

Addressing the Challenges in Cost Management of Construction Projects by Using AI

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Abstract

Cost management is one of the most important drivers of successful construction projects. Even with established norms like the Project Management Body of Knowledge (PMBOK), Indian construction projects are still afflicted by perennial cost overruns and wastages. This research explores how Artificial Intelligence (AI) can be applied to enhance cost management by enabling real-time decision-making, predictive analytics, and automation. This research uses literature reviews, case studies (DLF Downtown, Taramani), and expert surveys while exploring challenges and suggesting AI-based solutions. The study proposes key cost issues such as estimation error, poor coordination of stakeholders, scope creep, and late procurement. The study continues to outline how AI techniques such as Machine Learning (ML), Natural Language Processing (NLP), and Robotic Process Automation (RPA) can be used to address these issues. The study also correlates AI tools with PMBOK's cost management processes to create a hybrid framework for improved cost management. Challenges to implementing AI, such as high cost, lack of awareness, and integration issues, are addressed with expert opinions by industry experts. By adopting this integrated perspective, the paper presents an AI integration roadmap for construction cost management. The research identifies that while AI is in its infancy phase of adoption in India, upcoming policies are showing the way towards digitalization. The model laid out hereunder positions AI as a strategic driver of real-time, proactive, and sustainable cost management.

Keywords- Artificial intelligence, Construction, Cost management, India, Machine learning, PMBOK, Predictive analytics, Real-time monitoring

INTRODUCTION

Cost control is an essential part of successful project execution in the construction industry, being a key factor in the viability of the project, satisfaction of stakeholders, and sustainable infrastructure growth. With India set to become the third-largest construction market in the world by 2030, contributing almost 9% to the country's gross domestic product, the need for integrated, responsive, and intelligent cost control systems becomes inevitable. With guidelines such as the

Project Management Body of Knowledge (PMBOK) offering a structured approach to cost planning and management, conventional cost control practices employed in India continue to suffer from inefficiencies, delays, and cost overruns, which can be explained by the dynamic, complex, and resource-based nature of construction work. The traditional cost estimating methods are based primarily on manual processes, such as the use of spread sheets, static databases, and discrete human inputs. While these methods were effective during the earlier era of slower-paced

operations, they now struggle to match the speed, volume, and volatility of modern-day construction data [1]. Moreover, they reflect poor agility to respond quickly to project changes, such as changes in design, fluctuations in labour markets, and volatile raw material prices. As a result, Indian construction projects are typically plagued by scope creep, inefficient procurement, and inaccurate project forecasting, all of which add up to compromised profit margins and disturbed schedules [2]. Use of antiquated systems also adds to an industry-wide issue of resource planning, contractor collaboration, and financial transparency. Here, Artificial Intelligence (AI) has become an important factor that can revolutionize cost management with enhanced accuracy, efficiency, and forecasting. AI consists of a group of technologies, i.e., Machine Learning (ML), Natural Language Processing (NLP), and Robotic Process automation (RPA), each playing a specific role in the aspect of automation, generation of insights, and process optimization. For instance, ML algorithms can identify patterns of cost overruns through analysing historical data, market fluctuations, weather, and subcontractor performance [3].

Such technologies do away with the dependency on fixed cost models and enable continuous learning from previous projects, thereby enabling the project managers to have timely information in connection with emerging potential risks. The application of artificial intelligence reaches all four cost management processes identified in the PMBOK: Plan cost management, estimate costs, determine budget, and control costs. During planning, AI systems are used to simulate financial results in a range of risk scenarios, making more realistic budgeting possible. During estimating costs as shown in Fig. 1, AI can access large databases to create detailed forecasts based on labour productivity, local inflation trends, and supplier performance. During budget establishment, AI helps to allocate funds optimally by synchronizing project milestones and cash flow forecasts. During cost control, real-time monitoring systems, augmented with AI, track compliance with the budget, detect anomalies, and raise alerts, thus allowing early intervention. Indirect costs are an addition to all these delays in any project. As there is a delay in the project, the impact of overhead costs is higher [4].



Figure 1: Impact of AI in cost estimation [5].

One of the most important developments in cost management is the combination of AI and building information modelling (BIM), particularly in its 5D version. Whereas conventional 3D BIM is concerned with the spatial aspects of a building, 5D-BIM adds time

(4D) and cost (5D) dimensions, thus enabling people to model and analyse the cost implications of design or schedule choices in real time. AI-driven 5D-BIM software features scenario modelling functionality that runs different execution strategies and their cost

implications before project implementation. This move from reactive to proactive cost planning ensures that uncertainties are addressed way ahead of time, thus minimizing the possibility of over-budget and eleventh-hour contingencies. Real-time monitoring systems greatly enhance cost control through feedback integration between field execution and planning for the project. Technologies such as bluetooth low energy (BLE), RFID, and other wireless sensors enable real-time monitoring of material delivery, labour distribution, and machine usage across the construction site. The real-time streams of continuous data are analysed by artificial intelligence systems to compare planned performance metrics with actual performance metrics, thereby allowing for early identification of inefficiencies and the immediate suggestion of remedial actions [6]. This functionality is particularly useful in large and manpower-intensive projects where even minor deviations can snowball into enormous financial costs. Even vertical mass irregularity in structures, usually because of functional or design modifications, can significantly affect seismic performance and raise the threat of damage or collapse. Such irregularities influence structural stability and have a major impact on the cost of construction [7].

Apart from cost estimation and tracking, artificial intelligence is increasingly being utilized in contract management and risk management. Natural language processing algorithms can independently scan procurement and legal documentation to identify major financial terms, identify phrases with a high probability of causing risk, and assess compliance with contractual conditions. Such an ability not only saves time but also reduces the likelihood of disputes and litigation arising from overlooked details in contracts. Artificial intelligence algorithms can also assess vendors and subcontractors based on past data of projects, thus encouraging more sensible decision-making regarding team selection and resource procurement. Though the benefits are clear, the uptake has been slow because of a range of structural, financial, and cultural challenges. The most important of these challenges is the absence of awareness and

technical data among the construction fraternity. Engineers, contractors, and project managers are not aware of AI tools or are in no doubt about integrating these into existing processes [8]. Training modules and knowledge in AI are practically non-existent in conventional engineering programs, thus further hampering the industry's capacity to adopt innovation at scale. The second is the cost and complexity of integration. Most Indian construction companies—especially the small and medium-sized firms (SMEs)—possess legacy systems that are not API-based data sharing nor cloud-integrated. Consequently, adopting AI tools entails not only capital expenditure but also organizational re-engineering as well as software overhauls. This is a significant challenge for companies with narrow margins or those that lack experience in the digital transformation process. Data fragmentation is also an issue that hinders the effective use of artificial intelligence (AI). Construction generates a lot of data, including invoices, time sheets, alternative designs, progress photos, and drone surveys, most of which is marked by being unstructured and fragmented. The absence of a common platform or data repository hinders AI algorithms from yielding valuable insights. The convergence of AI with BIM, IoT, and cloud technology is paramount to achieve the necessary real-time, interdisciplinary openness of modern construction projects [9].

Cost-impacting uncertainties are known to stakeholders but uncertain to happen. An expert view to create a relative importance index (RII), which emphasizes cash flow problems, poor performance, and site management as major factors, was conducted, which are caused by delays, changes in scope, and estimate adjustments [10], [11]. Despite such challenges, the environment for artificial intelligence integration is increasingly favourable. Government-led initiatives such as Digital India, the Smart Cities Mission, PM Gati Shakti, and the National Infrastructure Pipeline are promoting more and more digitization in the sector of infrastructure development. Such initiatives emphasize the need for cost control in the integration of project schedules and cost factors. Hence, the integration of AI aligns

perfectly with the national goals of infrastructure efficiency and accountability. Additionally, global success stories offer strong templates for India to emulate. In countries like the United States, the United Kingdom, and Singapore, AI-driven systems are already used to automate procurement processes, reduce wastage, optimize the deployment of manpower, and enhance transparency in public sector projects. Such global examples demonstrate the application of AI solutions in different kinds of projects and geographies. Briefly, the Indian construction industry is at a crossroads where the use of Artificial Intelligence for cost management is now more than a technological nicety and has become a necessary operational imperative. With the sheer scale of anticipated infrastructure investment within the next decade, the time is ripe to move away from disjointed, manual cost control processes to consolidated, intelligent systems that enable real-time decision support. This study attempts to assess the preparedness, suitability, and potential of AI in transforming cost management practices in Indian construction and provide suggestions at policy and practice levels for effective adoption.

LITERATURE REVIEW

PMBOK defines four major cost management processes: Plan cost management, estimate costs, determine budget, and control costs. Systematic though they are, they are susceptible to fixed inputs and human oversight, like the usage of earned value management [12]. Literature recognizes that construction projects involving the utilization of traditional tools are vulnerable to human mistakes, data fragmentation, and reporting delays [13]. Critical delay factors (CDFs) in Indian construction projects using expert surveys and factor analysis, aiding stakeholders in prioritizing delays to enhance project success, was also done [14]. The uses of AI across sectors have validated its value in predictive modelling, automation, and anomaly detection. In healthcare, finance, and manufacturing, NLP and ML have improved diagnostic accuracy, fraud detection, and inventory management [15] [16]. Construction is finally coming around to

these digital advancements drones for real-time site data, predictive models for budgeting, and NLP for contract analysis [17]. 5D-BIM, with the addition of cost and scheduling parameters, further enhances AI through synchronized time and funds handling [18]. Research indicates that accuracy and transparency are enhanced through the application of BIM-AI tools. Despite this, there are some barriers: lack of standardized data sets, prohibitively expensive integration, and poor AI literacy among professionals. Some authors demand more interoperability with open standards like IFC or gbXML to integrate BIM-AI systems. Resistance from stakeholders and a lack of standardized frameworks hinder scalability. Overall, the literature indicates strong theoretical potential for AI in cost management but indicates the need for practical, localized models to drive adoption.

RESEARCH AIM AND OBJECTIVES

This research aims to identify and derive those AI tools that can be used to address the challenges of cost management in construction projects, and to identify the industry-specific barriers to this AI adoption.

Research Objectives

- To identify the key challenges in cost management in construction projects.
- To identify the methodologies in which AI can be used in the aspect of cost management in the construction industry, according to the Indian context.
- To identify which challenges of cost management, the tools and techniques of PMBOK and the tools of AI can be integrated potentially.
- To evaluate the industry-specific barriers and opportunities for AI adoption in the cost management of construction projects.

Research Questions

- What is cost management according to the project management guidebooks?
- What are the challenges faced in cost management in construction projects?

- How is AI used in other industries, and what are the major tools used?
- How can AI be used in the aspect of cost management in the construction industry?
- What are the key challenges in integrating AI-based cost tracking into existing project management frameworks?

RESEARCH METHODOLOGY

Objective 1: To Identify the Key Challenges in Cost Management in Construction

Methodology: Comparative literature review and industry survey were employed to examine the most critical construction cost management issues in the Indian context. PMBOK cost management guidelines, peer-reviewed scholarly research, and project-specific industry reports were examined. A structured questionnaire was also constructed and administered to stakeholders such as contractors, project managers, and consultants across different scales of projects to validate the findings and prioritize the most common challenges.

Data/Information Required: Relevant scholarly research, project performance reports, cost overrun case studies of the Indian construction industry, and expert views of the stakeholders that are directly engaged in cost activities on current projects.

Approach to Data Collection: Professional academic databases (Google Scholar, Scopus), company reports, and properly constructed surveys from experts. The answers were categorized by job title and years of experience for context comparison.

Objective 2: To Identify the Methodologies in Which AI Can be Used in the Aspect of Cost Management in the Construction Industry, According to the Indian Context

Methodology: A qualitative review of literature was done to research AI-based methodologies i.e., machine learning (ML), natural language processing (NLP), and robotic process automation (RPA) and their application in cost estimation, budgeting, and control. Case studies across various industries were analyzed to

derive techniques applicable in the construction industry. Cross-industry learnings were used to develop recommendations tailored to Indian practices.

Data/Information Required: Historical data regarding AI usage in the construction and other similar sectors, parameters for measuring performance, and comparative usage case comparisons.

Approach to Data Collection: Systematic literature review of AI adoption across academic and industry literature, complemented with case study examination of global and Indian infrastructure projects.

Objective 3: To Identify Which Challenges of Cost Management, the Tools and Techniques of PMBOK, and the Tools of AI Can be Integrated Potentially

Methodology: The mind-mapping method was utilized to establish rational linkages amongst AI tools, PMBOK cost processes, and cost management issues identified. The integration framework was validated and reviewed through expert interviews and survey comments from industry professionals in order to determine feasibility and real-world applicability.

Data/Information Required: PMBOK process documentation, AI tool features, experts' opinions on integration feasibility, and experience-based cost management pain areas.

Approach to Data Collection: Cost issues were translated to corresponding AI tools through visual mapping software within PMBOK's cost management process. Validation was done through expert review panels and semi-structured interviews.

Objective 4: To Evaluate the Industry-specific Barriers and Opportunities for AI Adoption in Cost Management of Construction Projects

Methodology: Qualitative through surveys and case study reviews. The significant barriers found were high initial costs, low digital literacy, and software incompatibility. Opportunities that come with national digitization efforts and increased construction industry expenditures were also evaluated.

Data/Information Required: Interviews with

experts, project-specific implementation barriers, policy documents, and technology readiness levels of construction firms.

Approach to Data Collection: Standardized questionnaires of construction professionals supplemented with in-depth interviews and secondary data analysis of policy reports (Digital India, Smart Cities, Gati Shakti) and industry reports.

RESULTS AND DISCUSSION

Objective 1: To Identify the Key Challenges in Cost Management in Construction Projects

Cost control is a fundamental aspect of effective project execution in construction because of its direct influence on profit, resource utilization, and sustainability. In India's ever-changing and intricate construction industry, overspends, delays, and misallocations of resources are still the norm. Even with enhanced forecasting tools and technologies, factors like inadequate planning, poor estimates, design changes, inflation, labour disputes, and unexpected site conditions tend to destabilize project budgets [19]. Among the significant contributory factors is the highly fragmented nature of the industry. Stakeholders clients, contractors, suppliers, and consultants work in disconnected silos, leading to poor coordination and communication. Lack of integration leads to redundancy, delays, and costs [20]. Moreover, legacy cost management tools such as spreadsheets and manual tracking systems still dominate, particularly in small to medium-sized organizations. The tools cannot give real-time feedback and automated reports, thus weakening their effectiveness. Current construction needs cost control to move away from conventional budgeting. More focus on sustainability means this now encompasses lifecycle costing, environmental footprint, and energy consumption. Effective cost control must be integrated with these broader goals to make schemes financially sustainable in the long term and meet regulatory requirements. Several studies have revealed recurring issues relating to costs. [21] discovered that the most significant factors behind cost overruns of Indian projects are incorrect project estimates, poor planning, and repeated design changes. H. Ambre and D. Demse emphasized that inefficiently managed

deadlines and delays in decision-making activities significantly enhance financial inefficiencies [22].

At a global level, inadequate awareness and training on cost control among stakeholders were identified as key impediments to effective cost management. In addition, [23] outlined project complexity impacts, which assert that increased uncertainty and coordination issues lead to failed control, slimmer margins, and misaligned budgets across various phases. Design inefficiencies are a key area of concern. Late design-stage design modifications introduced, or inadequate documentation, may lead to material waste and rework. These issues tend to arise due to varying client requirements or inadequate planning. Unless addressed properly, the design changes may have downstream consequences that interfere with cost control measures. Scope creep unapproved additions to the initial scope of a project with insufficient adjustments in time or cost is most prevalent in public infrastructure projects. [24] determined that almost half of India's road projects had cost overruns of more than 25% due to such changes [25]. These are manifestations of poor change management and an inability to foresee stakeholder influences during the start of planning. One of the recurring themes throughout the literature is the continued use of outdated cost control techniques. Traditional manual systems are slow and laborious to manage large amounts of information in real time. [26] emphasized that such dependence leads to the abandonment of early warning signs, thereby making it challenging for project teams to take corrective measures before the cost overrun. Rahman et al. (2024) also highlighted the external factors, including regulatory delay, supply chain disruption, and market fluctuation. Such macro-level risks are usually underestimated, which results in increased costs and jeopardizes timely project completion. Finally, critical issues in cost management include inaccurate estimations, poor planning and scheduling, poor design, scope creep, and outdated manual processes.

All the issues are also compounded by fragmented stakeholder systems and poor coordination.

Table 1: *Number of times the challenge of cost management has been reported (Objective 1).*

S. N.	Key Challenge	Times Reported
1	Inaccurate cost estimation	8
2	Poor planning and scheduling	7
3	Design changes and scope creep	7
4	Fragmentation of stakeholders	5
5	Outdated cost control methods	4
6	Lack of standardization in practices	4
7	Complexity in coordination among legal entities	6
8	Lack of real-time data access	3
9	Lack of trained personnel	4
10	Resistance to technological adoption	3
11	Difficult contingency planning and release	5
12	Delayed decision-making and approvals	6
13	Challenges with margin calculation	3
14	Unpredictable external factors (regulation, market changes)	4

Table 1 indicates that inaccurate estimation of costs, disintegrated project teams, inadequate planning and scheduling, legacy cost control processes, absence of standardization of professional roles, inadequate technological adoption, and resistance to process change within organizations. Each of these challenges interacts with others, so that they cumulatively form a complex web that increases the likelihood of cost overruns. To address these challenges, a multidimensional strategy is needed. This involves investing in professional development, embracing integrated project management systems, institutionalizing cost management as a strategic function, and encouraging international standards and certification of cost professionals. Policymakers and industry organizations also need to strive towards enhanced transparency, accountability, and coordination among project stakeholders.

Case Study Data Collection: DLF Downtown, Taramani

DLF Downtown in Chennai's Taramani is DLF

Cyber City Developers Ltd.'s mega IT park project in association with Singapore's GIC. Spanning 68 lakh sq. ft. in two phases at a cost of ₹5000 crore. As shown in Fig. 2, although through accurate planning, both phases of the project fell behind schedule—Phase 1 by 6 months and Phase 2 by 4 months—leading to cost overruns and financial losses. The pandemic disruptions, stakeholder coordination, and technical complexities unique to the site were the primary causes of the delay. Work on Phase 1 began in February 2020 with completion targeted by March 2021, but completion was finally achieved by September 2021. The COVID-19 pandemic resulted in unprecedented supply chain disruptions and labour shortages, which resulted in significant schedule disruptions, excessive overheads, increased rates of resources, and downtime, placing a lot of financial pressure.

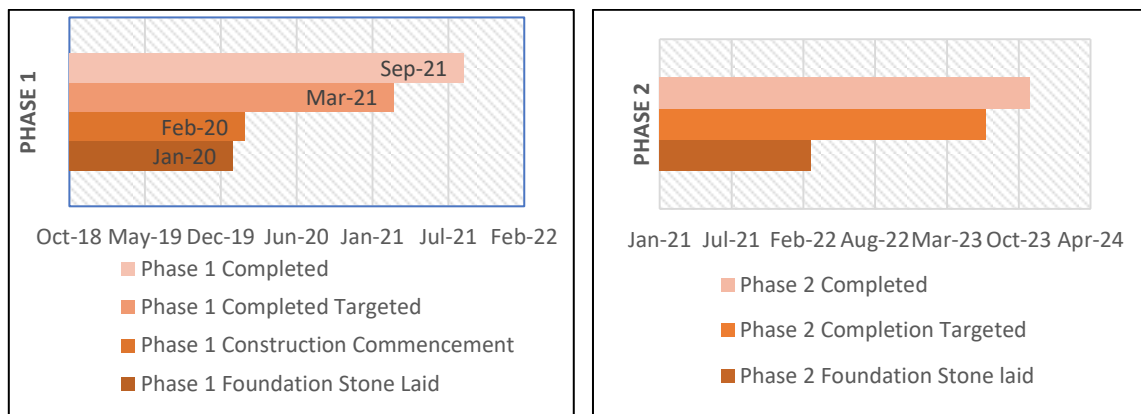


Figure 2: Chart representing the timeline of phase 1 and phase 2 start and completion [27].

The DLF Downtown project was adversely affected by years of inactivity. Purchased in 2008 for ₹750 crore, the project remained idle for over a decade because of SEZ clearance issues and the existence of a railway track on the land. Judicial complexities, idle capital cost, and missed market windows triggered cost escalations to a significant degree. Inflation, steel and cement price increases, and market-driven design changes (e.g., wellness centres) added to the budget. Financing through internal accruals and ₹1,200 crore debt were stretched by execution delays and disrupted cash flows. Technical issues—underestimated dewatering and poor soil conditions—required costly solutions like secant pile walls, with manpower and machinery costs. Delayed regulatory leasing cycles and hybrid work patterns caused by the pandemic complicated tenant acquisition. The project reflects literature findings: poor estimation, weak risk buffers, and outdated planning tools. The case highlights the need for real-time data, predictive analytics, enhanced risk modelling, and advanced stakeholder coordination to enable effective cost control on future projects.

Objective 2: To Identify the Methodologies in Which AI Can be Used in the Aspect of Cost Management in the Construction Industry According to the Indian Context

Artificial intelligence (AI) is increasingly used as a revolutionary tool in cost management across industries like finance, manufacturing, supply chain, and construction. AI-based systems enhance the accuracy of budgeting and

allow real-time tracking of financials through analyzing spending patterns and providing predictive analysis. AI-based tools prevent fraud and financial mismanagement by detecting anomalies in expense reporting. In construction, marked by its volatile cost structure and dynamic workflows, the role of AI in cost management is making gains. AI-based cost estimation software utilizes history, project characteristics, and market trends to predict budgets more effectively. Such systems enable the avoidance of risks of cost overrun and underestimation, which are typical in conventional methods [28]. AI-powered procurement platforms analyse supplier performance and pricing trends to streamline vendor selection and contract negotiation, reducing procurement costs and increasing efficiency.

Still, the effective use of AI in construction cost management is thwarted by issues including technophobia, disjointed project data, and the unavailability of standardized frameworks for applying AI. The reliance of AI tools on high-quality input data and the willingness of stakeholders to migrate away from traditional systems to smart decision-making systems also affect their accuracy [29]. AI has also transformed supply chain management—another primary driver of construction costs—through real-time tracking and automation. Predictive analytics platforms predict material demand fluctuations, while AIoT (AI for Internet of Things) provides real-time monitoring of inventory and logistics, optimizing utilization and minimizing waste [30]. The tools enhance operational effectiveness as well as

sustainability through reduced over-ordering, minimized storage expenses, and improved delivery accuracy. For instance, AI-based energy management systems track and regulate energy usage in buildings directly in a way that leads to reduced operational costs and carbon emissions. Similarly, AI facilitates optimization of transportation logistics and routes, thus balancing cost control with sustainability objectives [31]. However, the introduction of AI comes with threats like cybersecurity attacks, moral biases, and displacement of jobs—all of which need strong governance and strategic reskilling of the workforce. The cost of

implementation is one of the greatest hindrances to mass adoption of AI, especially among SMEs. The privacy, transparency, and concerns regarding algorithmic bias should also be resolved for ethical implementation, especially in areas such as finance, recruitment, and medicine.

AI Tools and Their Applications in Cost Management: A variety of AI technologies are applied across sectors to mitigate cost-related issues. In construction, these are increasingly being used to better control costs. These tools are used in terms of cost management by other industries, according to a study.

Table 2: Overview of AI tools and their applications in cost management (Objective 2).

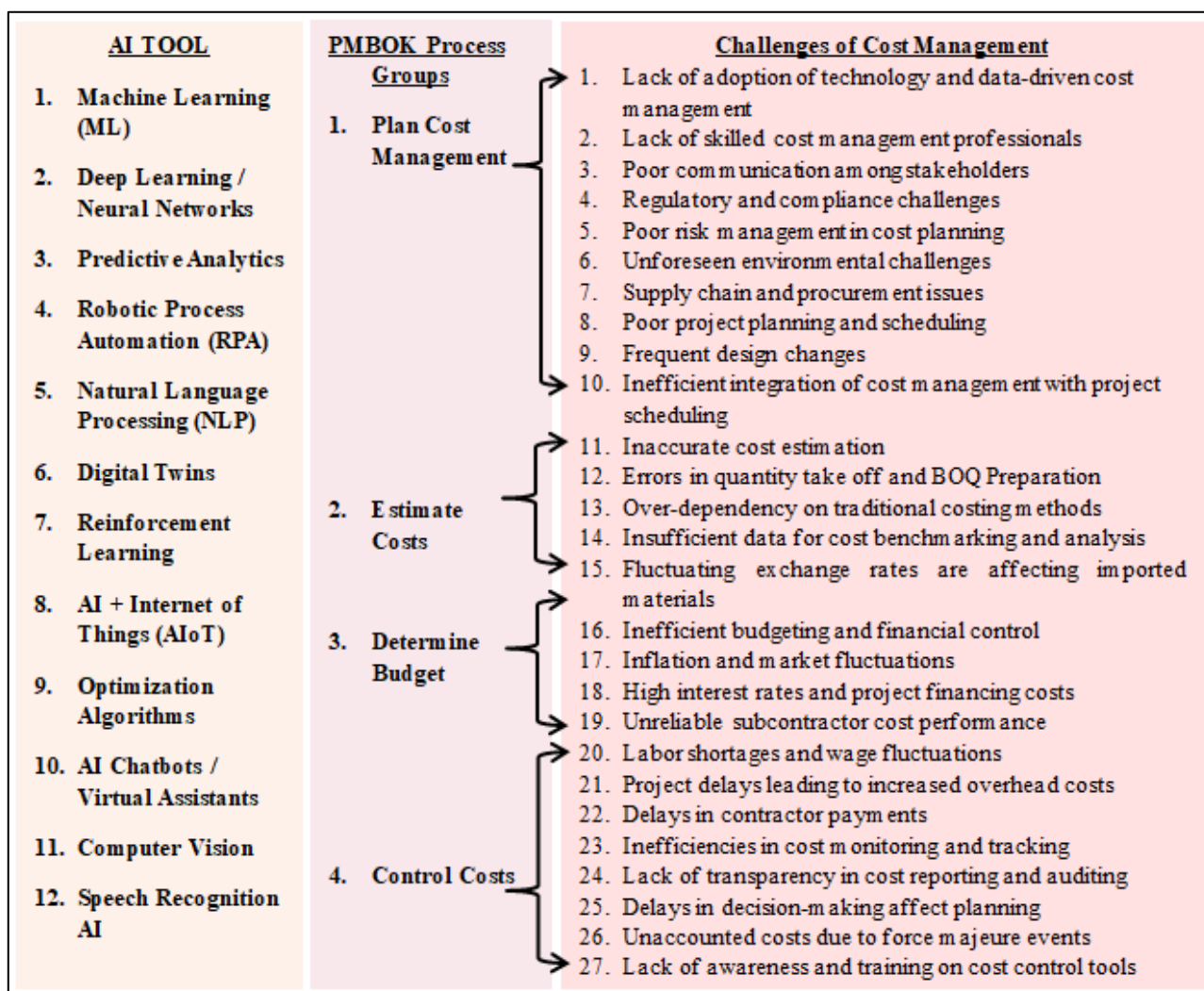
AI Tool	Uses of the Tool	Industry Using it	Usage in Terms of Cost Management
Machine Learning(ML)	Forecasting, anomaly detection, pattern recognition, risk modelling	Finance, Manufacturing,	Predicts costs, detects risks, and improves budgeting accuracy
Deep Learning & Neural Networks	Complex data modelling, image and speech recognition, behavioural analysis	Finance, Healthcare, Retail	Credit risk analysis, fraud detection, and patient care cost forecasting
Predictive Analytics	Trend forecasting, resource planning, and inventory optimization	Manufacturing, Supply Chain, Construction	Forecasts cost overruns, optimizes procurement, and prevents unnecessary stock.
(RPA)	Automates repetitive tasks like billing, payroll, and reporting	Finance, Construction, Healthcare	Reduces administrative costs and human error, speeds up processes
(NLP)	Processes unstructured data (contracts, reports), chatbots	Finance, Healthcare, Construction	Automates document analysis and customer support, reducing manual processing costs
Digital Twins	Simulates physical processes for planning and optimization	Manufacturing, Construction	Optimizes project planning, reduces design rework, and associated costs
Reinforcement Learning	Dynamic optimization, adaptive decision-making	Healthcare, Logistics	Efficient staff/resource scheduling, reducing idle time and labour costs
AI + Internet of Things (AIoT)	Real-time monitoring via sensors, automated control	Logistics, Construction, Manufacturing	Tracks equipment/material usage, reduces losses through proactive maintenance.
Optimization Algorithms	Solves resource allocation problems, cost minimization	Logistics, Manufacturing, Finance	Improves cost-efficiency in procurement, routing, and operations
AI Chatbots / Virtual Assistants	Customer support, HR, and IT helpdesk, routine query handling	Finance, Healthcare, Services	Reduces the cost of human support, automates low-value interactions
Computer Vision	Visual inspection, defect detection, quality assurance	Manufacturing, Warehousing	Minimizes rework and waste by catching defects early

Table 2 indicates that these tools have been effectively used in various industries such as healthcare, logistics, and finance, and are presently being embraced in construction for use such as real-time cost management, intelligent procurement, and automated reporting. AI can change construction cost management from a reactive, error-ridden activity to a predictive, automated, and data-driven process. Through facilitating improved forecasting, risk management, and automation of workflows, AI solves many of the persistent issues in conventional cost control. Although the path to widespread adoption involves braving integration and cost hurdles, the long-term

advantages of financial accuracy, alignment of stakeholders, and sustainability are not debatable. As building projects become more advanced, the function of AI in facilitating on-time and affordable delivery will increase.

Objective 3: To Identify Which Challenges of Cost Management, the Tools and Techniques of PMBOK, and the Tools of AI can be integrated potentially

Mind Mapping of Tools of AI, Challenges of Cost Management, and PMBOK Process Groups



According to the applications of each tool identified in objective 2, each tool can be used to solve the problems of each process group if incorporated with human expertise. Table 3

tabulates each AI tool that can be used to solve the cost management challenge, which falls under the process groups.

Table 3: Overview of AI tools and applications of AI in cost management. (Mindmapping of Objective 3).

AI Tool	Cost Management Challenges it can Solve	Process group
Machine Learning (ML)	- Inaccurate cost estimation - Errors in quantity take off and BOQ preparation	- Estimate Cost - Estimate Cost
Deep Learning/ Neural Networks	- Risk and uncertainty in cost management - Predicting fluctuations and unforeseen costs	- Plan Cost Management - Determine Budget
Predictive Analytics	- Inaccurate cost estimation - Inflation and market fluctuations - High interest rates and project financing costs - Delays in financial planning	- Estimate Cost - Determine Budget - Determine Budget - Plan Cost Management
Robotic Process Automation (RPA)	- Delays in contractor payments - Inefficiencies in cost monitoring and tracking - Errors in BOQ preparation	- Control costs - Control costs - Estimate Cost
Natural Language Processing (NLP)	- Poor communication among stakeholders - Lack of transparency in cost reporting	- Plan Cost Management - Control costs
Digital Twins	- Errors in BOQ - Project delays	- Estimate Cost - All process groups
Reinforcement Learning	- Inefficient project planning - Budget control in dynamic environments	- Plan Cost Management - Determine Budget
AI + Internet of Things (AIoT)	- Real-time cost monitoring - Delays in contractor payments - Supply chain inefficiencies	- Control costs - Control costs - Plan Cost Management
Optimization Algorithms	- Supply chain issues - Project financing costs	- Plan Cost Management - Plan Cost Management
AI Chatbots / Virtual Assistants	- Delays in decision-making affecting financial planning - Poor communication among stakeholders	- Control costs - Plan Cost Management
Computer Vision	- Errors in quantity take-off - Unforeseen environmental & challenges	- Estimate Cost - Plan Cost Management
Speech Recognition AI	- On-site communication gaps - Real-time reporting and updates	- Control costs - Control costs

Qualitative Analysis: Questionnaire Survey

A questionnaire survey by industry experts to

validate these AI tools and their efficiency in solving these problems. The questionnaire was answered by 34 industry experts.

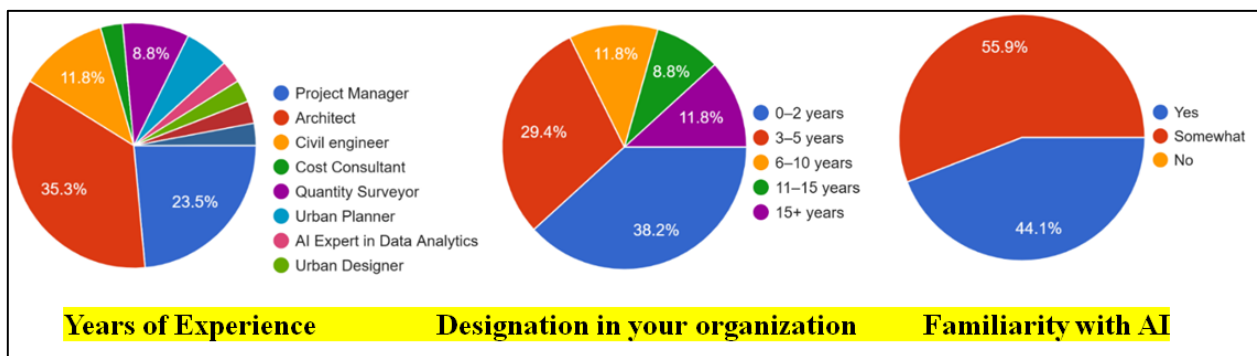


Figure 3: Chart representing the designation, experience, and familiarity [32].

Fig. 3 indicates that the survey was completed by professionals from the industry, primarily architects (35.3%), project managers (23.5%), and civil engineers (11.8%) primary cost and decision-making roles. AI experts were minimal, signifying limited intelligence but high potential for uptake through training. The prevalence of design and execution professions indicates AI tools should be easy to use and part of workflows such as estimation, budgeting, and procurement. The majority (67.6%) of the respondents had experience of less than 5 years, indicating a young, flexible workforce willing to accept digital technology. The existence of experienced professionals (10–15+ years)

indicates a requirement for balanced AI implementation—intermixing training with building confidence. Resistance, primarily from experienced professionals (around 30%), indicates fear of abandoning traditional practices. Overall, the findings indicate a technology-open but under-standardized setting for AI integration. A positive insight is that 100% of respondents are aware of AI, though 44.1% are confident. The rest need targeted training and sector-specific interventions such as pilot programs, toolkits, and training modules on the use of AI in cost estimating, predictive budgeting, and financial automation.

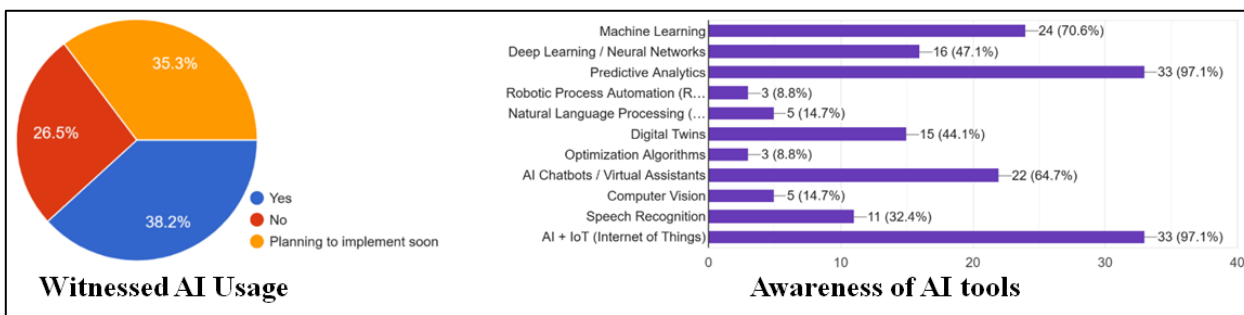


Figure 4: Chart representing the witness of these AI tools (Google form-Questionnaire).

Fig. 4 reveals that 38.2% of the respondents have used or implemented AI in construction, and 35.3% intend to implement it soon, reflecting a high trend of digital transformation in cost management. Only 26.5% were unaware of AI. Predictive Analytics and AI+IoT (97.1%) and machine learning (70.6%) are the highest in awareness, but more advanced tools such as

deep learning (47.1%), speech recognition (32.4%), and, most importantly, computer vision, NLP, and RPA (14.7–8.8%) reflect low awareness. This reflects interest in more frequent usage of AI’s core applications but low awareness of advanced tools, reflecting the need for specialized training and user-friendly tool development.

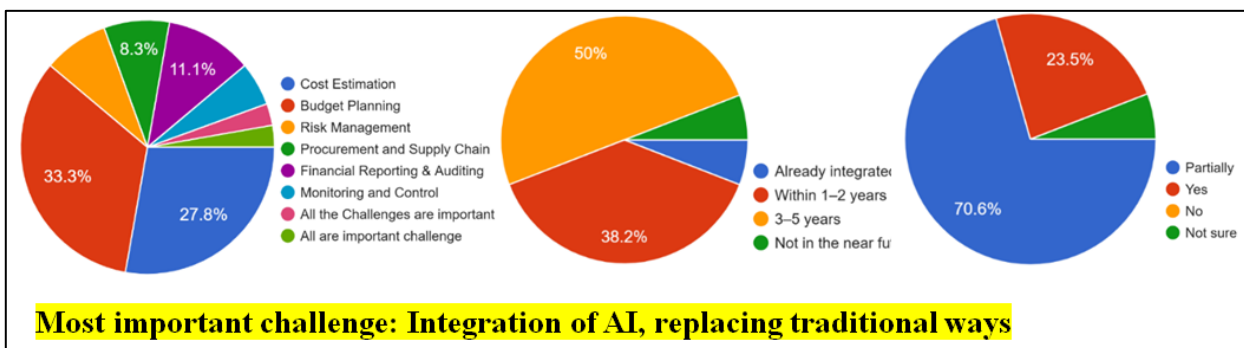


Figure 5: Chart representing the challenges that AI should address the status of integration of AI into construction, and whether AI will replace traditional costing methods.

Fig. 5 indicates that budget planning (33.3%) is the most important cost control area where AI is

needed, followed by cost estimation (27.8%), indicating AI’s usage in early-stage financial

projections. Risk management (11.1%) and monitoring and control (8.3%) indicate the need for AI at the implementation level, while procurement and financial reporting did not get much attention. A small group (5.6%) pointed to all areas as equally important, indicating AI’s end-to-end usage. Most of the participants (70.6%) believe that AI will replace traditional methods to some degree, liking the combination of human and AI. Only 23.5% expect AI to fully replace traditional methods, while 5.9% are uncertain, indicating guarded optimism and a need for human involvement. Budgeting is

viewed as being crucial in the case of fast-changing markets; AI’s capability to process huge amounts of data for scenario modelling is greatly appreciated. Cost estimation through AI provides greater accuracy and speed based on historical and real-time data. At integration, 50% anticipate complete adoption of AI in cost management during 3–5 years, 38.2% in 1–2 years, an indication of incredible momentum. Present integration is shown through only 5.9%, with 5.9% more being sceptical due to current hindrances, making the coming years pivotal to adoption and training.

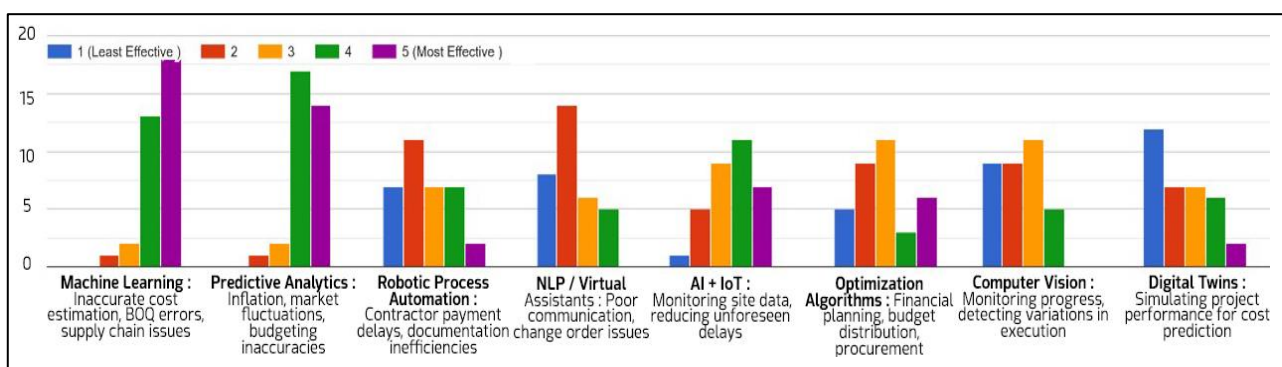


Figure 6: The chart showing whether AI can address the following challenges of cost management.

Fig. 6 indicates that most of the respondents used machine learning and predictive analytics to solve cost management issues like estimation errors and budget anomalies due to accuracy and data-handling abilities. AI + IoT and computer vision ranked with average confidence in quality control and real-time monitoring. RPA, NLP, and optimization algorithms are moderately useful, and digital twins are the least confident due to limited exposure. Overall, AI works best in the early phases of cost control, especially for planning and forecasting, and lower-ranked tools are due to limited exposure and real-world application compared to their potential.

An initiated mapping activity aligned ML and predictive analytics with estimate costs and determine budget, RPA and AIoT with control costs, and NLP/chatbots with plan cost management. Most (70.6%) favoured AI-human collaboration over pure automation, highlighting early-stage integration for optimal benefits. The results reflect the industry’s preparedness for AI, subject to overcoming challenges such as data standardization and skill acquisition.

Objective 4: To Evaluate the Industry-specific Barriers and Opportunities for AI Adoption in the Cost Management of Construction Projects

Despite the revolutionary capability of AI to revolutionize cost management in the construction industry through forecasting, automation, and decision-making, the technology has yet to gain wide acceptance. The literature points out several industry-related obstacles and opportunities defining such slow adaptation.

BARRIERS TO AI ADOPTION

- Technology Improvement and Interoperability:** Most organizations use disparate or legacy software systems, making it difficult to integrate AI. AI tools are often not tailored for cost management, leading to costly customization [33].
- Inadequate Data Fragmentation and Quality:** Large, untainted datasets are required by

trustworthy AI. Building data is usually siloed, unstructured, and hand-written, and, thus, less trustworthy for AI.

Organizational and Cultural Resistance: Resistance to change due to fear of losing a job, poor leadership, AI literacy, and resistance to change, slow adoption. Absence of internal AI champions worsens resistance [34].

High Cost and Uncertain ROI: Implementation of AI entails enormous investment in training, hardware, and software, with ROI only being apparent over multiple projects placing it beyond the reach of SMEs

Skills Gap and Training Deficiency: There is a shortage of construction and AI experts. Training systems lack AI content.

Project Uniqueness and Lack of Standardization: Site differences and regulation reduce AI model portability across projects

Limited Cost-specific Research: Most AI technologies are focused on safety and scheduling, with minimal focus on cost-oriented applications like budgeting or procurement

Poor Industry Collaboration: Limited data exchange and the absence of open platforms hinder the development of sector-wide AI.

OPPORTUNITIES FOR AI IN COST MANAGEMENT

Improved Costing and Budgeting: AI

processes massive datasets to develop real-time data-driven cost estimates. It updates initial estimates through the guidance of historical data, market data, and productivity rates, and dynamically adapts against environmental impacts and scope variations.

Automation of Repetitive Tasks: Artificial intelligence tools like NLP and RPA make processes like invoice verification, quantity take-offs, and budget tracking automated, free from human error, and enable specialists to concentrate on strategic tasks.

Real-Time Monitoring and Control: AI integrated with IoT and BIM enables real-time tracking of resources and costs. Such capability in advance alerts teams of cost overruns so they can step in on time.

Intelligent Procurement and Resource Management: Predictive analytics enable procurement planning, supplier quality selection, and labour and material management. ML applies performance data to optimize deployment and reduce costs.

Strategic Decision Support AI: facilitates “what-if” simulation, which aids in scenario planning to allow stakeholders to choose cost-cutting measures. Despite initial adoption, the benefits of AI, like forecasting, automation, monitoring, and decision-making, outweigh the drawbacks of high cost, resistance, bad data, and limited skills. Data quality, collaboration, and training are key to achieving the best out of it.

QUALITATIVE ANALYSIS: QUESTIONNAIRE SURVEY

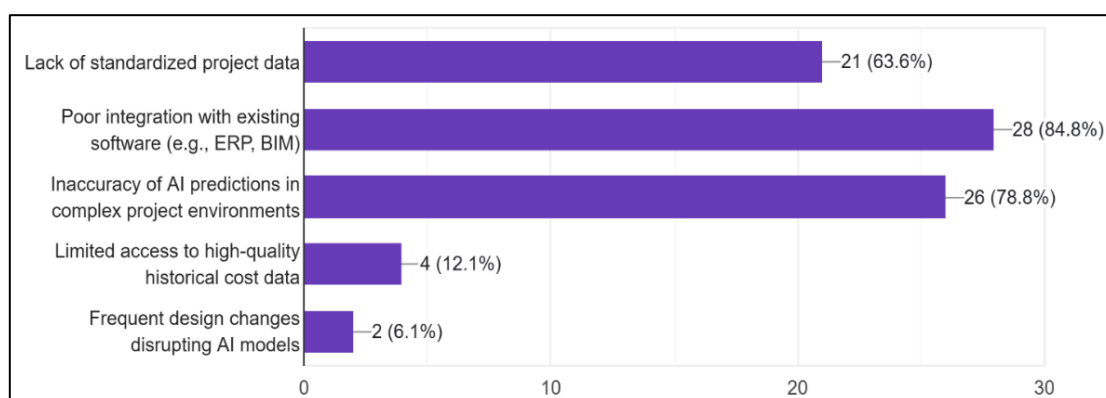


Figure 7: Chart representing designation of respondents.

Fig. 7 shows that 84.8% of the survey respondents identified poor interoperability with

BIM and ERP as the largest barrier to the adoption of AI. Other significant issues were the

limited accuracy of AI for intricate projects and uneven data. Fewer were a lack of historical cost data (12.1%) or design changes (6.1%). AI can

be used effectively with robust digital infrastructure, system integration, and adaptive models.

Biggest barrier in AI Adoption: Openness to receive training in AI, Trust in AI-generated Budget

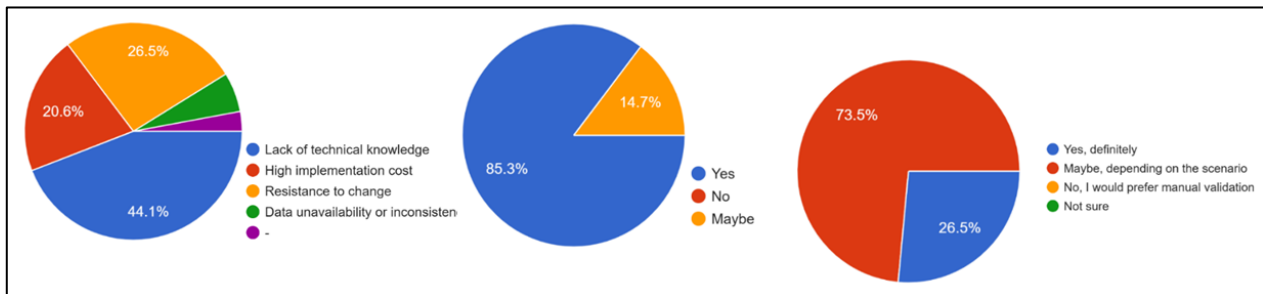


Figure 8: Chart representing the biggest barrier in AI Adoption, openness of organizations to receive training in AI, and trust in AI-generated budgets.

Fig. 8 pie chart shows that 44.1% of respondents have a lack of technical knowledge as their biggest barrier in AI adoption, highlighting the need for upskilling. Resistance to change (26.5%) and high implementation costs (20.6%) followed, with data inconsistency seen as lesser. This underscores that human and organizational factors are more than technical ones. Also, 85.3% of respondents support AI training, and

none rejected the idea outright, showing a strong willingness to upskill themselves. However, trust in AI remains constrained as 73.5% preferred AI-generated budgets with human oversight, while only 26.5% fully trusted AI alone. The findings support a hybrid model where AI assists, but human validation remains essential, reflecting the industry’s cautious but open approach to AI adoption.

External Challenges limiting the usage of AI, Critical data for AI-based tools

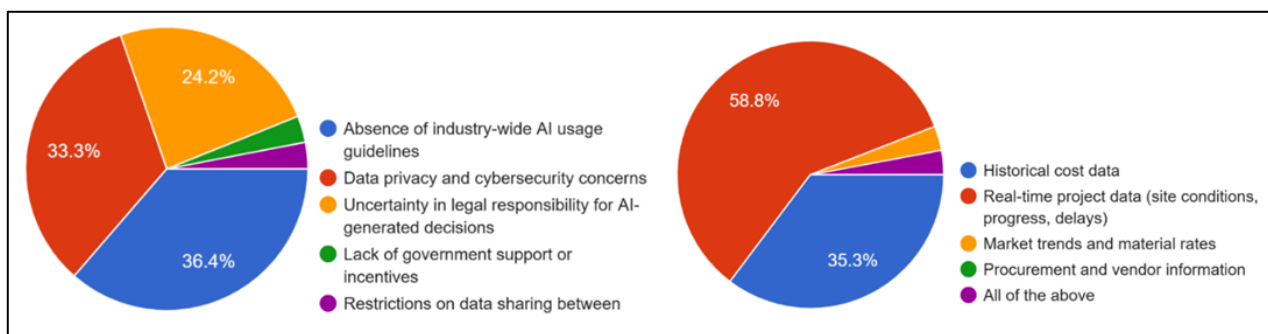


Figure 9: Chart showing external challenges limiting the use of AI and critical data for AI.

Fig. 9 demonstrates key external barriers to the adoption of AI and key information for AI construction cost management software. The main concern is the lack of industry-wide guidelines for AI usage (36.4%), legal uncertainty about decisions made by AI (33.3%), and data privacy (24.2%). Secondary issues are limited Government incentives and

data-sharing restrictions. For data, real-time project data (58.8%) is seen as most important to AI success, followed by historical cost data (35.3%). These findings emphasize the necessity of open regulatory environments, legal accountability, and strong real-time data systems to enable successful AI integration.

Case Study: Integrating AI into Cost Management at L&T’s Green Hydrogen Plant, Hazira, to Evaluate site-specific Barriers to Integrating AI

Table 4: Overview of project L&T’s Green Hydrogen Plant, Hazira (L & T [35]).

S. N.	Parameter	Details
1	Project Name	L&T Green Hydrogen Plant, Hazira
2	Location	A. M. Naik Heavy Engineering Complex, Hazira, Gujarat, India
3	Construction Start Date	January 2022
4	Commissioning Date	September 2022
5	Total Project Cost	₹25 Cr
6	Total Site Area	3,000 sqm
7	Built-up Area	6000 sqm
8	AI Tool Used	Insights NxT platform developed by Mindtree NxT
9	Production everyday	45 kilograms of high-purity (99.99%) green hydrogen daily.

Larsen & Toubro (L&T) embedded AI technologies at its Green Hydrogen Plant at Hazira, Gujarat, to drive cost management and operational efficiency, as shown in Table 4. The company used the Insights NxT platform and IoT systems to provide real-time monitoring, energy optimization, and predictive analytics in favour of cost-efficient, sustainable operations.

L&T Encountered Numerous Challenges While Implementing AI

- Fragmentation of data and system integration was a major obstacle, with civil, mechanical, and electrical data decentralized. AI had to have a common cost framework, which translated into aggregating heterogeneous datasets such as labour, procurement, and logistics.
- The variability of resources from variable availability of solar energy made cost allocation challenging. AI had to dynamically link energy consumption with hydrogen output to identify the correct costs per unit.
- Scarce historical data made AI training difficult since this was one of India’s initial green hydrogen projects. Initial predictions were not accurate because there were few benchmarks.
- Exorbitant deployment costs of IoT infrastructure and AI platforms placed a financial burden, even though future cost savings were the intention.
- Connectivity problems on the distant plant site resulted in real-time monitoring delays,

requiring edge computing.

- Cybersecurity issues cropped up when integrating AI into ERP systems, necessitating rigorous data protection protocols.
- Change management was critical, as the contractors were wary of AI tools. L&T needed to spend on training the workforce and digital preparedness.
- Nevertheless, the system facilitated: Less wastage (steel, cement, diesel), Real-time monitoring of budgets, Predictive maintenance to reduce downtime, and Better long-term cost projections.

CONCLUSION

Cost control is a big Indian construction challenge, driven by increasing project size, regulatory problems, and market volatility. Conventional standards like PMBOK bring discipline but are inefficient, with no ability to handle real-time problems and data-intensive processes. This research concludes that AI through predictive analytics, automation, and real-time monitoring has unprecedented potential. When Indian contexts are applied, AI improves estimation, budgeting, and expenditure control. Integration is, however, hindered by disparate data, legacy systems, human resource resistance, and capital-hungry costs. Above all, increasing awareness, government digitalization, and pilot projects signal increasing industry preparedness. A hybrid AI–PMBOK model is a potential solution.

Objective 1: Issues in cost management were recognized, ranging from poor estimation processes, outdated tracking practices, scope creep, and stakeholder mismanagement. The DLF Downtown case proves how delays in regulation and inadequate systems complicate matters further.

Objective 2: Identified AI techniques—Machine Learning, NLP, and Predictive Analytics—as being the most important in strengthening planning and forecasting.

Objective 3: Proved that the cost processes of PMBOK (Plan, Estimate, Budget, Control) can be enhanced with the aid of AI, specifically ML, RPA, and IoT.

Objective 4: Recognized barriers like limited AI skill and higher costs, while noting facilitators such as regulatory structures, modular resources, and training programs.

RECOMMENDATIONS AND FUTURE RESEARCH DIRECTIONS

- **AI Training and Curriculum Development:** Promote systematic AI literacy training in construction firms and integrate AI-driven cost management modules in civil engineering and project management courses to future-proof the industry workforce.
- **Standardized Procedures and Data Management:** Set national cost collection and storage standards to enable interoperability, improve data quality & enable training of AI models.
- **Compulsory Use of AI in Public Projects:** Adopt AI-based budgeting and tracking in government highway construction tenders to encourage sector-wide digital adoption.
- **Promote 5D-BIM and IoT Integration:** Use AI-driven BIM coupled with IoT for real-time cost tracking, visualization, and instant feedback on the go.
- **Apply NLP and Predictive Analytics:** Deploy NLP for contract risk analysis and ML for predicting fiscal impacts and contingency modelling.
- **Cross-disciplinary Change Management and Collaboration:** Create project manager,

engineers and data scientist teams with change management guidance to deploy AI.

- **Public-Private Partnerships:** Develop collaborations between universities, start-ups, and construction firms to develop low-cost, local AI solutions.
- **Support for SMEs:** Offer subsidies, tax relief, or interest-free loans to SMEs who invest in verified AI programmes or training modules.
- **Ethical and Legal Frameworks:** Ensure that AI deployment conforms to Indian data protection legislation and is transparent, particularly in public-sector use.

Future Scope of Study: Subsequent research can aim at formalizing a hybrid AI–PMBOK model, integrating AI into the other three PMBOK cost processes. Creating AI-driven decision-support systems for real-time budget simulation and risk alerting is another area. The intersection of AI and sustainability, like energy models and lifecycle costing, is promising. Further, policy-level studies need to align regulations with digital transformation and bring AI to SMEs through optimal business models and training strategies.

SUMMARY

The research investigates how artificial intelligence (AI) can resolve the long-standing construction cost management issues in India. Though frameworks such as PMBOK offer well-structured cost control procedures, they are often ineffective in managing real-time complexities, disparate data, and varying project variables. The study enumerated key problems like imprecise estimation, antiquated tracking systems, scope changes, and poor stakeholder coordination. These concerns cumulatively result in delays and cost overruns. Technologies based on AI, like machine learning (ML) and natural language processing (NLP), provide solutions by facilitating predictive forecasting, automated data analysis, and dynamic cost monitoring. A hybrid model was suggested, combining AI tools with PMBOK's four cost processes of plan, estimate, budget, and control costs. It upgrades every step with live insights, automation, and smart decision-making,

providing a proactive cost management approach. Despite challenges like high deployment expenses, restricted digital capabilities, and integration issues, the study reveals remarkable opportunities. National programs like Gati Shakti and Digital India facilitate the digitalization of the construction industry. To sum up, AI must be considered a strategic imperative for cost management in today's era. With appropriate training, resources, and policy initiation, AI has the potential to radically enhance cost efficiency, predictability, and project success in Indian construction.

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