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IMPLEMENTATION OF 4D BIM IN PAKISTAN: A SYSTEMATIC REVIEW OF CHALLENGES AND OPPORTUNITIES

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Abstract

4D Building Information Modelling (BIM) is a transformative digital process that integrates 3D model geometry with construction schedule data (time), enabling dynamic simulation and visualization of project sequences. For Pakistan's construction sector, which is vital to the economy yet plagued by chronic delays and cost overruns, 4D BIM offers a powerful solution for improved planning, risk mitigation, and stakeholder communication. This literature review finds that while awareness of BIM is growing, its adoption in Pakistan remains in its infancy, with a mere 11% implementation rate primarily limited to basic 3D modelling. The transition to 4D BIM is severely hampered by a lack of skilled personnel, high initial costs, out-dated contractual frameworks, and a critical absence of government-led policy and national standards. Key insights confirm that strategic interventions are urgently needed. The literature recommends the development of a national BIM mandate, the initiation of public-sector pilot projects on major initiatives like CPEC, and comprehensive capacity-building through industry-academia partnerships to foster the expertise necessary for leveraging 4D BIM's significant benefits for project transparency and efficiency.

Introduction

Pakistan's construction and infrastructure sector is a vital contributor to the national economy, providing significant employment and supporting urbanization and industrial growth. The industry has experienced notable expansion, with a reported annual growth rate of 9.05% in 2016–2017, yet it continues to face persistent challenges such as project delays, cost overruns, and quality shortfalls, often attributed to reliance on traditional management practices and fragmented project delivery methods [1], [2], [3]. In this context, Building Information Modelling (BIM) has emerged globally as a transformative digital approach, offering integrated platforms for design, construction, and facility management. BIM enables the creation of comprehensive digital representations of physical and functional characteristics of buildings, facilitating collaboration among stakeholders throughout a project's lifecycle [4]. The evolution to 4D BIM where time or scheduling data is linked to 3D models further enhances project planning, visualization, and monitoring, allowing for improved sequencing, risk management, and resource allocation [5], [6]. Despite these advantages, BIM and especially 4D BIM adoption in Pakistan remains limited, with studies indicating that only about 11% of industry professionals have implemented BIM, and its use is often restricted to basic 3D modeling rather than advanced applications like scheduling or cost estimation [1], [2], [7]. The research objective of this review is to assess the status, challenges, and opportunities of 4D BIM in Pakistan by synthesizing findings from recent academic literature. Key barriers identified include a lack of skilled personnel, limited awareness and training, high implementation costs, out-dated contractual systems, and insufficient government support [2], [3], [8], [9]. Opportunities, however, exist in leveraging BIM for sustainable development, improved project delivery, and enhanced competitiveness, provided that strategic interventions such as the development of national standards (e.g., adopting ISO 19650), targeted training programs, and policy incentives are pursued [8], [10]. The scope of this review is confined to secondary data from published research, surveys, and case studies, which, while offering valuable insights, may not capture the full diversity of on-ground practices or recent industry shifts. Limitations include potential biases in survey samples, the evolving nature of BIM technologies, and the lack of comprehensive local case studies, underscoring the need for ongoing empirical research and stakeholder engagement to inform effective 4D BIM implementation strategies in Pakistan [2], [3], [4], [5], [8], [10], [11], [12], [13], [14].

Understanding 4D BIM

4D Building Information Modelling (BIM) is the process of linking 3D digital models of construction projects with scheduling data, adding the time dimension to spatial information. This integration enables dynamic simulation of construction sequences, allowing stakeholders to visualize, plan, and optimize project delivery in ways not possible with traditional methods. Widely used tools for 4D BIM include Autodesk Navisworks, Synchro, and Revit, often paired with scheduling software like MS Project or Primavera to synchronize design and construction timelines. 4D BIM's core value lies in its ability to connect geometric data with construction schedules, providing real-time visualization of project progress and enabling proactive management. For example, the use of Navisworks' TimeLiner allows direct import of MS Project schedules, linking tasks to 3D model elements for accurate Gantt chart generation and visual simulation of construction activities [15], [16], [17]. This process not only improves communication among architects, engineers, contractors, and owners but also enhances transparency and risk mitigation throughout the project lifecycle [18], [19], [20], [21]. Quantitative evidence demonstrates significant benefits. Automated 4D BIM scheduling and optimization frameworks have achieved cost savings of up to 22.86% in case studies, with trade package-level management contributing up to 33.33% of project efficiency improvements [22]. In large infrastructure projects, BIM-based clash detection and resolution have resulted in estimated savings of 20% of contract value by identifying and resolving design conflicts before site operations, thus reducing rework and delays [23]. In China, integrating BIM with product lifecycle management improved project efficiency by 24.39% and 38.04% in two major projects compared to traditional methods [24]. In Peru, 4D BIM models facilitated progress monitoring and reduced modifications and rework, while 5D BIM (adding cost data) optimized costs by

5.28% [25]. Clash detection is a critical function of 4D BIM, with tools like Navisworks and Synchro enabling early identification of spatial and temporal conflicts. Automated plugins and optimization algorithms have reduced spatial-temporal clashes in underground pipeline projects from 45.5% to 0%, demonstrating the technology's potential for enhancing schedule performance and minimizing costly errors [21], [26], [27]. The visual simulation capabilities of 4D BIM also support better site logistics, material handling, and resource allocation, leading to improved workflow and reduced project uncertainties [16], [17], [28], [29]. Despite these advantages, challenges remain. The process of linking 3D models to schedules is still labour-intensive and requires significant expertise, with interoperability issues between design and scheduling platforms often cited as barriers to full automation [15], [30]. Adoption rates vary globally, with developing countries facing additional hurdles related to training, technological infrastructure, and integration of diverse software tools [16], [29], [31]. Nevertheless, the global trend is toward greater adoption, driven by the clear evidence of time and cost savings, improved collaboration, and enhanced project outcomes enabled by 4D BIM [18], [20], [31], [32], [33], [34].

Global Overview of 4D BIM Adoption

4D BIM adoption is marked by significant regional disparities, policy-driven accelerations, and persistent technical and organizational barriers. The integration of time (4D) into BIM models is recognized for improving project visualization, planning, and stakeholder communication, but its global uptake is uneven and often policy-dependent [35], [36], [37], [38], [39], [40], [41], [42]. In Europe, 35% of countries have implemented or plan to introduce BIM mandates, with the UK, Italy, Spain, and Germany leading in policy-driven adoption [41]. The UK's 2016 BIM mandate required Level 2 BIM for all centrally procured public projects, resulting in a reported 71% adoption rate in the construction industry by 2012, and a rapid transition to the collaboration stage of BIM implementation [40], [43]. However, even within the EU, adoption is heterogeneous: early adopters like Finland and the Netherlands contrast with countries such as Bulgaria, Greece, and Malta, which lack national BIM strategies [44]. The UK's approach, underpinned by the UK BIM Framework, emphasizes standards, guidance, and protocols, but the actual implementation is challenged by varying organizational readiness and knowledge gaps, especially among SMEs [40], [44]. The UK's innovation diffusion studies reveal a time lag between awareness and first use, with system compatibility and safe trialling identified as critical for broader uptake [39]. Singapore's BIM e-submission policy, introduced in 2010 and made mandatory for all projects by 2015, drove rapid adoption, particularly in design and construction phases, but less so in facility management [43]. The government's top-down approach, including regulatory requirements and digital submission platforms, resulted in high compliance but also highlighted the need for on-going training and standardization. In China, national policy requirements are the most significant driver of BIM adoption, with simulation analysis showing that "intention to use" BIM varies significantly with changes in policy, standardization, and industry popularity [37], [43]. Despite these advances, BIM in China is primarily applied in design and construction, with limited integration across the full project lifecycle [37], [43]. The UAE's smart city integration strategy leverages BIM for digital built environments, aligning with ISO 19650-5 for security-minded information management and smart asset management [35]. The UAE's focus on digital twins and smart asset management is part of a broader trend in the Gulf region, where BIM is increasingly linked to national digital construction strategies and smart city initiatives [41]. However, the literature lacks detailed quantitative adoption rates for the UAE, and the effectiveness of these strategies is still under evaluation.

Quantitative studies in Brazil and India reveal high awareness but low practical usage of 4D BIM. In India, surveys show that while stakeholders recognize the benefits of 4D BIM for visualization, schedule validation, and communication, actual implementation remains low due to lack of expertise, traditional contracts, and insufficient government mandates [36]. In Brazil, case studies indicate that BIM is more efficient in the design phase, with 4D modelling rarely used during construction due to difficulties in extracting information and lack of integration between design and construction teams [45], [46]. The Brazilian experience underscores the necessity of integrating BIM with structured management methods and early stakeholder involvement to realize its full potential [45]. Globally, the main drivers for 4D BIM adoption are government mandates, standardization, and industry-wide digital strategies [35]. The ISO 19650 standard, particularly parts 3 and 5, is increasingly referenced as a framework for information management and security in BIM-enabled environments [35]. However, barriers persist technical adoption issues, lack of skilled professionals, poor interoperability, and resistance to change are consistently reported across regions [38], [42], [44]. In Malaysia, for example, a survey of 235 professionals identified technical, behavioural, management, and digital education barriers as critical obstacles to BIM adoption in small projects (Waqar et al., 2023). The integration of 4D BIM with emerging technologies such as IoT, AI, and digital twins is a growing trend, with research highlighting the potential for enhanced real-time monitoring, logistics optimization, and data-driven decision-making [35], [47], [48], [49]. However, the lack of interoperability and standardized ontologies limits the automation and scalability of these solutions [47], [49]. Quantitative evidence from virtual reality integration studies shows improvements in planning accuracy (+89.1%), speed (+30%), and usability (+10.3%) compared to conventional methods, demonstrating the tangible benefits of advanced 4D BIM applications [50]. Policy frameworks and digital construction strategies are decisive in shaping 4D BIM adoption. In China, simulation analysis confirms that government incentives, standardization, and industry culture are the most influential factors, with management support and organizational readiness also playing significant roles [37], [43]. In Europe, the correlation between economic development and BIM mandate enforcement suggests that market maturity and policy readiness are prerequisites for successful digital transformation [44]). The lack of unified standards and cross-border collaboration remains a barrier to harmonized adoption, particularly in the EU [44]. A detail comparison of different developed nations is given in Table 1.

Table 1: ***Comparative analysis of global BIM policy mandates, adoption maturity, and implementation dynamics (2010–2025).***

Country	Policy Mandate	Adoption Rate	Key Success Models	Barriers	Quantitative Indicators and Empirical Findings	Citations
UK	BIM Level 2 mandated for all public projects (2016)	High; 71% industry adoption by 2012; macro-maturity means 2.95/5	Government-driven, phased roadmap; strong standards (BSI), UK BIM Framework; focus on collaboration, certification, and guidance	SMEs lag behind; need for more champions, drivers, and publications; time lag between awareness and use	50% project time reduction target (2013); strong positive correlation between macro-maturity and micro-adoption (r=0.85, p=0.007)	[51], [52], [53], [54], [55]
Singapore	BIM e-submission mandatory for all projects (2015)	High in design/construction, less in FM	Government-driven, phased; e-submission platform; regulatory requirements; focus on digitalization and productivity	On-going need for training, standardization, and expansion to FM	26 critical success factors identified: phase-by-phase expansion from building sector to smart city	[53], [56]

Country	Policy Mandate	Adoption Rate	Key Success Models	Barriers	Quantitative Indicators and Empirical Findings	Citations
UAE	Smart city integration, ISO 19650-5 alignment	Emerging; strong in digital twin/smart asset management	Policy-driven, digital construction strategies, smart city focus; integration with digital twins	Quantitative adoption rates not reported; effectiveness under evaluation	Emphasis on security-minded information management and smart asset management	[57]
China	National policy requirements; strong government incentives	Rapidly increasing, especially in design/construction	Policy-driven; simulation analysis shows policy, standardization, and industry popularity as top drivers	Limited lifecycle integration; insufficient government direction, legal issues, high cost, resistance to change	Task-technology fit and management support significant for 4D BIM acceptance; positive financial performance for adopters	[58], [59], [60], [59]
India	No national mandate; industry awareness high	Low practical usage	Recommendations: learn from mature markets, develop guidelines, standard contracts, and training	Lack of expertise, traditional contracts, insufficient government push	184 survey responses: full potential explored but not realized	[57], [61]
Brazil	No national mandate; company-level initiatives	Low, especially in construction phase	Case studies: more efficient in design; need for early stakeholder involvement and management integration	Difficulties extracting info from 3D models; lack of integration between design/construction	Single-case study: 4D rarely used in construction; collaborative environment improved	[62]
Malaysia	No national mandate; NCP 2030 policy push	Trailing; minimal implementation	Focus on awareness, cost-benefit info, sustainable development; workshops, training, standardization	Technical, behavioural, management, and digital education barriers; lack of awareness	235 professionals surveyed: technical adoption and management barriers most significant	[59], [63], [64], [65], [66], [67]

Country	Policy Mandate	Adoption Rate	Key Success Models	Barriers	Quantitative Indicators and Empirical Findings	Citations
Qatar	No national mandate; compared with UK	Medium-low (mean 2.19/5)	Need for more champions, drivers, and regulatory frameworks	Lack of professional certification /compliance board	62.5% rated macro-maturity as low	[51]

Status of 4D BIM in Pakistan

BIM adoption in Pakistan remains at an early stage, with 4D BIM (integration of scheduling and time) rarely implemented beyond pilot or isolated cases. Most literature and surveys focus on general BIM awareness, with only limited references to 4D BIM usage in practice [68], [69], [70], [71], [72],[73].

BIM Awareness and Adoption in Pakistan

Awareness of BIM among AEC professionals in Pakistan is moderate: a 2020 survey found 63% of professionals were aware of BIM, but only 17% had used it in projects, and the overall adoption rate was just 11% [71], [72]. Most BIM use is limited to 3D modeling for design and visualization, with 4D BIM (scheduling) and 5D BIM (cost estimation) rarely applied [68], [70], [71]. In Sindh, only 11% of firms reported any BIM implementation, and this was almost exclusively for 3D models [71]. The "buzz" about BIM is low to medium, with only 27% of organizations involved in any BIM adoption process [74]. Barriers include lack of expert knowledge, out-dated contracts, reliance on traditional tools, and limited engagement of consultants beyond architecture [69], [70], [74]. Direct evaluation of 4D BIM in Pakistan is scarce. Some architectural firms in Karachi (e.g., Ahmed Associates, Khatri Associates) have adopted 4D scheduling for large, internationally funded projects, but this remains the exception [74]. Most studies report that BIM is used for design review, 3D coordination, and lighting analysis, with 4D scheduling mentioned as a future potential rather than a current practice [68], [70], [74]. A study on CPEC mega-projects highlighted BIM's positive impact on planning and scheduling but did not provide quantitative data on 4D BIM penetration [73].

Role of Institutions: Universities and Government Agencies

Universities and professional bodies are recognized as critical for advancing BIM (and 4D BIM) adoption. Recommendations include integrating BIM into curricula, promoting research, and fostering industry-academia collaboration [68], [69], [72]. Government agencies have shown interest: a public sector pilot project demonstrated BIM's benefits and convinced stakeholders of its value, but systematic adoption remains limited [75]. The literature calls for government financing, policy support, and the creation of bonds between industry and academia to accelerate BIM uptake [72]. However, there is no evidence of large-scale, coordinated institutional initiatives specifically targeting 4D BIM.

Local Standards and Strategic Plans

Pakistan currently lacks a national BIM standard. The Pakistan Engineering Council (PEC), Pakistan Council of Architects and Town Planners (PCATP), and Capital Development Authority (CDA) have not issued formal BIM or 4D BIM guidelines [76]. Recent research recommends adopting ISO 19650 (the international BIM standard) with minimal modification as a national framework [76]. Strategic plans emphasize the need for contract clauses supporting BIM, industry awareness, and training, but these remain at the proposal stage [69], [74]. The absence of local standards and regulatory mandates is a major barrier to widespread 4D BIM adoption [69], [70], [71], [72], [74], [76].

Challenges Identified

Technical Barriers

Technical barriers are consistently identified as the most significant obstacles to 4D BIM adoption as shown in Fig. 1. High initial costs for software and hardware, ongoing expenses for updates, and the need for high-spec computers are major deterrents, especially in developing countries [77], [78], [79]. Interoperability issues where different BIM tools and platforms cannot seamlessly exchange data are repeatedly cited as a top challenge, leading to inefficiencies and errors in project delivery [80]. The lack of localized or domestic oriented 4D BIM tools further complicates adoption, as imported solutions may not align with local construction practices or regulatory requirements [79], [80]. In Brazil, for example, difficulties in extracting information from 3D models have directly disabled the use of 4D modeling during the construction phase, highlighting the need for better integration and automation [78], [80]. Inadequate IT infrastructure, unreliable internet, and limited access to cloud-based solutions are also reported, particularly in regions like Nigeria and Malaysia [77], [79].

Human Capital

Training and Skills A shortage of skilled professionals and insufficient training programs are pervasive barriers [77], [79], [81], [82], [83]. Surveys across multiple countries show that most stakeholders lack practical experience with 4D BIM, and training costs are prohibitive for many organizations. In Pakistan, the lack of BIM experts and limited educational opportunities are cited as the most repeated barriers, with most professionals still uninformed about the advantages of 4D BIM [79], [81]. The complexity of 4D BIM software and the absence of structured training further hinder skill development, resulting in a workforce unprepared for digital transformation.

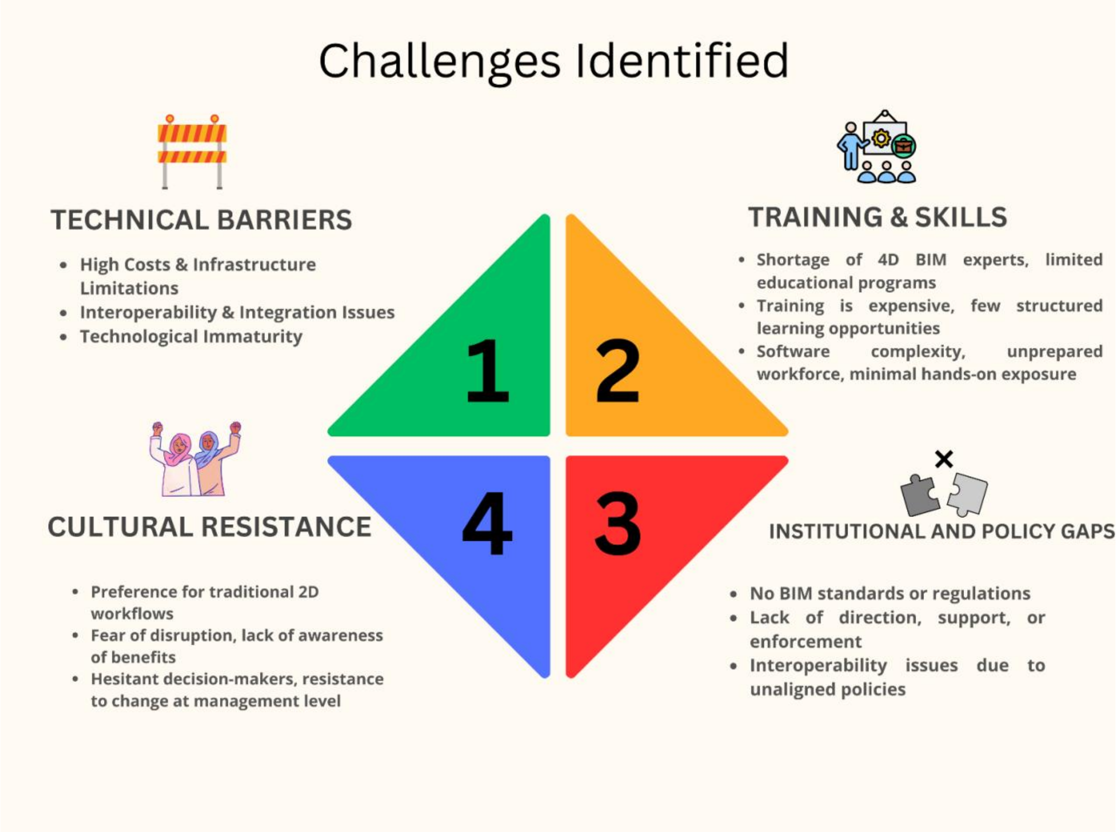

Figure 1 Challenges identified during the literature review

Institutional and Policy Gaps

The absence of a national BIM framework or standardized guidelines is a critical institutional barrier. Many developing countries lack government direction, clear legal frameworks, or incentives for 4D BIM adoption, leading to confusion, inconsistency, and fragmented implementation. Incomplete or non-existent standards exacerbate interoperability issues and hinder collaboration among stakeholders. Studies from Nigeria, Brazil, and the MENA region emphasize that insufficient government leadership and lack of policy support are among the most significant obstacles to widespread 4D BIM use [77], [78], [79], [81], [82], [83], [84].

Cultural Resistance

Cultural and organizational resistance to change remains a major challenge. The construction industry's conservative mind-set, preference for traditional 2D methods and reluctance to invest in new technologies slowed the transition to 4D BIM. Resistance is often rooted in a lack of awareness of

4D BIM's benefits, fear of workflow disruption, and the perception that digital tools are unnecessary for less complex projects. In many regions, decision-makers and senior management are hesitant to champion 4D BIM, further entrenching traditional practices [79], [82], [83], [85], [86], [87], [88], [89], [90].

Opportunities for Pakistan

Government-led initiatives such as the China-Pakistan Economic Corridor (CPEC), national housing schemes, and major highway projects present a unique opportunity to mainstream 4D BIM in Pakistan's construction sector. CPEC is driving a wave of infrastructure development, and research shows that integrating BIM especially for planning and scheduling can significantly improve project outcomes, reduce errors, and align Pakistan with international standards [91], [92], [93], [94], [95]. The government's focus on large-scale, multi-billion-dollar projects creates both the demand and the platform for digital construction tools like 4D BIM, which can enhance transparency, risk management, and technical safety [94], [95], [96], [97]. Academic institutions are increasingly involved in BIM research and curriculum development. Universities are integrating BIM and digital project management into engineering and architecture programs, which is essential for building local expertise and closing the training gap [98]. Studies highlight the need for education and training institutions to play a leading role in promoting BIM adoption, supporting research, and fostering industry-academia collaboration [96], [98]. This academic engagement is critical for developing a skilled workforce capable of implementing 4D BIM on complex projects. There is also strong potential for public-private partnerships (PPPs) to accelerate BIM adoption. Research recommends leveraging PPPs to share knowledge, resources, and risk, and to pilot BIM-enabled projects that demonstrate value to both government and industry stakeholders [95], [96], [98]. Such collaborations can help overcome financial and technical barriers, especially for small and medium-sized enterprises. Finally, the cost savings and project transparency enabled by 4D BIM are well-documented. Studies report that BIM-based planning and scheduling can reduce project costs by up to 33%, minimize rework, and improve communication among stakeholders [91], [99], [100]. These benefits are particularly relevant for Pakistan, where construction projects often suffer from delays, cost overruns, and coordination issues [91], [95], [100]. By capitalizing on these opportunities, Pakistan can position itself as a regional leader in digital construction and infrastructure delivery.

Conclusion and Recommendations

Based on the comprehensive review of literature, the implementation of 4D BIM in Pakistan represents a critical, yet largely untapped, opportunity to revolutionize its construction sector. The significance lies in directly addressing the industry's most persistent ailments: chronic project delays, severe cost overruns, and quality shortfalls. While the sector is a vital economic driver, its reliance on traditional, fragmented methods is unsustainable. The integration of the time dimension (4D) with 3D models offers a powerful antidote, enabling Pakistani project teams to visually simulate the entire construction sequence before breaking ground. This allows for the proactive identification of logistical clashes, optimized resource allocation, and vastly improved communication among all stakeholders. For a country embarking on massive, complex initiatives like CPEC, national housing schemes, and new highways, the ability to visualize and validate construction schedules could prevent millions of dollars in rework and shave months off project timelines, bringing its infrastructure development in line with global best practices.

However, achieving this potential is impossible without a foundational shift in institutional support and strategic planning. The current state is characterized by a stark disconnect between high-level opportunity and on-the-ground reality. Awareness of BIM is moderate, but practical use of 4D BIM is almost non-existent, trapped by a perfect storm of barriers. The most formidable obstacles are the severe lack of skilled personnel, the prohibitive cost of software for local firms, and a complete absence of a national regulatory framework or standardized guidelines. The industry's conservative culture and out-dated contractual models further stifle innovation. Therefore, simply hoping for organic adoption is a failed strategy. The transformation must be deliberately orchestrated from the top down, with the government and leading professional bodies like the Pakistan Engineering Council (PEC) taking the helm.

The literature provides very specific, actionable recommendations to break this impasse. First and foremost, the federal government must move beyond passive interest and establish a compulsory national BIM policy, mandating the use of 4D BIM for all publicly procured projects above a certain value. This policy must be accompanied by practical, Pakistan-specific 4D BIM guidelines, potentially adapted from the international ISO 19650 standard, to provide a clear roadmap for implementation. Second, this policy should be launched with a series of highly publicized pilot projects on select CPEC or other major infrastructure ventures. These pilots will serve as tangible proof-of-concept, demonstrating the quantifiable benefits such as reduced rework and improved schedule adherence to a sceptical industry. Third, a nationwide capacity-building mission is essential. This involves mandating the integration of BIM and 4D modelling into the core curriculum of engineering and architecture universities to build the future workforce, while simultaneously funding up skilling programs for current professionals. Finally, to overcome the cost barrier, the government should actively promote and subsidize the use of more affordable, open-source BIM platforms or negotiate nationwide licenses for commercial software, making the technology accessible to small and medium-sized enterprises. By executing this multi-pronged strategy of enforced policy, demonstrated value, and empowered talent, Pakistan can transition its construction industry from its current state of digital infancy to a future of enhanced efficiency, transparency, and competitiveness.

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