COST–BENEFIT ANALYSIS OF BIM IN LARGE INFRASTRUCTURE PROJECTS: PAKISTAN VS GERMANY

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Abstract- Building Information Modeling (BIM) is transforming design and construction by enabling integrated 3D models and collaborative workflows. In Germany, government mandates and industry initiatives have driven widespread BIM adoption (~70% of firms), whereas in Pakistan, BIM remains nascent (~11% adoption). This paper reviews recent evidence on BIM's economic and technical outcomes in building-type infrastructure projects in both countries. Studies consistently show that BIM can improve design quality and reduce errors, which translates into cost and time savings. For example, clash detection alone can save up to 10% of contract costs and shorten schedules by ~7% [5]. In Pakistan, stakeholders report that BIM could reduce project cost and time by up to 57% when properly implemented, even though current adoption is low and often limited to 3D drafting. In Germany, early adopters and public infrastructure programs anticipate more modest but reliable savings (on the order of 5–10%) due to higher baseline efficiency. Overall, BIM's benefit–cost profile tends to be positive once initial training and software costs are amortized, with the German government projecting industry-wide productivity gains and lifecycle efficiencies from its 2025 BIM mandate.

Keywords- Building Information Modeling, Cost-Benefit Analysis, Economic Analysis, Infrastructure Projects

1 Introduction

Building Information Modelling (BIM) is an all-encompassing approach that contains 3D design, analysis, and documentation of how a project develops. Complex projects now have the central trend of construction, where the approach is expected to have a higher level of coordination, fewer errors, and more open cost [1] [2]. BIM is expected to enhance the quality and efficiency of the planning and execution phases of any large infrastructure and building project. At Germany's federal level, BIM is a proactive policy: Since 2016, BIM can be required by the public agencies for large projects, and by end-2020 BIM is a requirement on all new federal infrastructure contracts [1]. As a result of this incident, there is an approximate estimate that 70% of German companies are currently incorporating BIM in one way or another, particularly in buildings and transport infrastructures [1].

In comparison, the construction sector in Pakistan has been far slower in becoming digitalized. A survey carried out in 2020 revealed just 11% national use and only 17% of professionals had ever utilized BIM [3]. Some of the problems inherent in Pakistan's fragmented processes, design changes, and delays can be reduced using BIM [3] [4]. This paper compiles recent research on the costs and benefits of BIM, often using end economic variables (such as ROI and savings) and technical results (error reduction, schedule), and identifies some main differences between Pakistan and Germany.

2 Methodology

This study employs a mixed-method approach combining systematic literature review, qualitative analysis, and quantitative data comparison to conduct a comprehensive cost-benefit analysis of BIM adoption in large building infrastructure projects in Pakistan and Germany.

The first step involved a systematic literature review of recent scholarly articles, government publications, industry white papers, and case studies from both countries, focusing on BIM applications in building-type infrastructure projects. Academic databases such as Scopus, Web of Science, and Google Scholar were searched using keywords including "BIM adoption," "BIM cost-benefit," "infrastructure projects," "Pakistan," and "Germany." Selection criteria prioritized studies published within the last five years to ensure relevance to current BIM practices. More than 40 studies were initially identified, of which less than half met the relevance and quality criteria for final inclusion in the analysis. Studies were included if they provided empirical data on BIM adoption, cost or schedule impacts, or implementation case studies in large infrastructure projects.

Qualitative analysis was employed to evaluate any situational context variables, including regulative frameworks, industry preparedness and readiness, cultural attitude, as well as technological barriers that negatively affect the adoption of BIM. The review retrieved descriptive data regarding the stages involved in BIM implementation, stakeholder participation, perceived difficulties and advantages, and differences in the two countries.

Quantitative analysis is devoted to the synthesis of numerical data presented in the literature, including rates of BIM adoption, estimated or calculated cost savings, schedule reductions, and ROI. Data project-specific was gathered and compared, thus establishing patterns and the magnitude of the BIM benefits per country where available. These were tabulated so that they could be compared directly.

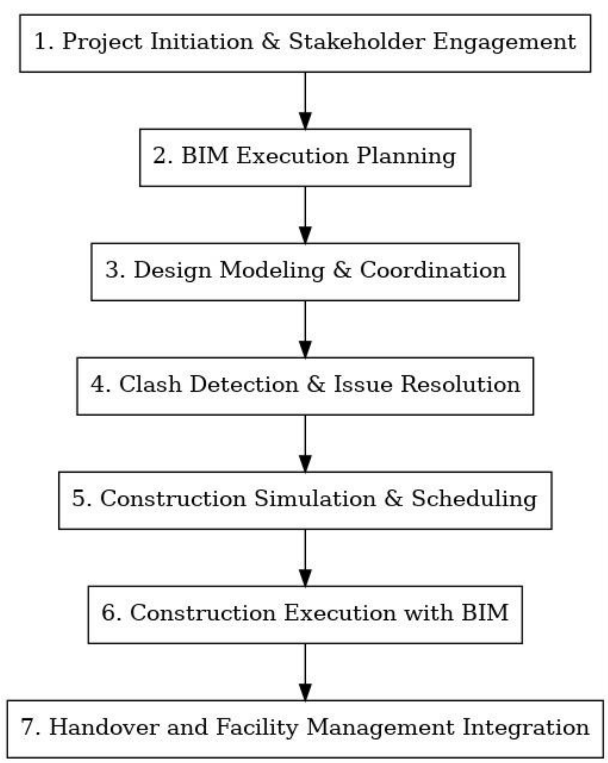

Fig. 1. BIM Implementation Phases Flowchart

This flowchart outlines the typical sequential steps involved in adopting Building Information Modeling (BIM) in large infrastructure projects:

1. Project Initiation & Stakeholder Engagement: Proactive involvement of the stakeholders to tie up all the project players to define BIM objectives and roles.

2. BIM Execution Planning: preparation of a full BIM Execution Plan, containing the standards, the software platform, the workflow of collaboration, and data management.

3. Design Modeling and Coordination: Creating the 3D BIM multi-discipline models of coordination.

4. Clash Detection & Issue Resolution: Identifying and resolving conflicts before construction.

5. Construction Simulation & Scheduling: Simulating sequences to optimize schedules and mitigate risks.

7. Handover and Facility Management Integration: Delivering as-built BIM data for maintenance and lifecycle management.

3 Context of BIM Adaptability

3.1 Pakistan

The construction industry in Pakistan is expanding (≈9% annual growth) [3], yet characterized by cost overruns, time overruns, and poor quality [3]. In the Pakistani AEC (Architecture, Engineering, Construction) circle, BIM is viewed as an emerging technology. There is growing awareness (63% of professionals heard of BIM [3]); nevertheless, the application is still at a niche level: according to the 2020 survey, only around 17% of respondents had used BIM on a project. Consequently, the actual uptake of Pakistan was calculated to be only 11% [3]. Its initial use was in 3D drafting/visualization rather than collaboration. However, the Pakistani professionals recognize the qualitative benefits of BIM: they give it one of the highest scores regarding the improvement of the design quality and decrease in rework [4]. Remarkably, surveys suggest that there may be huge returns: a 57% decrease in expenditure and time in case BIM were implemented to the best of its abilities [3]. These statistics point to a great number of inefficiencies in a conventional project (e.g., change orders, delays) that BIM might solve. The major obstacles reported were the high initial cost of software/training of BIM and the absence of industry standards [3] [4]. Overall, the potential in BIM is large in Pakistan, with a low baseline, but an enormous potential: gains will depend on investment in training, policy support, and successful pilot projects.

3.2 Germany

Germany is a leader in BIM policy. The federal government's "BIM4INFRA2020" roadmap and mandates have systematically accelerated adoption. Since 2017, BIM has been required on all public projects over €100 million [1], and by 2020 on all federal infrastructure building projects [1]. The result is broad industry uptake: recent studies report ≈70% of German construction firms using BIM in some capacity, mostly among architects and large contractors. The typical maturity level is BIM Level 2 (collaborative sharing of models), with Level 3 beginning in flagship projects. The government provides financial incentives and free digital tools (a national BIM portal) to reduce entry costs [1] [2]. In practice, Germany has integrated BIM into major building and transport works. For example, Deutsche Bahn's infrastructure digitization plans explicitly cite BIM for faster, error-reduced project delivery [2] [7]. Hence, German projects often already capture some BIM efficiencies.

While full quantitative reports on German BIM ROI are still emerging, policy documents underscore expected benefits: the Transport Ministry emphasizes BIM will make construction "faster, more transparent and more cost-effective" [2].

Expert analyses note that although German contractors incur extra design effort upfront, they gain early clarity and schedule assurance. In one study, early BIM use led to shorter schedules on average, reducing capital costs [6]. Moreover, federal plans expect lifecycle data integration (e.g., energy use, maintenance) will yield sustainability gains [2]. In summary, Germany's environment features high BIM utilization with structured ROI tracking, unlike Pakistan's nascent stage.

4 Economic Metrics

In both countries, there are measurable economic payoffs to BIM, but in different magnitudes. Numerous studies across the world have analyzed the monetary effects of BIM. In a survey carried out by Stanford University (CIFE, 2007) on 32 projects, it was noted that BIM had the potential to remove ~40% of unbudgeted change orders and save up to 10% of contract costs through clash detection while shortening schedules by ~7% [5]. According to more recent reviews, identify time savings, RFIs, and rework reductions as leading factors, with BIM most likely to decrease the total cost of business by 10-20% on large construction projects [6]. On the scale, Autodesk calculated relatively small savings on the ROI model of Revit (~2% average) by including only direct expenditures [6], thereby indicating that greater returns are derived indirectly.

4.1 Pakistan

Empirical cost data from Pakistan are scarce, but surveys hint at large potential. For instance, respondents in one study predicted BIM could cut project costs and durations by more than half [3]. If implemented, these savings would derive from avoiding rework, clashes, and late changes. A local project case (the Nespak office) modeled with BIM showed qualitatively that clashes would be detected early, improving accuracy and schedule. While that study did not list exact savings, it noted large reductions in coordination problems [8]. Another benchmark study (Hong Kong public housing) found BIM design effort increased by 45.9% but reduced construction cost by 8.61%, yielding a net ~6.92% total saving [7]. We can conservatively extrapolate: even a single-digit total cost saving would be significant for Pakistani budgets. Importantly, much of Pakistan's construction waste (material/labor inefficiencies, errors) could be mitigated by BIM data sharing [8]. In practice, any ROI must offset Pakistan's BIM setup costs. Public projects could catalyze ROI by standardizing BIM use in tenders. Anecdotally, Pakistani builders note that BIM's schedule certainty can lower financing costs – a non-cash benefit.

4.2 Germany

In Germany, BIM savings are already realized, although they are increasing. Industry reporting indicates that 5-10 percent reductions in costs can be what can be achieved when BIM workflows have matured. To illustrate, Switzerland (geographically near, same practice) compared two equal-height high-rise buildings: the one built with the use of BIM had higher initial costs but had 10% cheaper additional (extra) costs as opposed to the other traditional high-rise building [6]. This implies net savings on the construction phase. In Germany, transport schemes also give figures of a few per cent reductions in planning costs: Cable-grid infrastructure case estimated that its planning costs would be 25% cheaper due to the support of BIM coordination [6]. These small savings indicate that the non-BIM in Germany is already effective, the savings made by removing the small mismatches and enhance the accuracy of quantities. Interestingly, Germany's public BIM mandates force even the previously uninterested firms to invest, and a review of a government study cited its initial ramp-up phase with investment before ROI is realized [6]. After that, planners will be able to bid more reliably.

Statistically, surveys of German (and European) BIM users find ~70% report a positive ROI on BIM [9]. In Western Europe, half of the experienced firms measure BIM ROI on most projects. This aligns with Germany's expectations: as Transport Minister Wissing put it, "digitalization is a prerequisite for quick planning and construction. BIM will make construction more efficient, cost-effective, and transparent" [2]. In sum, German data support that BIM yields cost and schedule benefits in the mid- to long-term, although individual savings vary by project type.

5 Economic Metrics Technical Outcomes

The value of BIM can also be measured in dollars beyond, yet the reduction of errors and improved processes is often overlooked. It is the technical consequences that are highlighted by both Pakistani and German sources. BIM means that by allowing clash detection to take place, BIM is able to prevent delays by ensuring barriers in the field do not arise. The CIFE report from Stanford observed that only clash detection could save contract value ~10 percent [5]. The best BIM benefits are reported as reduced coordination, fewer RFIs, and better documentation in other surveys in the industry [7]. Rework is endemic in the case of Pakistan: in one survey, ~61 % of construction mistakes related to communication breakdown [7]. Those gaps are closed with the assistance of BIM, which can share one model. Practitioners claim that BIM automatically causes the information in the design to spread, minimizing drafting errors manually [7].

Germany's projects similarly show quality gains. For example, German rail and road projects using BIM have reported more stable timelines – each BIM project tends to meet its milestones more reliably than non-BIM ones [6]. Moreover, BIM's environmental modeling allows early energy and life-cycle analysis [2]: planners can estimate carbon footprints and reuse potential before breaking ground. This was demonstrated in a Pakistan case study of the Nespak building: using BIM energy analysis, annual energy use was estimated to drop from 80 to 50 tons/year by adding green design features [7]. Such efficiency analyses are rare in Pakistan today, but the example shows BIM's potential.

In sum, both countries see BIM as a quality and efficiency enhancer. Pakistan's surveys conclude that even if the direct cost impact is "least" (perceptions in 2014 [4]), BIM decisively improves design and reduces rework. Germany's detailed planning yields more quantifiable benefits: fewer RFIs, consistent data handover from design to construction, and eventual maintenance. A German transport master plan explicitly notes that improved planning quality (less uncertainty) yields immediate savings [6]. Thus, BIM drives error reduction and process integration in both settings; the difference is whether those gains have been fully monetized yet.

6 Comparative Summary

The comparative picture is thus: Pakistan – very low BIM usage today, meaning most buildings are designed and built with traditional 2D CAD and manual coordination [3] [4]. This represents a baseline with high waste and risk. BIM's introduction would first raise design costs but promises huge payoffs (survey respondents suggest halving overruns) [3]. Germany – high and growing BIM adoption, supported by policy. Here, BIM is no longer novel; cost/time savings from BIM are more marginal but more certain. Germany's large projects already use BIM data to cut change orders and speed approvals. The German model suggests that early BIM investments are amortized across a long project pipeline, whereas in Pakistan, each project must individually prove ROI.

Both countries value the same core benefits (fewer clashes, better forecasts), but operate at different maturity levels. Pakistani professionals need convincing case studies and government encouragement. German agencies prioritize standardization and life-cycle analysis (e.g., integrating BIM with facility management). Economically, we can illustrate the gap with representative figures: Pakistan reports 11% BIM adoption [3], whereas Germany reports ~70% [1]. Cost reductions of 10–20% are achievable in Europe [6], while Pakistan's optimistic survey suggests up to 57% savings are possible once BIM is implemented [3]. Time savings range similarly. The figure data below shows sample metrics for charting these contrasts.

Table 1. Comparative BIM Performance Metrics: Pakistan vs Germany

Country	BIM Adoption Rate (%)	Cost Savings (%)	Time Reduction (%)
Pakistan	~11% (limited early-stage adoption)	~57% (theoretical/pilot potential)	~57% (estimated from case studies)
Germany	~70% (mandated for public works)	~10% (realized average)	~7% (realized average)

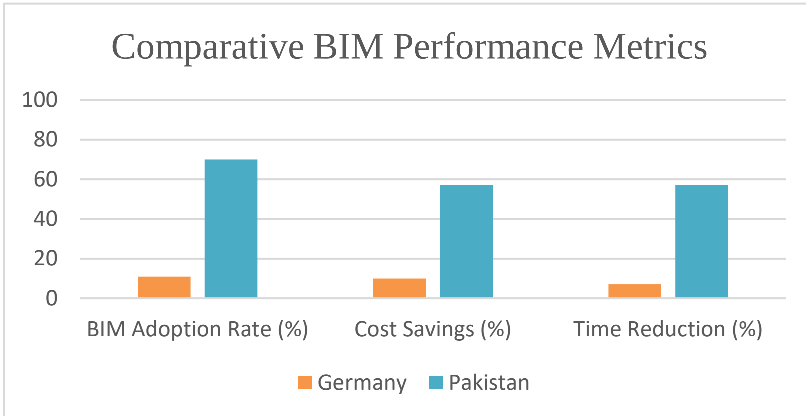

Fig. 2. Building Information Modeling (BIM) performance metrics

The bar chart in Fig. 2 visualizes key Building Information Modeling (BIM) performance metrics—adoption rate, cost savings, and time reduction—for Pakistan and Germany. The data reflect both realized and projected outcomes based on recent studies. Germany, with an established and policy-driven BIM framework, shows a 70% adoption rate, modest but consistent cost savings (~10%), and observed time reductions of around 7%, indicating a mature ecosystem that yields incremental improvements. In contrast, Pakistan's adoption rate is only 11%, but surveys and pilot case studies suggest potential cost and time savings as high as 57% each, if BIM is implemented optimally. These projections highlight Pakistan's significant untapped potential. The disparity in these metrics underscores how maturity and standardization influence measurable outcomes. Germany reaps smaller but dependable gains, while Pakistan has yet to unlock its larger estimated benefits.

7 Discussion

BIM offers clear cost and technical benefits in large construction projects, but realizing those gains depends on context. In Pakistan, the technology is at an early adoption stage: once barriers (cost, training, standards) are addressed, BIM could transform project delivery and yield substantial ROI. In Germany, BIM is maturing into the new norm: significant upfront and learning costs have mostly been absorbed, so the current focus is on leveraging BIM data across project lifecycles. In both settings, research shows positive returns: e.g., Stanford's study projects ~10% cost savings and 7% schedule compression with BIM [5], and even conservative estimates indicate multi-percent improvements on whole-project cost [6]. The German federal BIM initiative expects that by 2025, such improvements will be systematic [2]. For Pakistan, targeted pilot projects and policy frameworks could help capture similar efficiencies. Ultimately, our review finds that BIM yields both economic and technical value in building projects; the difference lies in how fully each country has integrated the technology and measured its results. Germany's BIM adoption was accelerated by institutional enablers like federal mandates and the national BIM portal, which offered free tools and standard guidelines. Pakistan could adopt similar scalable solutions, such as launching a national BIM hub, mandating BIM in select public projects, and offering training incentives to drive broader uptake and standardization. Pakistan should mandate BIM in public projects, establish a national task force, and develop standard protocols. Embedding BIM in curricula and supporting public-private training can further institutionalize adoption.

While this study focuses on Pakistan and Germany, the comparative insights have broader relevance for other Global South countries facing similar infrastructure challenges and digitalization gaps. The stark difference in adoption and outcomes highlights how policy support, training investment, and industry incentives can accelerate BIM uptake. Countries with low adoption rates could leverage Pakistan's early lessons, such as the potential for large gains despite a low baseline, and Germany's structured rollout strategies. This comparative model offers a foundation for policy borrowing, scalability planning, and potential regional collaborations across Asia, Africa, and Latin America, where BIM adoption remains limited but highly beneficial.

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