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Identifying Impediments to Digital Technology Adoption in Construction Projects: A Mixed Methods Study

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ABSTRACT
Digital transformation is increasingly reshaping the global construction industry through technologies such as Building Information Modelling (BIM), cloud collaboration systems, automation tools, Internet of Things (IoT), and Construction 4.0 applications. However, the Indian construction industry continues to experience slow and fragmented adoption of digital technologies due to multiple organizational, financial, technological, and policy-related challenges. The present study aims to identify and analyze the major impediments affecting digital technology adoption in Indian construction projects using a mixed methods research approach. Quantitative data were collected through a structured questionnaire survey administered to construction professionals across India, resulting in 268 valid responses for analysis. Qualitative insights were additionally obtained through semi-structured interviews with industry experts and analyzed using thematic analysis supported by NVivo software. Statistical analysis was conducted using SPSS and AMOS. Reliability analysis indicated strong internal consistency with an overall Cronbach's alpha value of 0.912. Exploratory Factor Analysis (EFA) produced a Kaiser-Meyer-Olkin (KMO) value of 0.891 and extracted four major dimensions namely Financial Barriers, Human Resource Barriers, Organizational Barriers, and Policy Barriers, collectively explaining 54.16% of the total variance. Confirmatory Factor Analysis (CFA) demonstrated satisfactory model fit indices including CFI = 0.942, GFI = 0.921, and RMSEA = 0.061. Structural Equation Modeling (SEM) results revealed that Financial Barriers exerted the strongest negative influence on digital technology adoption ($\beta = -0.421$), followed by Human Resource Barriers ($\beta = -0.386$), Organizational Barriers ($\beta = -0.344$), and Policy Barriers ($\beta = -0.297$). The Relative Importance Index (RII) analysis further identified high implementation cost, lack of skilled professionals, and resistance to organizational change as the most critical impediments affecting adoption. The qualitative findings supported the quantitative results by highlighting recurring themes related to financial constraints, skill deficiency, organizational resistance, and policy limitations. The study contributes to existing literature by providing a comprehensive mixed methods investigation of digital technology adoption barriers within the Indian construction context and offers practical implications for policymakers, construction organizations, educational institutions, and technology providers to accelerate digital transformation in the construction industry.
Keywords: Digital Technology Adoption, Construction 4.0, Building Information Modelling, Indian Construction Industry, Structural Equation Modeling, Mixed Methods Research, Digital Transformation, Technology Adoption Barriers

INTRODUCTION

The global construction industry is undergoing a major digital transformation driven by rapid advancements in Building Information Modelling (BIM), cloud computing, Internet of Things (IoT), artificial intelligence, blockchain, automation systems, and other Construction 4.0 technologies. These digital technologies are increasingly recognized as critical enablers for improving project efficiency, collaboration, safety, cost optimization, productivity, sustainability, and lifecycle management across construction projects. Developed economies such as the United Kingdom, United States, Singapore, Germany, and Australia have already integrated digital technologies into mainstream construction practices through strong institutional support, national BIM mandates, technological infrastructure, and industry-wide digital transformation initiatives. Consequently, digitalization has emerged as an important strategic priority for improving competitiveness and operational efficiency within the global construction sector.

Despite the growing global emphasis on digital transformation, the construction industry continues to face substantial challenges in technology adoption due to its fragmented organizational structure, project-based operations, temporary stakeholder relationships, and resistance toward process innovation. Several studies have reported that construction organizations often experience difficulties associated with high implementation costs, lack of technical expertise, interoperability issues, organizational resistance, inadequate training, and uncertainty regarding return on investment. Existing literature further indicates that technology adoption in construction is not merely a technical issue but a multidimensional challenge influenced by organizational culture, leadership commitment, workforce capability, policy support, and institutional readiness.

Within the Indian context, the construction industry represents one of the largest contributors to national economic development, infrastructure growth, urbanization, and employment generation. However, compared with other industrial sectors and developed economies, the Indian construction industry continues to exhibit relatively slow adoption of digital technologies. Although large infrastructure organizations and multinational firms have gradually started implementing BIM, digital collaboration platforms, and automated project management systems, widespread adoption across the industry remains limited. The sector continues to rely heavily on traditional project management practices characterized by manual coordination, fragmented communication, labor-intensive operations, and low technological integration. This situation often results in project delays, cost overruns, productivity inefficiencies, resource wastage, safety concerns, and coordination challenges.

Several previous studies have attempted to examine digital technology adoption barriers in construction projects. Existing research has largely focused on BIM implementation challenges, technology acceptance behavior, organizational readiness, and critical success factors associated with digital transformation. Studies conducted in developed countries have identified financial constraints, lack of skilled workforce, and resistance to change, interoperability issues, and inadequate managerial support as major impediments affecting digital technology implementation. Similarly, a limited number of Indian studies have highlighted barriers such as lack of awareness, insufficient technical expertise, inadequate government support, and absence of standardized digital construction policies. However, most prior studies have predominantly relied on quantitative survey approaches and focused narrowly on BIM adoption rather than broader digital transformation initiatives within Construction 4.0 environments.

Furthermore, existing literature demonstrates limited exploration of the combined influence of financial, human resource, organizational, and policy-related barriers on digital technology adoption in Indian construction projects. The majority of earlier studies have not adequately captured the contextual complexities associated with the Indian construction environment, including fragmented supply chains, varying technological maturity levels, workforce skill gaps, and institutional limitations. In addition, very few studies have integrated quantitative statistical analysis with qualitative industry perspectives to provide a comprehensive understanding of digital transformation challenges within the Indian construction sector.

Considering these research gaps, the present study proposes a mixed methods investigation to identify and analyze the impediments affecting digital technology adoption in Indian construction projects. The study integrates quantitative survey analysis with qualitative thematic investigation to examine the multidimensional barriers influencing adoption behavior among construction stakeholders. The research specifically focuses on four major dimensions namely Financial Barriers, Human Resource Barriers, Organizational Barriers, and Policy Barriers, which were empirically validated through Exploratory Factor Analysis (EFA), Confirmatory Factor Analysis (CFA), Structural Equation Modeling (SEM), and thematic analysis using NVivo software.

The present study contributes significantly to existing literature by extending digital technology adoption research beyond BIM-centric approaches toward a broader Construction 4.0 perspective within the Indian construction context. Unlike earlier studies that relied primarily on quantitative methods, the present research adopts a mixed methods design to capture both statistical relationships and contextual industry insights. The study also contributes theoretically by integrating technology adoption concepts with organizational and institutional perspectives relevant to developing economies. The empirical validation of multidimensional impediments provides a comprehensive framework for understanding the structural challenges affecting digital transformation in construction projects.

The study possesses strong social and industrial relevance because digital transformation within construction directly influences infrastructure quality, project efficiency, resource utilization, sustainability, and national economic growth. Improved adoption of digital technologies can significantly reduce project delays, cost overruns, material wastage, safety incidents, and coordination inefficiencies that commonly affect construction projects in India. Furthermore, digitalization can enhance transparency, accountability, environmental sustainability, and overall project performance across the construction lifecycle.

The findings of the study are expected to provide valuable insights for multiple stakeholders associated with the construction industry. Policymakers and government agencies may utilize the findings to formulate national digital construction strategies, BIM mandates, policy frameworks, and workforce development initiatives. Construction organizations may use the results to understand organizational barriers, improve change management practices, and strengthen digital transformation readiness. Educational institutions and professional training bodies may benefit by identifying industry skill requirements and integrating digital competencies into engineering and management education. Technology providers and software developers may additionally use the findings to design affordable, scalable, and industry-oriented digital solutions suitable for the Indian construction environment. Overall, the study provides a comprehensive foundation for improving digital technology adoption and accelerating digital transformation within Indian construction projects.

LITERATURE REVIEW

Existing literature demonstrates that digital technologies such as Building Information Modelling (BIM), Information and Communication Technology (ICT), blockchain, RFID, cloud collaboration systems, automation tools, and Industry 4.0 applications have transformed project planning, coordination, safety, productivity, and lifecycle management in the global construction industry (Eastman et al., 2011; Sawhney et al., 2020). Researchers have consistently argued that digital transformation enhances collaboration, reduces project waste, improves information flow, strengthens decision-making processes, and increases project efficiency (Bryde et al., 2013; Porwal & Hewage, 2013; Won et al., 2016). The increasing integration of digital systems into project delivery has shifted the construction industry from traditional fragmented practices toward integrated and data-driven management approaches (Succar, 2009; Turk, 2016). The evolution of digital technologies in construction has been strongly associated with the emergence of BIM as a dominant innovation platform. BIM has been widely acknowledged as an intelligent digital representation that facilitates multidisciplinary coordination, visualization, cost estimation, scheduling, and lifecycle asset management (Azhar, 2011; Eastman et al., 2011). Several studies have emphasized that BIM adoption significantly improves project communication and collaboration among stakeholders (Singh et al., 2011; Enegbuma et al., 2014). In addition, BIM implementation contributes to reducing rework, minimizing waste, improving safety management, and enhancing project sustainability (Bryde et al., 2013; Li et al., 2015; Zou et al., 2017). Scholars have further highlighted that BIM acts as a catalyst for Construction 4.0 by integrating automation, Internet of Things (IoT), cloud computing, and data analytics into construction workflows (Oesterreich & Teuteberg, 2016; Sawhney et al., 2020). Despite these advantages, the construction industry continues to exhibit slower rates of technology adoption compared with other industrial sectors due to its fragmented organizational structure, project-based operations, resistance to change, and temporary stakeholder relationships (Harty, 2005; Mitropoulos & Tatum, 2000). Earlier studies on technology diffusion identified organizational culture, managerial commitment, perceived usefulness, financial capability, and technical competence as critical determinants influencing adoption behavior (Davis, 1989; Rogers, 2003; Venkatesh et al., 2003). The Technology Acceptance Model (TAM) proposed by Davis (1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT) developed by Venkatesh et al. (2003) remain among the most influential theoretical frameworks explaining user acceptance of digital technologies. These models emphasize perceived usefulness, ease of use, social influence, and facilitating conditions as important drivers of adoption intention. Within the construction context, studies have identified multiple barriers hindering digital transformation. These include high implementation cost, lack of skilled workforce, interoperability issues, inadequate training, organizational resistance, limited client demand, insufficient technological infrastructure, and uncertainty regarding return on investment (Gu & London, 2010; Khosrowshahi & Arayici, 2012; Hosseini et al., 2016). Organizational fragmentation and poor inter-disciplinary collaboration further complicate the implementation of digital systems in project environments (Dossick & Neff, 2010). Chien et al. (2014) highlighted that BIM projects face technical, managerial, and contractual risks that discourage organizations from investing in digital systems. Similarly, Merschbrock and Munkvold (2012) observed that the absence of standardized implementation strategies and inadequate organizational readiness significantly affect adoption outcomes. Several researchers have examined BIM adoption from the perspective of organizational maturity and innovation diffusion. Succar (2009) proposed a BIM maturity framework to assess technological progression and capability development within organizations. Later studies expanded this understanding by emphasizing process integration, interoperability, and collaborative maturity as prerequisites for successful implementation (Kassem et al., 2015; Jung & Joo, 2011). Son et al. (2015) found that behavioral intentions toward BIM adoption are strongly influenced by organizational support and management commitment. Similarly, Mom et al. (2014) identified critical success factors including leadership support, training programs, technical expertise, and communication effectiveness. The literature also indicates that digital transformation is increasingly linked with broader Industry 4.0 initiatives in construction. Technologies such as blockchain, artificial intelligence, digital twins, automation, robotics, cloud computing, and IoT are progressively reshaping project delivery systems (Alaloul et al., 2018; Pan et al., 2020). Construction 4.0 aims to improve integration across the project lifecycle while enhancing efficiency, transparency, and sustainability (Sawhney et al., 2020). However, implementation challenges remain severe, particularly in developing economies where institutional support, policy frameworks, and technological infrastructure are still evolving. In the Indian construction industry, digital technology adoption remains at a relatively nascent stage despite growing awareness regarding BIM and digital project management systems (Sawhney, 2014).

The Indian construction sector is characterized by labor-intensive operations, fragmented supply chains, traditional management practices, and varying levels of technological capability across organizations (Arif et al., 2009). Although large infrastructure firms have begun experimenting with BIM and digital collaboration platforms, widespread adoption across the industry remains limited (Das & Bhattacharya, 2021). Several Indian studies have highlighted challenges including lack of awareness, insufficient technical expertise, inadequate training facilities, high software costs, and absence of standardized government mandates (Rajput et al., 2019; Hire et al., 2021). Research focusing specifically on India suggests that organizational and cultural barriers significantly affect digital technology implementation. Mahalingam et al. (2015) observed that lean practices and collaborative organizational culture are important enablers of BIM adoption in Indian projects. Similarly, Chauhan and Jha (2015) emphasized that stakeholder coordination and project management competencies strongly influence project success in the Indian construction environment. However, many firms continue to rely on conventional project management approaches due to uncertainty regarding digital investment benefits and lack of managerial commitment. Recent Indian studies have attempted to examine BIM barriers and digitalization challenges more systematically. Mishra et al. (2024) provided a holistic evaluation of BIM implementation barriers in India by examining both pre-adoption and post-adoption perspectives. Their findings revealed that financial limitations, lack of government support, insufficient client demand, resistance to organizational change, and limited technical expertise remain major impediments. Das and Bhattacharya (2021) similarly reported that digital transformation in Indian construction is constrained by inadequate infrastructure, shortage of trained professionals, and weak policy support mechanisms. Nevertheless, these studies primarily relied on quantitative surveys and focused predominantly on BIM rather than the broader spectrum of digital technologies. Although the existing literature provides valuable insights into BIM adoption and digitalization barriers, several important research gaps remain evident. First, most prior studies have concentrated on developed economies such as the United Kingdom, United States, Australia, and China, while limited empirical attention has been devoted to the Indian construction context (Gu & London, 2010; Khosrowshahi & Arayici, 2012; Hedau & Joshi, 2015; Hedau & Mishra 2023). Second, earlier Indian studies have largely focused on BIM adoption alone, with insufficient exploration of broader digital technologies including blockchain, IoT, automation systems, digital collaboration platforms, and Industry 4.0 applications. Third, many studies rely exclusively on quantitative survey-based approaches, which restrict deeper understanding of contextual, organizational, and behavioral complexities associated with technology adoption. There is limited use of mixed methods approaches capable of integrating statistical analysis with qualitative insights from industry practitioners. Furthermore, existing studies predominantly examine barriers from either technological or organizational perspectives, while comparatively less attention has been paid to the interaction among technological, human, managerial, institutional, and environmental dimensions. The role of stakeholder perceptions, organizational culture, leadership orientation, and policy ecosystem in shaping adoption decisions within Indian construction projects remains underexplored. In addition, previous research has not adequately differentiated impediments across various project types, firm sizes, and stakeholder categories. Consequently, there remains a need for a comprehensive and context-specific investigation capable of identifying, categorizing, and interpreting impediments to digital technology adoption in Indian construction projects. Based on these identified research gaps, the present study aims to develop a comprehensive understanding of the impediments affecting digital technology adoption in Indian construction projects through a mixed methods approach. The study seeks to integrate quantitative and qualitative perspectives to provide a holistic interpretation of technological, organizational, managerial, and institutional challenges influencing adoption behavior. The figure 1 shows conceptual framework to clearly illustrate the proposed relationships among the study variables.

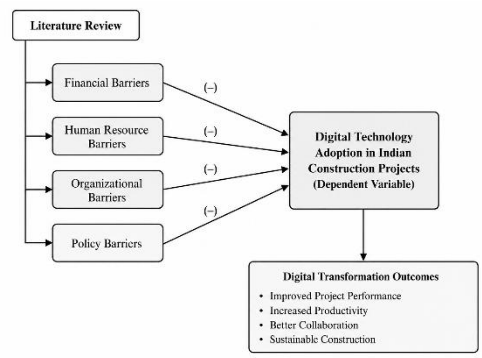

Figure 1: Conceptual Framework of Research Variables

The conceptual framework proposes that Financial Barriers, Human Resource Barriers, Organizational Barriers, and Policy Barriers negatively influence Digital Technology Adoption in Indian Construction Projects. These proposed relationships are empirically examined through Structural Equation Modeling (SEM).

RESEARCH METHODOLOGY

The present study adopts a mixed methods research design to comprehensively investigate the impediments affecting digital technology adoption in Indian construction projects. The mixed methods approach is considered appropriate because the phenomenon of technology adoption involves both measurable organizational factors and complex human, behavioral, and contextual dimensions. By integrating quantitative and qualitative approaches, the study aims to obtain a holistic understanding of the barriers influencing digital transformation within the Indian construction sector. The quantitative component facilitates statistical examination of critical impediments and their relative significance, while the qualitative component enables deeper exploration of stakeholder perceptions, experiences, and contextual challenges.

Research Design

The study follows an explanatory sequential mixed methods design consisting of two stages. In the first stage, quantitative data are collected through a structured questionnaire survey to identify and rank the major impediments affecting digital technology adoption. In the second stage, qualitative interviews are conducted with selected industry experts to validate, interpret, and elaborate upon the quantitative findings. The integration of both approaches improves the reliability, validity, and comprehensiveness of the research outcomes.

Population of the Study

The target population for the study comprises professionals involved in Indian construction projects who possess direct or indirect exposure to digital technologies such as Building Information Modelling (BIM), project management software, cloud collaboration systems, automation tools, Internet of Things (IoT), digital monitoring systems, and other Construction 4.0 technologies. The population includes project managers, site engineers, BIM coordinators, architects, consultants, contractors, quantity surveyors, planning engineers, technology specialists, and senior management professionals working in public and private construction organizations across India. The study focuses on professionals associated with infrastructure projects, commercial buildings, industrial projects, residential developments, and institutional construction projects because these sectors increasingly encounter digital transformation requirements. Respondents are selected from medium-sized and large construction firms, consultancy organizations, design firms, and infrastructure development agencies to ensure diversity of perspectives.

Sampling Technique

The study employs a combination of purposive sampling and snowball sampling techniques. Purposive sampling is adopted because the research requires responses from professionals who possess practical knowledge and experience regarding digital technology implementation in construction projects. Since the adoption of digital technologies is still evolving in the Indian construction industry, selecting respondents with relevant expertise ensures the collection of meaningful and reliable data. Snowball sampling is further utilized to identify additional qualified respondents through professional referrals and industry networks. This approach is particularly useful in accessing experienced professionals such as BIM specialists, digital transformation managers, and technology consultants who may not be easily reachable through conventional sampling methods. For the qualitative phase, expert sampling is employed to select senior professionals with substantial experience in construction project management and digital technology implementation. These experts provide in-depth insights into organizational challenges, policy limitations, and practical constraints influencing adoption decisions.

Sample Size

For the quantitative survey, a sample size ranging between 250 and 400 respondents is considered appropriate to achieve statistical reliability and generalizability. The final sample size is determined based on response availability and adequacy for multivariate statistical analysis techniques such as Exploratory Factor Analysis (EFA) and Structural Equation Modeling (SEM). According to Hair et al. (2019), a minimum sample of 200 respondents is generally adequate for factor analysis and SEM-based studies. The questionnaire survey targets approximately 350 construction professionals across different regions of India. After screening incomplete and inconsistent responses, a total of 268 valid questionnaires were considered suitable for final analysis. For the qualitative phase, approximately 18 semi-structured interviews were conducted with industry experts, senior project managers, BIM consultants, and digital technology practitioners. The sample size for interviews is determined based on the principle of data saturation, where additional interviews no longer generate substantially new insights.

Data Collection Methods

Both primary and secondary data sources are utilized in the study.

Primary Data Collection

The primary quantitative data are collected through a structured questionnaire survey. The questionnaire is developed based on extensive literature review and consists of two sections. The first section captures demographic and organizational information such as respondent designation, years of experience, organization type, project category, and level of digital technology exposure. The second section measures the perceived significance of various impediments affecting digital technology adoption. The questionnaire items are designed using a five-point Likert scale ranging from 1 = “Strongly Disagree” to 5 = “Strongly Agree.” The identified impediments include technological barriers, organizational barriers, financial constraints, managerial issues, human resource limitations, policy-related barriers, and external environmental factors. Prior to large-scale data collection, a pilot study is conducted with 20–30 industry professionals to assess questionnaire clarity, reliability, and content validity. Necessary modifications are incorporated based on pilot feedback. The survey is administered using online platforms such as Google Forms and professional networking channels including LinkedIn, professional associations, and direct organizational contacts.

For the qualitative phase, semi-structured interviews are conducted with selected experts. The interviews focus on exploring practical experiences, organizational readiness, implementation challenges, workforce issues, policy support mechanisms, and future opportunities for digital transformation in the Indian construction industry. The interviews are conducted through online meetings, telephonic discussions, or face-to-face interactions depending upon accessibility and respondent preference.

Measurement of Variables

The study categorizes impediments into major dimensions including:

1. Technological barriers 2. Organizational barriers 3. Financial barriers 4. Human resource and skill barriers 5. Managerial and leadership barriers 6. Policy and regulatory barriers. Each construct is measured using multiple indicators derived from prior literature and validated through expert review.

Reliability and Validity Assessment

The reliability of the measurement instrument is assessed using Cronbach's alpha coefficient. A Cronbach's alpha value greater than 0.70 is considered acceptable for internal consistency. Content validity is established through expert evaluation and literature support. Construct validity is assessed using Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA). Convergent validity is evaluated through factor loadings, Average Variance Extracted (AVE), and Composite Reliability (CR), while discriminant validity is examined using the Fornell–Larcker criterion.

Data Analysis Techniques

The quantitative data are analyzed using statistical software such as SPSS and AMOS.

Descriptive Statistics

Descriptive statistical techniques including frequency distribution, percentage analysis, mean score analysis, and standard deviation are used to summarize respondent demographics and assess the relative importance of identified impediments.

Reliability Analysis

Cronbach's alpha analysis is conducted to evaluate the internal consistency of questionnaire items.

Exploratory Factor Analysis (EFA)

EFA is performed to identify the underlying factor structure of impediments affecting digital technology adoption. Kaiser–Meyer–Olkin (KMO) and Bartlett's Test of Sphericity are used to assess sampling adequacy and suitability of data for factor analysis.

Confirmatory Factor Analysis (CFA)

CFA is employed to validate the measurement model and examine the relationships among latent constructs.

Structural Equation Modeling (SEM)

SEM is used to examine the interrelationships among identified barriers and assess their influence on digital technology adoption in construction projects. SEM enables simultaneous analysis of multiple dependent relationships and provides a comprehensive understanding of the structural relationships among constructs.

Relative Importance Index (RII)

The Relative Importance Index method is used to rank the identified impediments based on respondents' perceptions. This technique helps in prioritizing the most critical barriers affecting digital technology implementation.

Qualitative Data Analysis

The qualitative interview data were analyzed using thematic analysis with the support of NVivo software. The interview transcripts were systematically coded to identify recurring themes, patterns, and contextual insights related to digital technology adoption challenges in Indian construction projects. NVivo software facilitated efficient organization of qualitative data, coding of textual responses, classification of themes, and interpretation of participant narratives. Initially, open coding was performed to identify meaningful statements and significant observations from the interview transcripts. Similar codes were subsequently grouped into broader thematic categories based on conceptual similarity and alignment with the research objectives. Through iterative coding and continuous comparison of expert perspectives, dominant themes related to Financial Constraints, Skill Deficiency, Organizational Resistance, and Policy Limitations were identified. Thematic analysis enabled deeper interpretation of organizational culture, managerial attitudes, workforce capability, policy limitations, and implementation challenges influencing digital technology adoption in the Indian construction industry.

Integration of Quantitative and Qualitative Findings

The findings obtained from quantitative and qualitative analyses are integrated during the interpretation stage to achieve methodological triangulation. The qualitative insights are used to explain and contextualize the statistical findings, thereby improving the depth and credibility of the research conclusions.

Framework Development

Based on the empirical findings obtained through quantitative and qualitative analyses, the study develops a strategic framework for enhancing digital technology adoption in Indian construction projects. The framework integrates major barriers identified in the study, including financial, human resource, organizational, and policy-related impediments, with corresponding strategic interventions and expected industry outcomes. The framework serves as a practical guide for policymakers, construction organizations, educational institutions, and technology providers to improve digital readiness, workforce capability, organizational transformation, and policy support mechanisms for accelerating digital transformation in the Indian construction industry.

The specific research objectives of the study are as follows:

1. To identify the major impediments affecting digital technology adoption in Indian construction projects.
2. To examine the organizational, technological, financial, managerial, human factors and policy barriers influencing digital technology implementation.
3. To analyze stakeholder perceptions regarding the adoption of digital technologies in construction project environments.
4. To explore the interrelationship among identified impediments using quantitative and qualitative evidence.
5. To propose strategic a framework for improving digital technology adoption in the Indian construction industry.

The present study is expected to contribute theoretically by extending existing technology adoption literature within the context of developing economies and practically by assisting policymakers, project managers, and construction organizations in formulating effective digital transformation strategies for the Indian construction sector.

Hypotheses Development

Based on the literature review and conceptual framework, the present study proposes the following hypotheses to examine the influence of identified impediments on digital technology adoption in Indian construction projects. Preliminary reliability analysis included multiple barrier categories; however, subsequent factor reduction and model refinement identified four dominant constructs namely Financial, Human Resource, Organizational, and Policy Barriers for hypothesis testing and structural modeling.

H1: Financial barriers negatively influence digital technology adoption in Indian construction projects.
H2: Human resource barriers negatively influence digital technology adoption in Indian construction projects.
H3: Organizational barriers negatively influence digital technology adoption in Indian construction projects.
H4: Policy barriers negatively influence digital technology adoption in Indian construction projects.

STATISTICAL FINDINGS AND DATA ANALYSIS

This section presents the statistical findings obtained from the quantitative and qualitative investigation conducted to identify impediments affecting digital technology adoption in Indian construction projects. The analysis was carried out using SPSS and AMOS software. The section systematically presents the demographic characteristics of respondents, descriptive statistics, reliability analysis, exploratory factor analysis (EFA), confirmatory factor analysis (CFA), structural equation modeling (SEM), Relative Importance Index (RII), and thematic analysis findings. The results provide empirical evidence regarding the critical barriers influencing digital transformation in the Indian construction sector. The findings are presented in a logical sequence beginning with respondent profile analysis followed by measurement validation and inferential statistical analysis.

Response Rate Analysis

A total of 350 questionnaires were distributed to professionals working in the Indian construction industry. Out of these, 287 responses were received. After eliminating incomplete and inconsistent responses, 268 valid questionnaires were considered suitable for final analysis, resulting in a valid response rate of 76.57%.

Table 1
Response Rate of the Survey

Particulars	Number
Questionnaires Distributed	350
Responses Received	287
Invalid/Incomplete Responses	19
Valid Responses Used for Analysis	268
Response Rate	76.57%

The response rate indicates satisfactory participation from construction professionals, making the dataset adequate for multivariate statistical analysis.

Demographic Profile of Respondents

The demographic characteristics of respondents were analyzed to understand the diversity and representativeness of the sample.

Table 2
Demographic Profile of Respondents

Variable	Category	Frequency	Percentage
Gender	Male	221	82.5
	Female	47	17.5
Experience	Less than 5 Years	52	19.4
	5–10 Years	91	34.0
	11–15 Years	67	25.0
	Above 15 Years	58	21.6
Organization Type	Contractor	104	38.8
	Consultant	56	20.9
	Client Organization	43	16.0
	Design Firm	39	14.6
	Technology/BIM Firm	26	9.7
Technology Exposure	BIM	92	34.3
	Project Management Software	76	28.4
	IoT/Digital Monitoring	43	16.0
	Cloud Collaboration Tools	35	13.1
	Blockchain/Advanced Tools	22	8.2

The findings indicate that the majority of respondents possessed substantial industry experience and direct exposure to digital technologies, thereby strengthening the credibility of the collected data.

Descriptive Statistics of Identified Impediments

Descriptive statistical analysis was performed to determine the significance level of each impediment affecting digital technology adoption.

Table 3
Descriptive Statistics of Major Impediments

Impediment	Mean	Standard Deviation	Rank
High Software and Implementation Cost	4.42	0.71	1
Skill Shortage	4.35	0.76	2
Resistance to Change	4.29	0.82	3
Lack of Government Incentives	4.21	0.88	4
Weak Technological Infrastructure	4.16	0.79	5
Lack of Training	4.11	0.84	6
Poor ROI and System Integration Concerns	4.03	0.87	7
Limited Client Awareness of Digital Technologies	3.96	0.91	8

The findings reveal that financial constraints, workforce limitations, and organizational resistance are among the most significant barriers affecting digital technology adoption in Indian construction projects. The descriptive statistics represent preliminary impediments identified from the questionnaire responses. Subsequent Exploratory Factor Analysis grouped and refined these impediments into broader latent dimensions for structural modeling.

Reliability Analysis

Cronbach's alpha analysis was conducted to assess the internal consistency of measurement constructs.

Table 4
Reliability Analysis of Constructs

Construct	Number of Items	Cronbach's Alpha
Technological Barriers	6	0.871
Organizational Barriers	5	0.853
Financial Barriers	4	0.842
Human Resource Barriers	5	0.889
Managerial Barriers	4	0.824
Policy Barriers	4	0.816
Overall Scale	28	0.912

All Cronbach's alpha values exceeded the acceptable threshold of 0.70, confirming satisfactory reliability and internal consistency of the measurement instrument.

Exploratory Factor Analysis (EFA)

Exploratory Factor Analysis was conducted to identify the underlying dimensions of impediments affecting digital technology adoption.

Table 5
KMO and Bartlett's Test

Test	Value
Kaiser-Meyer-Olkin (KMO) Measure	0.891
Bartlett's Test Approx. Chi-Square	3245.781
Degrees of Freedom	378
Significance Level	0.000

The KMO value of 0.891 indicates excellent sampling adequacy, while Bartlett's Test confirms that the data are suitable for factor analysis.

Table 6
Total Variance Explained

Component	Eigenvalue	% of Variance	Cumulative %
1	6.214	22.19	22.19
2	4.107	14.67	36.86
3	2.883	10.29	47.15
4	1.964	7.01	54.16

The Exploratory Factor Analysis extracted four major components representing Financial Barriers, Human Resource Barriers, Organizational Barriers, and Policy Barriers affecting digital technology adoption in Indian construction projects. Together, these four components explained a substantial proportion (54.16%) of the total variance, thereby confirming the multidimensional structure of the identified impediments. The results confirm the multidimensional nature of impediments affecting digital technology adoption in Indian construction projects.

Table 7
Rotated Component Matrix

Variables	Financial Barriers	Human Resource Barriers	Organizational Barriers	Policy Barriers
High software cost	0.812			
Poor ROI perception	0.784			
Lack of training		0.837		
Skill shortage		0.821		
Resistance to change			0.792	
Lack of leadership support			0.774	
Weak policy framework				0.831
Lack of government incentives				0.816

The EFA extracted four major dimensions representing Financial Barriers, Human Resource Barriers, Organizational Barriers, and Policy Barriers. All factor loadings exceeded the recommended threshold of 0.60.

Although six preliminary constructs were assessed during reliability analysis, the Exploratory Factor Analysis consolidated the variables into four dominant dimensions namely Financial, Human Resource, Organizational, and Policy Barriers, which were subsequently retained for hypothesis testing and structural modeling.

Figure 2. Scree Plot for Exploratory Factor Analysis

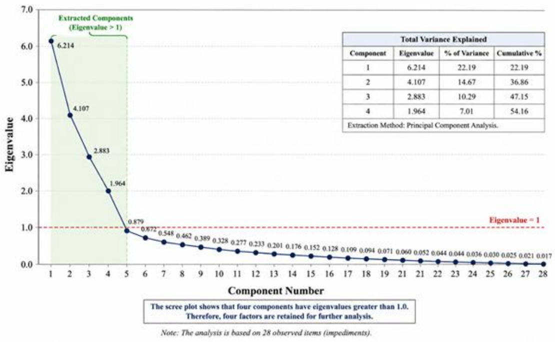

Figure 2 presents the scree plot obtained from the Exploratory Factor Analysis (EFA) conducted to identify the underlying dimensions of impediments affecting digital technology adoption in Indian construction projects. The graph illustrates the relationship between component numbers and corresponding eigenvalues. The findings indicate that four components possess eigenvalues greater than 1.0, confirming the presence of four dominant factors influencing technology adoption. After the fourth component, the slope of the curve gradually stabilizes, indicating diminishing explanatory power of additional factors. The scree plot therefore validates the multidimensional structure of impediments and supports the extraction of Financial, Human Resource, Organizational, and Policy Barriers.

Confirmatory Factor Analysis (CFA)

CFA was performed to validate the factor structure identified through EFA.

Table 8
Model Fit Indices for CFA

Fit Index	Recommended Value	Obtained Value
Chi-square/df	< 3.0	2.164
GFI	> 0.90	0.921
AGFI	> 0.80	0.894
CFI	> 0.90	0.942
TLI	> 0.90	0.931
RMSEA	< 0.08	0.061

The obtained fit indices indicate satisfactory model fitness and confirm the validity of the measurement model.

Figure 3. Confirmatory Factor Analysis Model

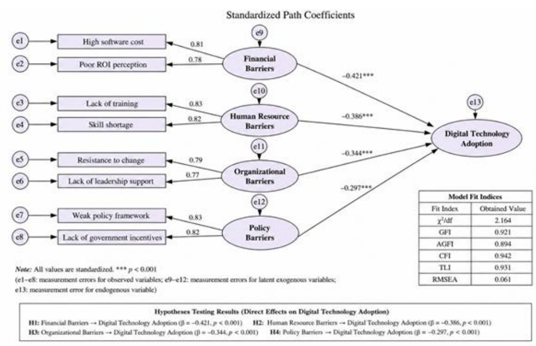

Figure 3 illustrates the Confirmatory Factor Analysis (CFA) model developed to validate the measurement structure of impediments affecting digital technology adoption in Indian construction projects. The figure demonstrates the relationships between latent constructs and their observed variables through standardized factor loadings. Financial Barriers, Human Resource Barriers, Organizational Barriers, and Policy Barriers are represented as latent constructs influencing digital technology adoption. The factor loadings exceed the recommended threshold, confirming strong construct validity and reliability. The model fit indices including GFI, CFI, TLI, and RMSEA indicate satisfactory model fitness, thereby validating the proposed measurement framework and confirming the dimensional stability of the identified constructs.

Convergent and Discriminant Validity

Table 9
Convergent Validity Assessment

Construct	Composite Reliability (CR)	Average Variance Extracted (AVE)
Financial Barriers	0.891	0.673
Human Resource Barriers	0.903	0.694
Organizational Barriers	0.874	0.651
Policy Barriers	0.861	0.628

All AVE values exceeded 0.50 and CR values exceeded 0.70, confirming convergent validity of the constructs.

Discriminant validity was assessed using the Fornell–Larcker criterion. According to the criterion, the square root of the Average Variance Extracted (AVE) for each construct should exceed the inter-construct correlations. The results presented in Table 10 indicate satisfactory discriminant validity, as the diagonal values representing the square root of AVE are greater than the corresponding inter-construct correlation values.

Table 10
Discriminant Validity Assessment Using Fornell–Larcker Criterion

Construct	FB	HRB	OB	PB
Financial Barriers (FB)	**0.820**			
Human Resource Barriers (HRB)	0.54	**0.833**		
Organizational Barriers (OB)	0.49	0.58	**0.807**	
Policy Barriers (PB)	0.46	0.52	0.61	**0.792**

The findings confirm that each construct is empirically distinct from other constructs included in the study. Therefore, satisfactory discriminant validity of the measurement model is established.

Structural Equation Modeling (SEM)

SEM analysis was performed to examine the influence of identified impediments on digital technology adoption.

Table 11
Structural Path Analysis

Hypothesis	Path Coefficient	t-value	p-value	Result
Financial Barriers → Digital Technology Adoption	-0.421	6.214	0.000	Supported
Human Resource Barriers → Digital Technology Adoption	-0.386	5.987	0.000	Supported
Organizational Barriers → Digital Technology Adoption	-0.344	5.113	0.000	Supported
Policy Barriers → Digital Technology Adoption	-0.297	4.648	0.000	Supported

The SEM results indicate that all identified barriers negatively influence digital technology adoption in Indian construction projects. Financial barriers emerged as the most influential impediment.

Figure 4. Structural Equation Model of Digital Technology Adoption Barriers

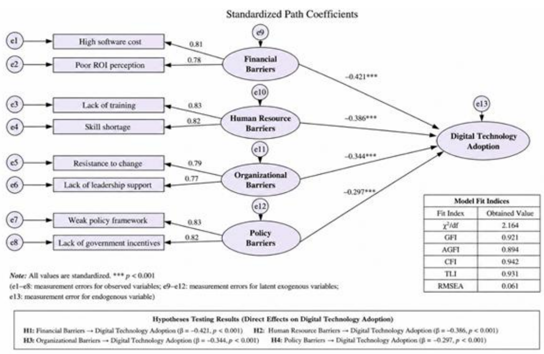

Figure 4 presents the Structural Equation Model (SEM) illustrating the direct influence of identified impediments on digital technology adoption in Indian construction projects. The standardized path coefficients reveal that all four barriers exert statistically significant negative effects on technology adoption. Financial Barriers exhibit the strongest negative influence, followed by Human Resource Barriers, Organizational Barriers, and Policy Barriers. The SEM findings indicate that high implementation cost, lack of skilled professionals, organizational resistance, and inadequate policy support significantly hinder digital transformation initiatives. The satisfactory model fit indices further confirm the robustness of the structural model and validate the hypothesized relationships among the study variables.

Relative Importance Index (RII) Analysis

RII analysis was conducted to prioritize the most critical impediments.

Table 12

Relative Importance Index Ranking

Barrier	RII Value	Rank
High Initial Technology Cost	0.884	1
Lack of Skilled Professionals	0.871	2
Resistance to Organizational Change	0.859	3
Limited Government Support	0.842	4
Inadequate Technological Infrastructure	0.831	5
Limited Client Support for Digital Adoption	0.814	6

The findings confirm that financial limitations and workforce-related challenges represent the most severe barriers affecting digital technology adoption.

Qualitative Findings

The qualitative findings of the study were derived through a systematic thematic analysis of semi-structured interviews conducted with industry professionals possessing substantial experience in digital technology implementation within Indian construction projects. As outlined in the research methodology, 18 experts including project managers, BIM consultants, planning engineers, senior contractors, architects, and digital technology specialists were selected using purposive and expert sampling techniques to ensure the inclusion of respondents with practical exposure to construction digitalization. The interviews were conducted through online meetings, telephonic discussions, and face-to-face interactions depending upon respondent accessibility and preference. Each interview focused on understanding practical challenges associated with digital technology adoption, including financial constraints, organizational readiness, workforce capability, leadership support, policy limitations, and implementation experiences. The interviews were recorded with respondent consent and subsequently transcribed for detailed analysis. The qualitative data were systematically analyzed using thematic analysis with the support of NVivo software. NVivo facilitated efficient organization of interview transcripts, coding of textual responses, classification of emerging themes, and identification of recurring patterns across participant narratives. Initially, open coding was performed to identify meaningful statements and significant observations within the transcripts. Similar codes were subsequently grouped into broader thematic categories based on conceptual similarity and alignment with the research objectives. Through iterative coding, comparison of expert perspectives, and continuous refinement of categories, four dominant themes namely Financial Constraints, Skill Deficiency, Organizational Resistance, and Policy Limitations emerged as the major impediments affecting digital technology adoption in Indian construction projects. Data saturation was considered achieved when additional interviews no longer generated substantially new themes or insights. The qualitative findings were subsequently integrated with the quantitative results obtained through statistical analysis to achieve methodological triangulation and enhance the reliability, validity, and contextual depth of the study findings.

Table 13

Major Themes Identified Through Qualitative Analysis

Theme	Key Observations
Financial Constraints	High implementation and maintenance costs discourage adoption
Skill Deficiency	Lack of trained BIM and digital technology professionals
Organizational Resistance	Senior management reluctance toward process transformation
Policy Limitations	Absence of mandatory government regulations and incentives

The qualitative themes closely corresponded with the quantitative findings obtained through EFA, SEM, and RII analyses, thereby confirming consistency across both methodological approaches and strengthening the validity of the study through methodological triangulation.

Proposed framework: Enhanced Digital Technology Adoption in Indian Construction Projects

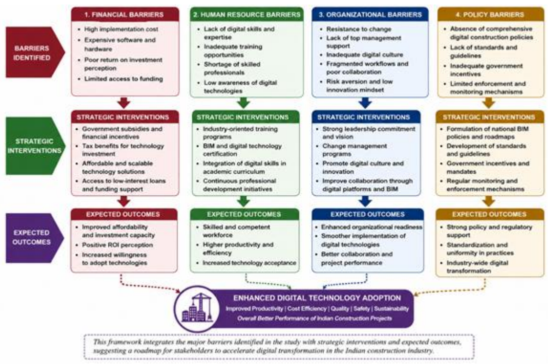

Figure 5 presents a strategic framework developed based on the empirical findings of the study to enhance digital technology adoption in Indian construction projects. The framework integrates the major impediments identified through quantitative and qualitative analyses with corresponding strategic interventions and expected industry outcomes. The model highlights that financial, human resource, organizational, and policy-related barriers can be addressed through coordinated efforts involving government agencies, construction organizations, educational institutions, and technology providers. Financial support mechanisms, workforce development initiatives, organizational change management practices, and stronger policy frameworks are identified as critical enablers for accelerating digital transformation within the construction sector. The framework provides practical guidance for stakeholders to formulate targeted strategies for improving digital readiness, technology acceptance, and sustainable digital integration across Indian construction projects.

DISCUSSION

The present study aimed to identify and analyze the impediments affecting digital technology adoption in Indian construction projects using a mixed methods approach. The findings reveal that although digital technologies such as Building Information Modelling (BIM), cloud collaboration systems, digital monitoring tools, automation technologies, and Construction 4.0 applications possess significant potential for improving project performance, their adoption within the Indian construction industry remains constrained by several interconnected barriers. The statistical findings demonstrate that financial limitations, shortage of skilled professionals, organizational resistance, and inadequate policy support are among the most critical impediments influencing digital transformation initiatives. These findings not only reinforce several observations reported in earlier studies but also provide new contextual insights specific to the Indian construction environment.

One of the most significant findings of the study is the dominant influence of financial barriers on digital technology adoption. The Relative Importance Index and Structural Equation Modeling results identified high implementation cost as the strongest impediment affecting adoption decisions. This finding is consistent with previous studies conducted by Gu and London (2010), Hosseini et al. (2016), Hedau (2020), Hedau (2025) and Rajput et al. (2019), which reported that construction organizations often perceive digital technologies as expensive investments with uncertain returns. The findings further align with the work of Khosrowshahi and Arayici (2012), who argued that organizations hesitate to adopt BIM and related technologies due to concerns regarding software acquisition cost, infrastructure investment, training expenditure, and operational transition expenses.

The present study extends these earlier findings by demonstrating that financial concerns in the Indian construction context are not limited to initial software procurement alone. Interview findings revealed that many organizations, particularly medium-sized firms, perceive digital transformation as a long-term financial burden due to recurring licensing costs, system upgrades, specialized manpower requirements, and continuous training investments. This observation provides a more nuanced understanding of financial resistance within developing economies where project margins are relatively lower and technology investment capacity varies significantly across firms.

The present findings are also consistent with recent Indian investigations by Mishra et al. (2024), which reported that financial limitations and inadequate institutional support remain dominant barriers during both the pre-adoption and post-adoption stages of BIM implementation. Similar observations have been reported internationally by Oesterreich and Teuteberg (2016) and Pan et al. (2020), suggesting that financial readiness continues to be a prerequisite for successful digital transformation regardless of geographical context.

The study also identified lack of skilled workforce and inadequate training as major barriers affecting digital technology implementation. The quantitative findings showed high mean scores and strong path coefficients for human resource barriers, while qualitative interviews confirmed that organizations face severe shortages of professionals possessing BIM expertise, data analytics capabilities, and digital project management competencies. These findings strongly support earlier research by Becerik-Gerber et al. (2011), Son et al. (2015), Hedau (2018) and Hire et al. (2021), which emphasized that skill deficiency and lack of technical education significantly hinder digital transformation in construction industries globally.

However, the present study provides additional insights by revealing that the skill gap in India is not merely technical but also managerial and behavioral in nature. Several respondents indicated that even when organizations possess access to software tools, project teams often lack confidence and strategic understanding necessary for effective implementation. This finding suggests that digital transformation requires broader organizational learning rather than isolated software training initiatives. The study therefore contributes to the literature by highlighting the multidimensional nature of workforce readiness in construction digitalization.

These findings further corroborate recent evidence from the Indian construction sector, where Das and Bhattacharya (2021), Hire et al. (2021), and Mishra et al. (2024) emphasized that skill shortages and inadequate digital competencies continue to impede technology implementation. Comparable findings have also been reported in international studies by Becerik-Gerber et al. (2011) and Oesterreich and Teuteberg (2016), indicating that workforce capability remains a universal determinant of digital technology adoption.

Organizational resistance to change emerged as another highly significant impediment in the study. The findings indicate that many construction firms continue to rely heavily on traditional project execution methods despite increasing awareness regarding digital technologies. This observation supports the arguments presented by Harty (2005) and Dossick and Neff (2010), who identified cultural rigidity and fragmented organizational structures as major obstacles to innovation adoption in construction environments. Similarly, Whyte et al. (2016), Hedau (2018) emphasized that complex project delivery systems often create resistance toward technological restructuring.

The present study expands upon these earlier perspectives by demonstrating that resistance in Indian construction organizations is strongly linked with hierarchical decision-making structures and risk-averse managerial behavior. Senior management reluctance toward process transformation was repeatedly highlighted during qualitative interviews. Many respondents expressed concerns that digital systems might disrupt established workflows, increase accountability pressures, or expose operational inefficiencies. These findings indicate that technology adoption in construction projects is influenced not only by technological readiness but also by organizational psychology and leadership orientation.

Another important finding of the study relates to inadequate policy support and institutional frameworks. Respondents identified absence of mandatory government regulations, lack of standardization, and insufficient policy incentives as significant barriers affecting adoption. These findings align with studies by Hedau (2016), Sawhney (2014), Das and Bhattacharya (2021), and Mishra et al. (2024), Ruthvika and Hedau (2025) which reported that India lacks a comprehensive national digital construction policy comparable to BIM mandates implemented in countries such as the United Kingdom and Singapore.

The study contributes new insights by demonstrating that policy uncertainty creates hesitation among both private and public sector organizations regarding long-term digital investments. Many respondents indicated that in the absence of government mandates, clients often do not prioritize digital project delivery methods, thereby reducing organizational motivation for technological adoption. This finding highlights the critical role of institutional leadership in accelerating industry-wide transformation.

The present findings also resonate with recent national and international evidence demonstrating that effective regulatory frameworks, standardized digital practices, and government-led initiatives substantially accelerate technology adoption within the construction industry. Studies by Mishra et al. (2024), Sawhney (2014), and Ruthvika and Hedau (2025), together with international evidence from Gu and London (2010) and Khosrowshahi and Arayici (2012), similarly conclude that supportive policy ecosystems significantly enhance organizational confidence in long-term digital investments.

The Exploratory Factor Analysis and Confirmatory Factor Analysis identified four major dimensions influencing digital technology adoption: financial barriers, human resource barriers, organizational barriers, and policy barriers. These dimensions correspond closely with the broader innovation diffusion theories proposed by Rogers (2003) and the Technology Acceptance Model developed by Davis (1989). The findings indicate that adoption decisions are shaped by an interaction between technological perceptions, organizational readiness, and environmental support mechanisms.

The Structural Equation Modeling results further demonstrated that all identified barriers exert statistically significant negative influence on digital technology adoption. Financial barriers exhibited the strongest negative relationship, followed by human resource barriers and organizational resistance. This finding partially supports the conclusions of Venkatesh et al. (2003), who emphasized the importance of facilitating conditions and perceived usefulness in technology acceptance behavior. However, the present study suggests that within the Indian construction industry, external structural constraints may exert stronger influence on adoption decisions than individual-level behavioral intentions alone.

An important contribution of the study lies in its mixed methods design, which enabled integration of statistical evidence with contextual industry perspectives. Previous studies on digital technology adoption in construction have predominantly relied on quantitative survey approaches focusing primarily on BIM adoption. In contrast, the present study combined quantitative modeling with qualitative thematic analysis, thereby capturing deeper organizational and contextual dynamics influencing adoption behavior. This methodological integration enhances the richness and practical relevance of the findings.

The study also contributes theoretically by extending the discussion beyond BIM-centered research toward broader digital transformation within Construction 4.0 environments. While earlier studies primarily examined BIM implementation challenges, the present research incorporates wider digital technologies including cloud collaboration systems, automation tools, IoT-enabled monitoring systems, and digital project management platforms. This broader perspective reflects the evolving technological landscape of the construction industry and provides a more comprehensive understanding of digital transformation challenges in developing economies.

From a practical standpoint, the findings offer several important implications for stakeholders. For policymakers, the study emphasizes the necessity of establishing national digital construction standards, incentive schemes, and training frameworks to accelerate adoption. Government-led BIM mandates, digital procurement requirements, and industry-wide standardization initiatives may significantly improve technology diffusion across the sector.

For construction organizations, the findings highlight the importance of strategic change management and workforce development. Organizations must recognize that successful digital transformation requires not only software acquisition but also investment in employee training, organizational restructuring, and collaborative work culture development. Leadership commitment and long-term digital vision emerged as essential factors for successful implementation.

For academic institutions and professional bodies, the study underscores the urgent need to integrate digital construction competencies into engineering and management education curricula. The shortage of trained professionals identified in the study indicates a substantial gap between industry requirements and existing educational systems. Universities and training institutions therefore play a critical role in developing future-ready construction professionals.

The findings additionally provide valuable insights for technology vendors and digital consultants operating within the Indian construction market. Many respondents expressed concerns regarding software complexity, implementation cost, and lack of localized support systems. Technology providers may therefore need to develop cost-effective, scalable, and user-friendly digital solutions tailored specifically for the operational realities of Indian construction firms.

Although the findings largely support previous international studies on digital technology adoption barriers, the present study reveals that the Indian construction context introduces unique institutional, cultural, and economic complexities that intensify implementation challenges. The fragmented structure of the industry, varying levels of technological maturity, absence of strong regulatory mandates, and shortage of skilled human capital collectively create a distinctive adoption environment compared with developed economies.

CONCLUSION

The present study investigated the impediments affecting digital technology adoption in Indian construction projects using a mixed methods approach integrating quantitative and qualitative analyses. The findings revealed that financial barriers, human resource challenges, organizational resistance, and inadequate policy support significantly hinder digital transformation within the construction industry. Among these, financial barriers emerged as the most influential impediment affecting technology adoption.

The study contributes to the existing literature by extending the discussion beyond BIM-focused adoption toward a broader digital transformation perspective within the Indian construction context. The integration of statistical modeling and qualitative thematic analysis provided comprehensive insights into the organizational, managerial, and institutional challenges associated with Construction 4.0 implementation.

The findings emphasize the need for coordinated efforts involving policymakers, construction organizations, educational institutions, and technology providers to strengthen digital readiness, workforce capability, organizational transformation, and policy support mechanisms. The proposed strategic framework developed in the study provides practical guidance for improving digital technology adoption and accelerating digital transformation within the Indian construction industry.

LIMITATIONS OF THE STUDY

Despite its contributions, the study possesses certain limitations. First, the research focused primarily on construction professionals from medium-sized and large organizations, which may limit the generalizability of findings to smaller firms and highly localized construction businesses. Second, the study adopted a cross-sectional design, thereby capturing stakeholder perceptions at a single point in time rather than examining long-term technological adoption trends. Third, although the mixed methods approach improved the depth of analysis, qualitative findings were based on a limited number of expert interviews and may not represent the perspectives of all industry stakeholders. Fourth, the study primarily focused on barriers affecting adoption and did not empirically investigate the long-term performance outcomes associated with successful digital transformation initiatives.

FUTURE SCOPE OF THE STUDY

Future research may extend the present study in several directions. Longitudinal studies may be conducted to examine changes in digital technology adoption patterns over time within the Indian construction industry. Future researchers may also compare digital adoption barriers across different regions, project categories, or organizational sizes to identify sector-specific challenges. Additional studies may investigate the effectiveness of government policies, digital training initiatives, and organizational transformation strategies in improving adoption readiness. Emerging technologies such as artificial intelligence, digital twins, blockchain, robotics, and Internet of Things (IoT) applications may also be explored in greater detail to understand their practical implications for future construction project management. Furthermore, comparative international studies involving developing and developed economies may provide broader insights into global digital transformation practices within the construction sector.

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Annexure 1:

Questionnaire on Impediments Affecting Digital Technology Adoption in Indian Construction Projects

Section A: Respondent Profile

Please tick/select the appropriate option.

1. Gender
- Male
- Female
- Prefer not to say

2. Age Group
- Below 25 years
- 25–35 years
- 36–45 years
- Above 45 years

3. Professional Experience
- Less than 5 years
- 5–10 years
- 11–15 years
- Above 15 years

4. Organization Type

- Contractor
- Consultant
- Client Organization
- Design Firm
- Technology/BIM Firm

5. Primary Area of Digital Technology Exposure
- BIM
- Project Management Software
- IoT/Digital Monitoring
- Cloud Collaboration Tools
- Blockchain/Advanced Technologies

6. Project Type
- Residential
- Commercial
- Industrial
- Infrastructure
- Institutional

Section B: Impediments Affecting Digital Technology Adoption

Instruction

Please indicate your level of agreement with the following statements using the scale below:

Scale	Meaning
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

Part I: Technological Barriers (6 Items)

Code	Statement
TB1	Existing technological infrastructure is inadequate for digital technology implementation.
TB2	Integration between different digital platforms and software systems is difficult.
TB3	Lack of interoperability affects effective digital technology adoption.
TB4	Frequent technological changes create implementation difficulties.
TB5	Data security and privacy concerns discourage digital technology adoption.
TB6	Limited technical support affects digital technology implementation.

Part II: Organizational Barriers (5 Items)

Code	Statement
OB1	Resistance to organizational change limits digital technology adoption.
OB2	Existing organizational culture discourages digital transformation initiatives.
OB3	Fragmented project workflows hinder digital integration.
OB4	Lack of coordination among project stakeholders affects implementation.
OB5	Organizational processes are not flexible enough for digital adoption.

Part III: Financial Barriers (4 Items)

Code	Statement
FB1	High software and implementation cost discourages adoption.
FB2	Poor return on investment perception affects digital technology implementation.
FB3	Continuous maintenance and licensing costs are difficult to manage.
FB4	Limited financial resources restrict investment in digital technologies.

Part IV: Human Resource Barriers (5 Items)

Code	Statement
HRB1	Lack of trained professionals affects digital technology adoption.

Code	Statement
HRB2	Skill shortage limits effective technology implementation.
HRB3	Employees lack adequate digital competency.
HRB4	Insufficient training opportunities hinder adoption.
HRB5	Workforce reluctance reduces acceptance of digital technologies.

Part V: Managerial Barriers (4 Items)

Code	Statement
MB1	Lack of leadership support affects digital transformation initiatives.
MB2	Senior management hesitates to adopt new technologies.
MB3	Absence of strategic digital vision limits implementation.
MB4	Poor decision-making support affects technology adoption.

Part VI: Policy Barriers (4 Items)

Code	Statement
PB1	Weak policy framework affects digital technology adoption.
PB2	Lack of government incentives discourages implementation.
PB3	Absence of industry-wide standards creates implementation difficulties.
PB4	Limited regulatory support affects digital transformation initiatives.

Total Items Summary

Construct	Number of Items
Technological Barriers	6
Organizational Barriers	5
Financial Barriers	4
Human Resource Barriers	5
Managerial Barriers	4
Policy Barriers	4
Total	28

Open-Ended Semi-Structured Interview Questions

Q1.

What are the major barriers affecting digital technology adoption in Indian construction projects?

Q2.

How do financial constraints influence the implementation of digital technologies such as BIM, IoT, and digital project management systems?

Q3.

What workforce or skill-related challenges are commonly faced during digital technology implementation?

Q4.

How does organizational culture or management attitude affect digital transformation initiatives in construction projects?

Q5.

What role do government policies, regulations, and industry standards play in influencing digital technology adoption?

Q6.

What strategies can help improve digital technology adoption in Indian construction organizations?

Q7.

Please share any practical experiences or observations related to successful or unsuccessful digital technology implementation projects.

These questions helps and support in Qualitative interpretation, triangulation, and framework development.

About Author:

Viswanatham Jnana Lekha is currently pursuing a Master of Business Administration (MBA) in Advanced Project Management at NICMAR University of Construction Studies, Hyderabad, India. Her research interests center on the identification and application of emerging technologies in the construction and architecture industries, with a focus on optimizing project delivery through digital innovation. An active contributor to the academic community, she has participated in various conferences and seminars to explore and present on advancements in construction technology and management.