educational programs must undergo substantial transformation to integrate BIM at the foundational levels of instruction alongside the development of continuing education infrastructure for current practitioners. The economic aspect suggests the need for innovative financing, possibly characterized by small firms receiving government subsidies to adopt technology, shared-service models that defray the costs to individual firms, and market certification with BIM capabilities as a rewarded investment. The cultural shift toward collaborative and data-centric practices is a longer-term change and will require professional organizations, universities, and industry leaders to adopt new practices, model the desired behavior, and mentor change-averse practitioners for the sustained practice evolution that is envisioned.

The absence of clearly defined policies across various research methods points to the need for government action to provide leadership for the establishment of Building Information Modelling (BIM) standards, the enforcement of technology for public projects, and the development of tools to legislate and reduce the ambiguity around the policies for implementation. Government mandates to enforce the use Building Information Modelling (BIM) technologies in construction projects in Singapore, the United Kingdom, and the Nordic countries have shown to transform the industry, particularly, when accompanied with supportive mechanisms such as government-funded training, standards, and step-by-step implementation plans for the industry to build its capabilities. Targeted government efforts in construction procurement for strategic market transformation have been evidenced in the development of public infrastructure, institutional buildings and housing that Pakistan's government provides. Findings indicate that the implementation of demand-side policies together with the creation of supply-side policies and infrastructure will provide synergistic opportunities that will positively surpass the rate of uptake of either of the two interventions alone.

CONCLUSION

The final objective was to complete an elaborate examination of BIM practices as implemented across Pakistan's AEC field. Any existing circulation practices of BIM within AEC were documented, barriers to BIM practices were documented, and for strategic dissemination of BIM practices, data was documented. Best case scenario for Pakistan's AEC field, BIM estimation on sustainability has only been used by 23% of firms and BIM practices sustainability estimation is severely underutilized given the energy crisis and environmental issues Pakistan faces. Other case scenario BIM documented performance improvement was, material waste was reduced, waste was reduced, costs were estimated accurately, project duration was improved, and construction energy sustainability was improved. Documenting these performance improvements proves the benefits of construction technologies used within Pakistan and the construction industry as a whole. The industry as a whole lack an implementation strategy based on the documented performance improvements. Common industry barriers of high costs, skill shortages and the so called an entrenched club of culture within industry. Lack of investment in in-house technologies from construction SMEs and the high costs of departmental technologies was considered a fair observation.

Employing multiple research methods of surveys, case studies, and stakeholder interviews generated triangulated evidence that enhanced the reliability of findings by integrating quantitative evidence on patterns of adoption and qualitative evidence on implementation. Research shows that addressing technical, economic, organizational, and policy dimensions must be done simultaneously, as these are interconnected to successfully overcome the adoption and implementation of all dimensions of BIM. The proposed adaptive BIM implementation framework's continued cross coordination of actions in the areas of education, training infrastructure, policy, finance, and culture can facilitate a rapid transformation of the construction sector in Pakistan toward digitally integrated, sustainable construction and achieve the rapidly changing goals of the construction sector in Pakistan in the context of international climate agreements.

Pakistan's construction sector has the greatest potential to integrate BIM as a sustainable construction enabling technology. For all stakeholders to realize the construction sector's potential, the research shows that the necessary technology is available, the benefits are measurable and achievable, and evidence of adoption can be demonstrated in the Pakistan context. For the construction sector to realize its potential and be internationally competitive, the government, professional bodies, academia, and the industry must all exercise integrated sustained strategic leadership to encourage widespread adoption of BIM practices. The construction sector will be able to achieve the country’s climate goals and improve energy efficiency. Improved project delivery and great environmental sustainability are key to the country’s growing prosperity.

RECOMMENDATIONS

Pakistan's construction sector needs to pursue synergistic initiatives to tackle defined challenges, build upon current capabilities, and capitalize on the initial successes of implementation. The government should develop compulsory BIM requisites for public sector construction contracts surpassing determined monetary limits to generate market demand that drives capability evolution. In the meantime, the government can formulate national BIM standards, contractual frameworks, and legal BIM clarifications that can mitigate the uncertainties surrounding BIM implementation. Academic courses for architecture and engineering should fully cover BIM so that students develop the necessary competencies needed to be productive members of the workforce. Professional bodies should issue certificates for BIM competencies and provide frameworks for the maintenance of continuing education to avoid obsolescence of the practitioners' skills. Industry bodies can mitigate the pressure on small construction firms needing BIM resources by establishing shared BIM service constructions. Toward establishing SCB BIM service constructions, banks can develop SCB BIM technology loans. Focus on achieving and documenting high visibility sustainable construction projects that can be used as replicable BIM demonstration projects to the industry. These synergistic initiatives, adequately phased to allow capability development to catch up, can preposition the construction industry in Pakistan for its much-needed transformation to a digitally and sustainably integrated industry.

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