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Analysing Factors Affecting Implementation of Automated Construction Progress Monitoring in Indian Construction Industry

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***Abstract:** Automated construction progress monitoring has evolved as a critical element in modern construction projects, increasing efficiency and decision-making processes. It has gained recognition as a revolutionary technology in the global construction industry. However, its successful implementation in India presents distinct problems driven by a variety of factors such as technological challenges, financial restrictions, a shortage of qualified labour, resistance to technology adoption, a high initial investment, and so on. This research explores the importance of automated construction progress monitoring, examines the factors that influence its adoption, and makes recommendations for its implementation in the Indian construction industry. By recognising these variables, construction stakeholders can better negotiate the hurdles and reap the benefits of automated monitoring technology.*

***Keywords:** Automated Construction Progress Monitoring, Real-Time Monitoring, Implementation Challenges, Technology Adoption, Indian Construction Industry, Construction Project Management*

I. INTRODUCTION

In India, the construction sector, which plays a major role in employment, infrastructure development, and economic growth, has experienced both remarkable growth and persistent difficulties. But historically, this industry has been growing with inefficiencies, delays, and cost overruns, which has prompted research into exploration of innovative technologies to deal with these issues. Construction projects are notorious for their inefficiencies, overruns, and delays [2][16]. Using automated construction progress monitoring has become popular as a game-changing solution to these issues. Project managers and other stakeholders can now gather, analyse, and report data in real-time, giving them the information, they need to make well-informed decisions.

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Traditional methods of construction progress monitoring, which frequently rely on manual data gathering and subjective assessments, have shortcomings that obstruct successful project management. These constraints include data collecting delays, errors, and a lack of real-time project performance information. In response to these issues, automated construction progress monitoring evolved as a disruptive solution [4][13].

Automated construction progress monitoring includes integrating many technologies to acquire, process, and analyse data linked to construction activities in real time. These technologies work together to give useful information about the progress, quality, and safety of construction projects [5]. The key technologies used in automated construction progress monitoring are:

- **GPS (Global Positioning System):** This technology is used to track the location of construction equipment and vehicles. It gives real-time data on the movement and positioning of equipment on the construction site.
- **Laser Scanners:** Laser scanning technology captures detailed 3D representations of construction sites, enabling for precise measurements, as-built documentation, and quality control checks.
- **Drones (Unmanned Aerial Vehicles, or UAVs):** Drones with cameras and sensors are used for aerial surveying and monitoring. They take photographs, videos, and data from a variety of perspectives, offering a complete view of the construction site.
- **Cameras and Video Surveillance:** Surveillance cameras are used to monitor construction activities and collect visual data. This technology helps with site security, project progress documentation, and safety monitoring.
- **Data Analytics Software:** Sensor data is processed and analysed using advanced software and algorithms. Data analytics facilitates the creation of reports, the visualisation of project progress, and the detection of patterns or anomalies.
- **Mobile Apps:** Mobile applications allow project managers and stakeholders to remotely access real-time data and reports, allowing for more timely decision-making and communication.
- **IoT (Internet of Things):** IoT technology connects numerous sensors and gadgets on construction sites to the internet, enabling real-time data sharing and remote control of equipment.

- **Building Information Modeling (BIM):** BIM technology allows for the creation of digital models that depict the complete construction process. BIM can be combined with monitoring systems to compare the as-designed model to the as-built structure in order to control quality and track progress.
- **Augmented Reality (AR) and Virtual Reality (VR):** These technologies offer immersive experiences for project visualisation and decision-making. They allow stakeholders to virtually navigate construction projects and detect potential difficulties.
- **Machine Learning and Artificial Intelligence (AI):** Machine learning and AI algorithms can be used to analyse massive datasets, forecast project delays, improve resource allocation, and detect patterns in construction data.

These technologies when integrated correctly, automated construction progress monitoring systems can provide real-time insights, improve project control, decision-making, productivity, and site safety. The technologies employed may vary depending on the unique needs and size of the construction project.

Automated construction progress monitoring comprises the use of numerous sensors, data analytics tools, and information technologies to continually gather, process, and analyse data linked to construction activities. This method provides real-time visibility into the status, quality, and safety of construction projects. By doing so, it provides project managers, contractors, and stakeholders with the information they need to make timely decisions, allocate resources efficiently, and mitigate risks [7]. As the construction industry embraces digital transformation, automated monitoring systems have become an essential component of construction project management. However, the successful implementation and use of these technologies are dependent on a variety of circumstances. Understanding these aspects is critical for construction industry stakeholders who want to get the most out of automated construction progress monitoring while addressing potential issues [1].

Implementing progress monitoring methods outlined in project management allows for the coordination, evaluation, and tracking of construction projects. Performance validation and daily on-site planned activities can be inspected and compared with the aid of progress monitoring. For a construction project to be successful, tracking and updating construction progress is one of the most important but crucial components [8]. While inefficient progress monitoring techniques can result in project delays, efficient tactics enable timely remedial actions for impacted projects. Thus, developing a workable monitoring strategy is crucial for ensuring the effectiveness of data gathering and lowering the possibility of error. Currently available digital monitoring technologies assist the user in resolving issues. The integration of computer-based technology for performance tracking and visualisation in as-built construction projects is increasingly important for improving the efficacy and efficiency of monitoring procedures [3][12]. This research attempts to provide a thorough examination of the factors that influence automated construction progress monitoring. By identifying and comprehending these factors, construction professionals may negotiate the complexity of establishing automated monitoring systems. This knowledge will not only improve the adoption and integration of new technologies, but will also help to achieve the underlying objective of enhancing the overall efficiency, productivity, and sustainability of construction projects in the 21st century.

Significance: The importance of automated construction progress monitoring research cannot be overstated in addressing major industry concerns. While automated construction progress monitoring has proved significant benefits around the world, its successful deployment in India poses a unique set of obstacles and opportunities. These factors are influenced by the country's diversified technical environment, cultural attitudes towards technology, socioeconomic issues, and the regulatory structure that governs construction projects. Understanding and analysing these factors is critical for guaranteeing the successful adoption and implementation of automated monitoring systems in India, which will improve project efficiency, decision-making, and the general growth of the construction industry. This study is critical for realising the full potential of these technologies, increasing project efficiency, and promoting safety and sustainability in construction. This research, by identifying and resolving influencing elements, can considerably benefit construction stakeholders, economies, and communities that rely on efficient and effective construction projects. This research, by identifying and resolving influencing elements, can considerably benefit construction stakeholders, economies, and communities that rely on efficient and effective construction projects.

II. METHODOLOGY

The questionnaire-based survey approach is used to determine effective factors influencing the implementation of automated construction progress monitoring in the Indian construction industry. The process is separated into six parts, as illustrated in Figure 1.

- **Structured Data Collection:** The first stage is to collect structured data and identify factors influencing the implementation of automated construction progress monitoring using appropriate literature research and a structured questionnaire survey.
  - **Literature Review:** Conducting a thorough examination of existing literature, reports, research papers, and case studies to develop the theoretical foundation and current understanding of automated construction progress monitoring and its affecting factors.
  - **Survey and Questionnaires:** Conduct surveys and questionnaires with construction industry professionals, project managers, technology providers, and other stakeholders. The surveys will collect quantitative information about the challenges and opportunities related with automated monitoring systems.

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- **Comparative Analysis:** The second step is to cross-check and confirm the results from other data sources, such as surveys, case studies, and interviews, to ensure strong conclusions. Following the comparative analysis, a list of refined factors will be compiled from the survey and literature study.
- **Data Analysis:** The data acquired from the survey and literature will undergo a rigorous examination using ranking and computation of the Relative Importance Index (RII). First, the participant's judgments of the relevance of each aspect will be ranked on a scale of 1 to 5, with 1 denoting the least importance and 5 representing the most important. Next, the RII approach will be used to determine the relative relevance of each element. The procedure is adding up the scores supplied by participants for each factor and dividing the total by the highest possible score. Finally, the RII scores will be analysed to identify the components with the greatest significance. The factors with the greatest RII scores will be deemed the most important, while those with the lowest RII scores will be considered less relevant. This analytical procedure guarantees a thorough knowledge of the factor's relative relevance as perceived by the participants.
- **Mitigation Strategies:** Create a set of frameworks for mitigation strategies and best practises to address challenges and optimise influencing factors based on the findings of the literature review, data analysis, and case studies.
  - **Recommendations Development:** Using the research findings, create realistic recommendations and best practises for addressing the identified factors and maximising the implementation of automated monitoring systems.

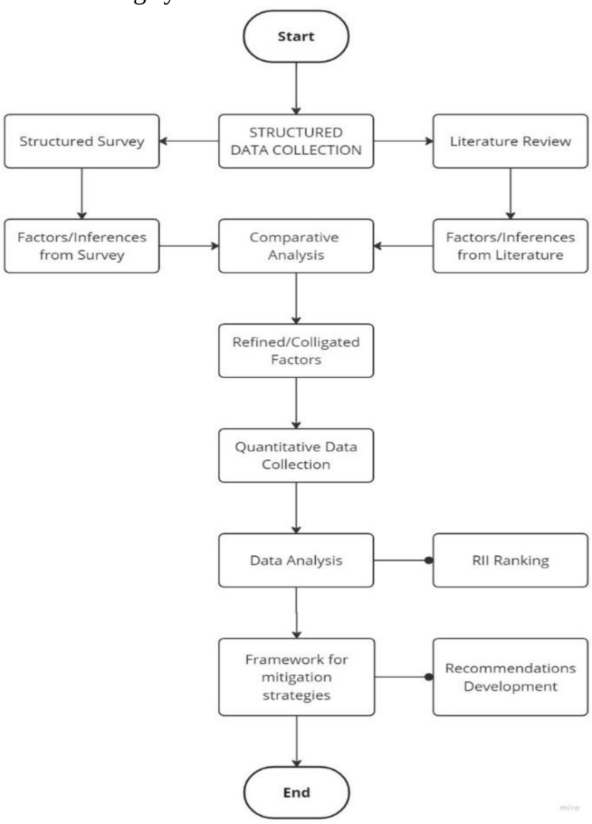

Figure 1: Methodology Diagram

III. LITERATURE REVIEW

Through the use of progress monitoring protocols outlined in project management, construction projects are coordinated, evaluated, and monitored. Monitoring progress facilitates performance validation and the inspection and comparison of daily planned operations on-site. For a construction project to succeed, tracking and updating construction progress is a crucial yet necessary component [6]. While ineffective progress monitoring techniques can result in project delays, efficient tactics allow impacted projects to quickly make necessary corrections. Finding a feasible monitoring strategy is therefore crucial to ensuring the effectiveness of data collecting and lowering the possibility of inaccuracy. These days, modern digital monitoring technologies help the user get over their concerns. The integration of computer-based technology for performance tracking and visualisation in as-built construction projects is increasingly important for improving the efficacy and efficiency of monitoring procedures [1]. In relation to automated construction progress monitoring, researchers have identified a number of technologies for data collection, including geographic information systems (GIS), laser scanning, photogrammetry, videogrammetry, radio frequency identification (RFID), global positioning systems (GPS), barcodes, ultra-wideband (UWB), and RFID (AR). However, nine of the aforementioned technologies—laser scanner, photogrammetry, videogrammetry, RFID, UWB, Kinect sensors, infrared thermography, swarm nodes, and augmented reality—have been identified as close-range monitoring technologies used in the construction industry [9]. Furthermore, modern methods like computer vision (CV) and machine learning (ML) have been found to work well with the previously described technologies to produce more precise results.

Numerous research works have determined the prerequisites and practical aspects, mostly focusing on individual monitoring systems. Nevertheless, not much research has been done on the automated construction progress monitoring process using digital technology to identify important areas and practical implementation constraints. The studies for building progress monitoring were reviewed using scientometrics in order to identify knowledge gaps and identify potential areas for future research [4]. It was determined that there had been a significant movement in the construction industry away from traditional methods and toward automation and digitalization. Another study looked into how automated progress monitoring techniques affected the three main project performance indicators: cost, time, and quality. Furthermore, the benefits of automatic progress tracking were confirmed for the effective and efficient real-time environment. The completed research studies had determined the key components and multidimensional factors based on project performance that were influencing the automated industry's evolution [6].

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To give confidence in the stakeholders, however, factors influencing automated monitoring implementation and emphasising technology features for enhanced comprehension must be looked into. The conducted research has pinpointed the multiple aspects based on project success as well as significant factors that are influencing the automated industry's evolution. Nonetheless, as industry practitioners have expressed reluctance to adopt automated monitoring technologies due to a perceived theoretical gap and lack of clarity, it is imperative to identify the critical aspects and qualities. Furthermore, scholars have emphasised that the absence of specifications, reference frameworks, and knowledge management standards poses substantial challenges that contribute to the construction industry's reluctance to adopt new technology [10].

Site managers should be aware of the project's status promptly and accurately. They should know if the project is proceeding according to schedule, budget, quality standards, and safety precautions. The progress control helps to recognise the present as-built status of a construction project effectively, to detect differences between as-built and as-planned progress and to aid in deciding on remedial steps. Conventional data collection and activity progress monitoring mostly rely on foremen's daily or weekly reports, which are analysed and then uploaded to a computer [5]. Even though progress monitoring is crucial, the traditional approach can be difficult since it is costly, inefficient, time-consuming, low quality, too infrequent to allow for timely management action, possibly unable to speed up the distribution of progress information, non-systematic, and complex. Automating the control procedures is the most cost-effective approach to assess performance. This means automating progress evaluation as well as, to the greatest extent feasible, planning assignment, resources, and project structure for allocating duties and responsibilities at every step of the building project [11]. The maximum benefits of utilising an integrated information technology (IT) system would be ensured by this double automation. In addition to the data that are automatically gathered, additional data must be manually obtained. In order to increase productivity, they suggested a framework for semi-automated project monitoring and control. The framework's ultimate objective was to seamlessly integrate data acquired manually and automatically.

A. Construction Progress Monitoring

Construction progress tracking, sometimes called construction progress monitoring, acts as a project's road map for a construction project. Maintaining alignment and ensuring the project is moving in the right direction is achieved by an ongoing process of review and check-ins. The information you need to know how your project is progressing—are we on track, on budget, and achieving quality standards—is provided by effective progress monitoring. In order to enable decision-makers identify any problems, allocate resources sensibly, and maintain project momentum for a timely and successful completion, the goal is to present a clear picture of the project's current state at any given time. It is the force that guarantees that all parties involved are aware of what is occurring, when it is happening, and how well it is happening—all without the hassles of unneeded surprises or guessing [11].

B. Challenges in Traditional Construction Progress Monitoring

Manual Data Collection: Traditional construction project monitoring focuses on manual data collection methods such as paper reports and Excel spreadsheets. This method is time-consuming and prone to mistakes owing to manual entry. The reliance on manual data collecting increases the likelihood of inaccuracies and delays [9]. Inaccurate data can lead to poor decision-making, and data entry delays might impede timely review of project progress.

Lack of Real-Time Information: Traditional construction project monitoring is frequently characterised by periodic reporting, resulting in a lack of real-time information. The lack of real-time information makes it difficult to quickly identify and handle concerns [7]. Delayed understanding of project developments might result in delayed response times, hampering the ability to minimise risks and address developing difficulties.

Limited Communication and Collaboration: Traditional construction project monitoring frequently encounters obstacles due to inadequate communication lines and limited collaboration among project stakeholders. Limited communication and collaboration can lead to misunderstandings and delays [2][14][15]. A lack of seamless collaboration among team members may hamper project progress.

Dependency on Physical Presence: Traditional construction project monitoring methods frequently require staff to be physically present on the construction site for data collecting. The need on physical presence creates issues in terms of travel limits and on-site obligations. Delays may arise owing to the time it takes for personnel to travel to and from the construction site [10]. This can lead to higher travel expenditures and possibly schedule interruptions.

Risk of Information Loss: Traditional construction project monitoring relies on paper-based documentation and human record-keeping, which raises the risk of losing crucial project information. The possibility of information loss endangers the project's historical data. Losing this data may limit the capacity to undertake detailed studies and learn from previous efforts [3]. The lack of historical insights might influence decision-making, making it difficult to detect patterns, trends, and lessons gained for continuous improvement.

C. Automated Progress Monitoring Technologies

The chosen papers included case examples, difficulties, and advantages of several automated methods. Using technology to support progress monitoring, these strategies were divided into six main groups. These include computer vision-based techniques, tag-based approaches, geospatial technologies, building information modelling and related commercial software, traditional Information & Communication Technologies (ICT), and extended reality. They are covered below:

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Conventional ICT: These consist of email, multimedia tools, interactive voice response (IVR), handheld computers (Personal Digital Assistants or PDAs), and handheld computing devices. These are the simplest methods, which are communication tools based on information technology. These technologies are mainly less expensive and have less automation, but they can improve stakeholder communication, which aids in information tracking [8].

Tag-based Techniques: They entail the usage of tags and codes that can be fastened to different resources on-site and are mostly utilised for equipment tracking, employee badge scanning, material tracking, and inventory management. Barcodes, quick response (QR) codes, RFID (radio frequency identification) tags, and ultra-wideband (UWB) tags are a few examples of these. Every tag operates on the principles of Automatic Identification and Data Capture (AIDC) [3]. It is important to remember that tag-based technologies are unable to work in tandem with other vision-based methods, graphically depict site changes, or extract spatial element information directly.

Geospatial Techniques: These include core technologies such as the Geographic Information System (GIS) and the Global Positioning System that rely on sensors to determine a place (GPS). These methods are applied to the collection, processing, and modelling of georeferenced data. Large infrastructure projects requiring the handling and storage of massive volumes of data can benefit from the usage of GIS [5]. While GPS helps with the spatial analysis and navigation of various site operations, it can be a helpful geospatial tool that prioritises location in database administration.

Building Information Modelling (BIM) Based: BIM is a process that helps with proper project management by improving the visualisation of construction sites through the use of various tools, technologies, and contracts. Additionally, BIM supports the construction industry's stakeholder management procedures for various areas of engagement, satisfaction, communication, and teamwork [1]. This can be used in conjunction with paid scheduling programmes such as Microsoft Project to facilitate effective progress monitoring.

Computer Vision-Based Construction Progress Monitoring (CV-CPM): This is a young field that focuses on using visual inputs to retrieve information. Digital pictures, movies, thermal photos, as-built point clouds, panoramas, and photospheres are some examples of these inputs. These methods include 3D laser scanning, range imaging, photogrammetry, videogrammetry, and fixed surveillance. Learning, 3D scene modelling, video tracking, 3D position estimation, object recognition, scene reconstruction, object detection, and event detection are some of the sub-domains of computer vision that can be utilised to track development. Digital twin technology is also being investigated as a potential solution for efficient real-time project monitoring [9].

Extended Reality (XR) Based: Human-machine interactions are supported by the relatively newer technology, which enables a combined real and virtual world. Based on the variations in vision, these methods can be further divided into augmented reality (AR), virtual reality (VR), and mixed reality (MR). These methods can be used to handle network and computer technologies in progress monitoring as well as the gathering of digital data. Every one of these technologies has its benefits and drawbacks when it comes to monitoring construction sites [8]. Therefore, in order to identify these and exploit them effectively, a thorough analysis is required. It should be mentioned that several case studies have demonstrated the effective integration of appropriate technology into sites, and it has been discovered that time and cost overruns have been significantly decreased.

IV. FACTORS AFFECTING IMPLEMENTATION OF AUTOMATED CONSTRUCTION PROGRESS MONITORING

A. Technological Infrastructure Challenges

The successful adoption of automated construction progress monitoring in the Indian construction industry relies on overcoming certain technological infrastructure challenges. To begin, internet connectivity is a key challenge, especially in remote construction sites where access to high-speed internet may be limited. Because of the dependency on real-time data transfer, powerful and dependable internet connections are required for continuous monitoring [1].

Second, the availability and cost of modern hardware provide a significant challenge. Adoption of cutting-edge monitoring equipment frequently necessitates significant investments, and the price and accessibility of these hardware components can be a hurdle, especially for smaller construction firms operating on tight budgets.

B. Cost Considerations

The use of automated construction progress monitoring in the Indian construction sector necessitates careful evaluation of a variety of cost-related aspects. The initial cost necessary to establish monitoring systems is a major financial commitment. This includes the expenditures of procuring hardware, software, and other key components. The financial feasibility of this initial expenditure is an important consideration for construction projects, particularly those with constrained budgets [3]. Maintenance expenditures are a continuous financial consideration. Periodic maintenance, upgrades, and potential repairs are required to ensure that monitoring systems continue to function properly and perform optimally. These ongoing costs must be considered into the long-term budget to ensure that the monitoring system remains functional. Software licence costs are another component of the financial environment. The use of complex monitoring software frequently requires licence agreements, which adds to the overall cost of deployment [7]. These fees, as well as potential scalability considerations, must be evaluated and understood in order to make informed decisions.

C. Socioeconomic Considerations

The introduction of automated construction progress monitoring in the Indian construction sector is heavily influenced by socioeconomic issues that affect both the viability and acceptance of this transformative technology.

Budget limits are a significant barrier, especially for building projects that operate within strict budgetary parameters [11]. The allocation of resources to implement automated monitoring systems competes with other critical project expenses, necessitating a fine balance to ensure financial viability.

Another important factor to consider is the availability of skilled workers. The proper operation and maintenance of monitoring systems necessitate a team with the requisite technical knowledge. Challenges may occur in obtaining and maintaining experienced staff, limiting the efficient use of monitoring systems in building projects [9].

D. Technology Adoption

The effective application of automated construction progress monitoring in the Indian construction sector is dependent on important criteria of technology acceptance. The preparation of construction stakeholders, such as project managers, labourers, and decision-makers, is critical. It is critical to ensure that these stakeholders are prepared and willing to adopt new technologies. Training programmes, awareness campaigns, and proactive involvement are critical components for creating a climate suitable to the use of automated monitoring systems [6].

The seamless integration of monitoring technologies into existing construction processes is critical to its effectiveness. Instead, then disrupting existing operations, technology should complement and enhance them. Aligning automated monitoring systems with the unique requirements and complexities of Indian construction methods necessitates a thorough evaluation of integration points, modification, and interoperability with other project management tools [1].

Resistance to technology adoption in the workplace poses a societal barrier. Construction workers may be hesitant or sceptical of adopting new technologies, necessitating extensive training programmes and change management tactics to promote acceptance and proficiency [9]. Overcoming this resistance is critical for reaping the full benefits of automated construction progress monitoring.

V. RESULTS AND DISCUSSIONS

A. Description of Survey Participants

The analysis of survey participants in the construction industry provides a detailed picture of demographic composition, experience levels, and familiarity with Automated Construction Progress Monitoring. As shown in Figure 2, the distribution of respondents across various industry roles demonstrates a broad representation, with project and construction managers accounting for the largest segment (34.67%). This suggests that individuals in charge of project execution and management are actively participating in the survey, indicating a strong interest in advances in construction monitoring technologies. Engineers, who account for 28.00% of respondents, play an important role in implementing Automated Construction Progress Monitoring systems effectively. Contractors, architects, and technology providers/technicians all contribute to the survey in proportions of 14.67%, 10.67%, and 6.67%, indicating a diverse range of stakeholders involved in construction projects.

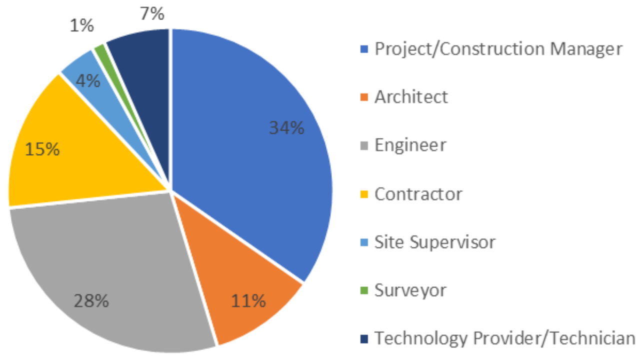

Figure 2: Distribution of the Respondents Across Various Roles

Figure 3 shows that the majority of respondents had 6-10 years of experience in the construction industry, accounting for 48% of the total. This group is likely to have extensive hands-on experience and knowledge accumulated through years of involvement in construction projects, making their insights especially valuable in assessing the challenges and opportunities associated with Automated Construction Progress Monitoring implementation. Furthermore, 32% of respondents reported 1-5 years of experience, indicating a sizable representation of individuals new to the industry who may offer fresh perspectives on technological advancements. Respondents with more than ten years of experience made up 12% of the sample, bringing seasoned expertise to the survey and potentially providing insights into long-term trends and industry development.

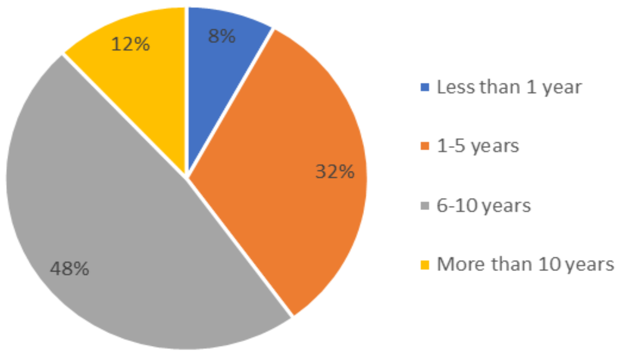

Figure 3: Distribution of Respondent's Experience Level

Survey participants' familiarity with Automated Construction Progress Monitoring varies depending on their level of exposure and understanding of the concept. While 36.00% of respondents reported being very familiar with Automated Construction Progress Monitoring, a sizable proportion (9.33%) reported being completely unfamiliar. The remaining respondents ranged in familiarity, with 29.33% rating themselves as familiar, 12.00% as not very familiar, and 13.33% as very familiar, as shown in Figure 4. This distribution highlights the wide range of perspectives in the construction industry on Automated Construction Progress Monitoring, reflecting varying levels of exposure, understanding, and potential readiness to adopt automated monitoring technologies.

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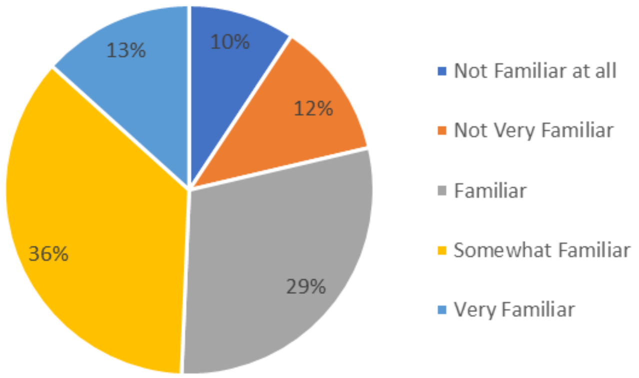

Figure 4: Distribution of Respondent's Familiarity with the Concept of Automated Construction Progress Monitoring

Figure 5 also shows a Sankey Diagram, which illustrates the complex relationship between respondent roles, experience levels, and familiarity with Automated Construction Progress Monitoring. This graph provides a clear visual representation of the distribution of respondents across various professional backgrounds and experience brackets, highlighting differences in Automated Construction Progress Monitoring familiarity. The thickness of the connecting lines in the diagram indicates the relative proportion of respondents in each category, allowing for a quick and intuitive understanding of how familiarity with Automated Construction Progress Monitoring varies depending on respondent roles and levels of experience in the construction industry. This visual aid improves data interpretability, allowing for more in-depth exploration of the patterns and relationships revealed by the survey results.

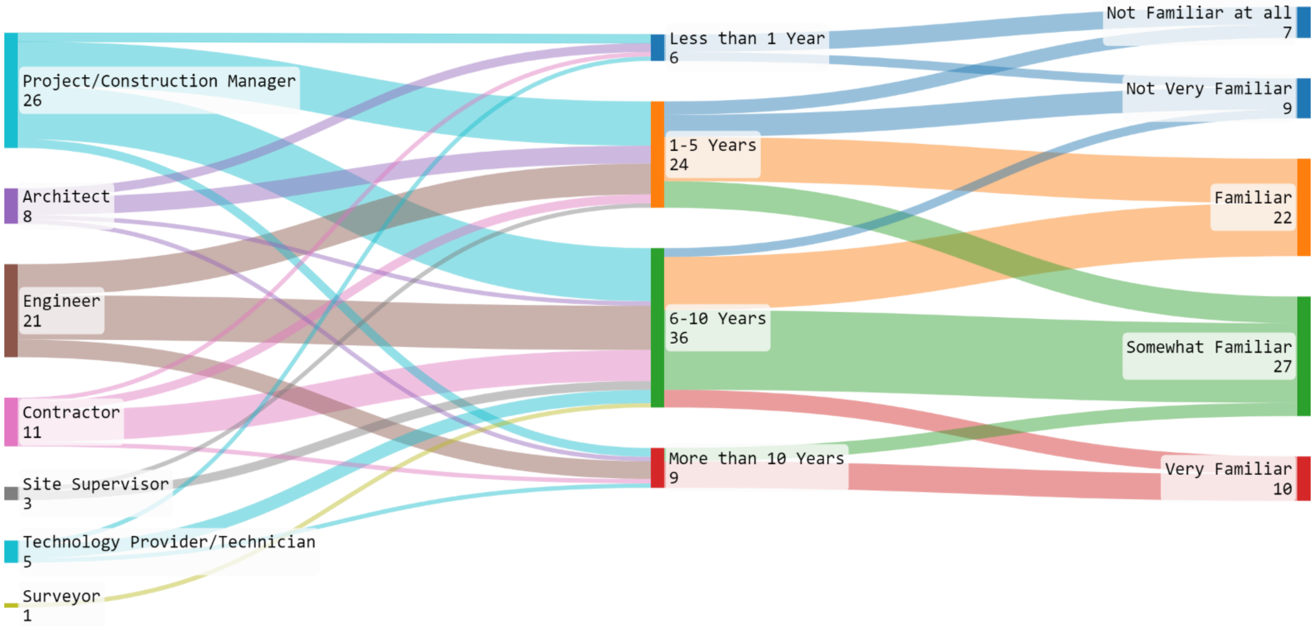

Figure 5: Sankey Diagram Showing Relationship Between Respondent Roles, Their Experience Levels, and Their Familiarity

B. Research Findings and Results

The survey findings provide a comprehensive overview of the current practises and challenges encountered in construction project monitoring within the surveyed sample, shedding light on key aspects that influence project management in the Indian construction industry.

First, as shown in Figure 6, the findings show a high reliance on manual data collection methods such as paper-based reports or measurements. While 6 respondents reported using no manual methods at all, indicating some level of digitalization or automation in their monitoring processes, 11 respondents expressed complete reliance on manual methods. This range of responses demonstrates the diversity of approaches to data collection within the industry, reflecting varying levels of technological integration and readiness among construction professionals.

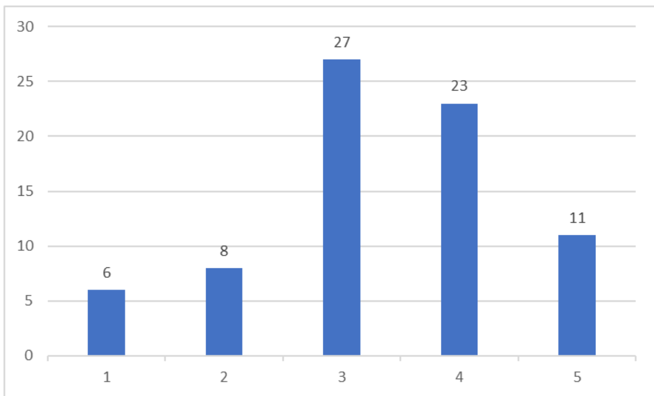

Figure 6: Reliability of Manual Data Collection on Likert Scale (1-Not Reliable, 5- Completely Reliable)

Furthermore, as shown in Figure 7, the survey found that the vast majority of respondents (84%) encountered difficulties or errors during manual data collection in their construction projects.

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These challenges include data inaccuracies, time-consuming processes, and difficulties maintaining consistency and reliability in reporting. The prevalence of such challenges emphasises the need for more efficient and dependable data collection methods to improve the accuracy and timeliness of project monitoring.

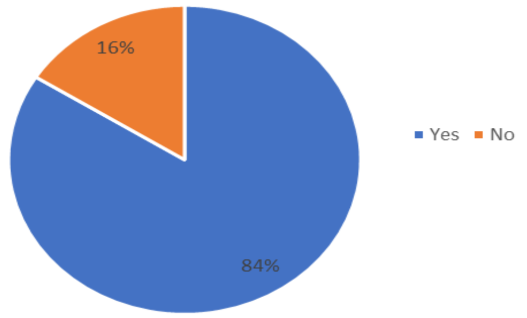

Figure 7: Respondents Encountered Challenges in Manual Data Collection

In terms of on-site presence for data collection and monitoring activities, the findings indicate a significant reliance on physical presence, with 21 respondents indicating that personnel must be present at construction sites, as shown in Figure 8. This reliance on on-site monitoring may present difficulties in resource allocation, as well as limitations in flexibility and responsiveness to real-time project developments.

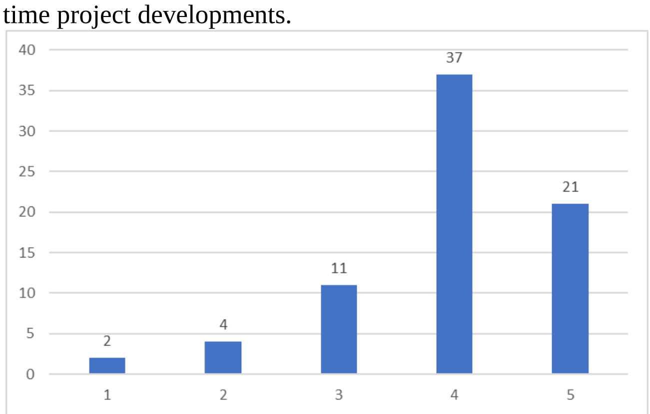

Figure 8: Personnel Requirement to be Physically Present at the Site for Data Collection or Monitoring Activities

Furthermore, as shown in Figure 9, the majority of respondents (88%) reported that travel constraints or on-site dependencies caused delays in construction projects, emphasising the importance of logistical challenges on project timelines and overall efficiency.

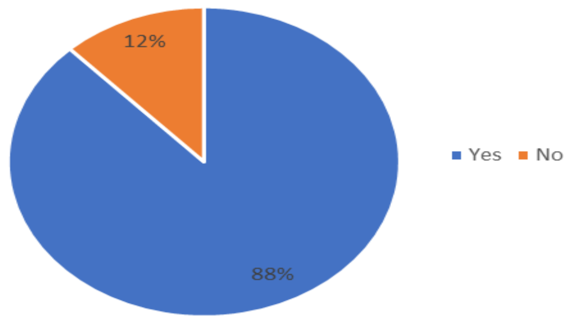

Figure 9: Respondents Encountered Challenges for Travel Constraints and On-Site Dependencies

Figure 10 shows that the majority of respondents (69%) use a combination of digital and paper-based methods for documentation and record-keeping. While digital solutions provide benefits in terms of accessibility, organisation, and data retrieval, the continued reliance on paper-based documentation indicates a degree of inertia or difficulties in transitioning to fully digital workflows. This hybrid approach may represent a transitional stage in the industry's adoption of digital technologies, with opportunities for further optimization and streamlining of documentation processes.

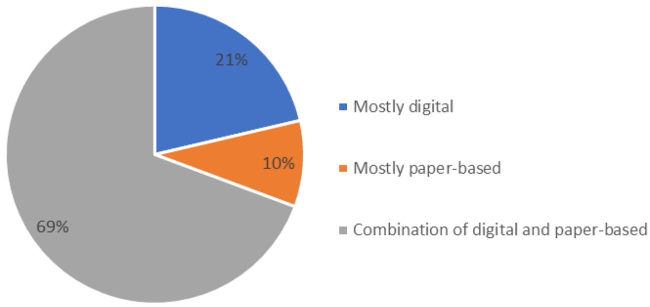

Figure 10: Documentation and Record-Keeping Practices

As illustrated in Figure 11, the survey investigated the use of various technologies in construction project monitoring practises. The findings revealed widespread adoption of technologies such as cameras and video surveillance (69%), mobile apps (65%), and building information modelling (BIM) (56%). These technologies enable real-time data capture, visualisation, and analysis, allowing stakeholders to make better decisions and streamline project workflows. However, certain technologies, such as Radio Frequency Identification (RFID) and Augmented/Virtual Reality (AR & VR), were found to be less commonly implemented, indicating potential areas for further investigation or investment in emerging technologies within the industry.

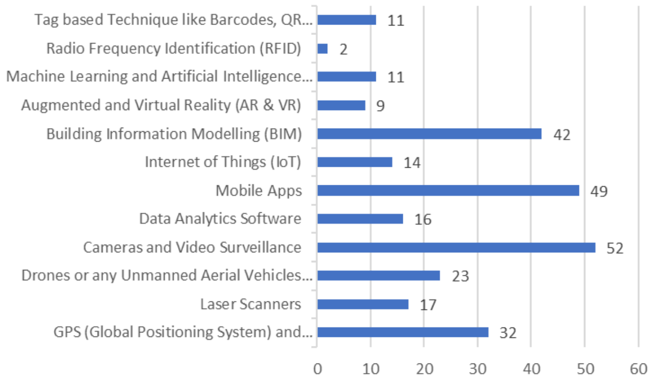

Figure 11: Technologies Currently Being Adopted for Construction Project Monitoring Practices

Figure 12 illustrates how respondents rated the availability of real-time information in their current construction project monitoring practises. The results show that respondent's perceptions vary, with the majority falling somewhere in the middle.

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In particular, 48% of respondents rated real-time information availability as "average" (rated 3), while 20% rated it as "below average" (rated 2). On the extremes, only 2.67% rated it as "very poor" (rated 5), while 1.33% rated it as "excellent" (rated 1). These findings indicate that, while a significant portion of respondents believe real-time information availability is satisfactory, there is still room for improvement in terms of project data timeliness and accessibility.

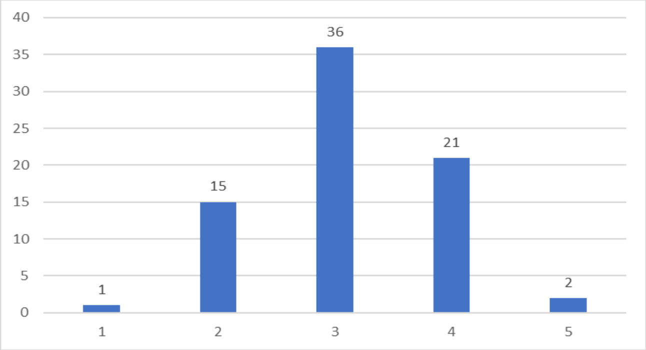

Figure 12: Real-Time Information Availability in Current Construction Projects

Furthermore, as illustrated in Figure 13, the survey investigated whether delays in receiving project information caused any issues or challenges in construction projects. The vast majority of respondents (78.67%) reported issues or challenges as a result of delays in receiving project information. This suggests that delays in accessing timely and relevant information have a tangible impact on project performance, potentially resulting in inefficiencies, disruptions, or missed opportunities for proactive decision making. These challenges can take many different forms, such as project timeline delays, cost overruns, resource misallocation, or compromised work quality.

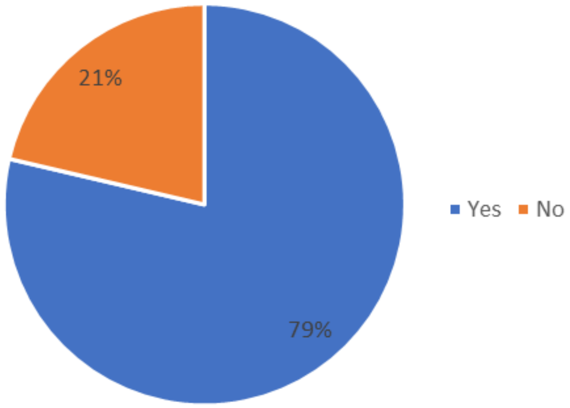

Figure 13: Respondents Encountered Challenges due to Delays in Receiving Real-Time Project Information

Overall, the research findings shed light on the current state of construction project monitoring practises in the Indian construction industry, highlighting areas of reliance, challenges, and opportunities for technological advancement and optimization. These findings can help inform strategies for improving project management practises, increasing efficiency, and driving innovation in the construction industry.

C. Relative Importance Index (RII) Analysis

The Relative Importance Index (RII) is used to analyse and rank the importance of various factors influencing the implementation of Automated Construction Progress Monitoring based on survey responses, particularly those on a Likert scale. It is a method for determining the relative importance of various factors based on survey responses. It assists in determining which factors are most important to respondents. The RII calculation consists of assigning weights to each Likert scale response, multiplying these weights by the corresponding responses, adding these values, and normalising the result by dividing it by the maximum possible score. This normalised value is expressed as a percentage, giving a clear picture of the perceived importance of factors. A higher RII indicates greater perceived significance.

The formula for calculating RII is as follows:

RII = $\sum W / (A \times N)$ where,

W = respondent's weighting of every factor (ranging from 1 to 5)

A = highest weight (5 in this case)

N = total number of participants (75 in this case)

Table 1: RII Analysis for the Factors Affecting the Implementation of Automated Construction Progress Monitoring

Factors Based on Their Perceived Impact on the Implementation of Automated Construction Progress Monitoring											
S.NO.	Factors	No. of Participants Selecting					Total Weightage (W)	Total no. of Participants (N)	A X N	Relative Important Index (RII)	Ranking
		Least Impact (1)	Low Impact (2)	Moderate Impact -3	High Impact (4)	Most Significant Impact (5)					
1	Internet Connectivity	2	7	38	26	2	244	75	375	0.651	8
2	Availability and Cost of Advanced Hardware	1	5	19	32	18	286	75	375	0.763	1

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3	Integration with Existing Systems	5	7	28	23	12	255	75	375	0.68	5
4	Budget Constraints	2	12	19	30	12	263	75	375	0.701	2
5	Skilled Labour Availability	6	5	33	12	19	258	75	375	0.688	4
6	Resistance to Technology Adoption	3	9	26	23	14	261	75	375	0.696	3
7	Readiness of Construction Stakeholders	2	5	35	28	5	254	75	375	0.677	6
8	Integration with Construction Processes	9	12	33	14	7	223	75	375	0.595	10
9	Regulatory Framework	9	9	45	10	2	212	75	375	0.565	12
10	Cultural Attitudes Towards Technology	1	12	33	24	5	245	75	375	0.653	7
11	Government Initiatives	5	21	30	14	5	218	75	375	0.581	11
12	Data Security and Privacy	0	19	35	16	5	232	75	375	0.619	9

As shown in Table 1, the survey results for assessing the perceived impact of various factors on the implementation of Automated Construction Progress Monitoring in the Indian construction industry provide nuanced insights into industry professionals' priorities, challenges, and considerations.

Among the factors investigated, "Availability and Cost of Advanced Hardware" emerged as the most significant consideration, as indicated by its highest total weightage and relative importance index (RII). This suggests that respondents understand the critical role of advanced hardware technologies like sensors, drones, and monitoring devices in facilitating effective Automated Construction Progress Monitoring implementation. The emphasis on hardware availability emphasises the importance of access to modern technology solutions and the affordability of acquiring and deploying such equipment, which are necessary. Among the factors examined, "Availability and Cost of Advanced Hardware" emerged as the most significant consideration, as demonstrated by its highest total weightage and relative importance index (RII). This suggests that respondents understand the importance of advanced hardware technologies like sensors, drones, and monitoring devices in enabling effective Automated Construction Progress Monitoring implementation. The emphasis on hardware availability emphasises the importance of having access to modern technology solutions as well as the affordability of purchasing and deploying such equipment, both of which are required for real-time monitoring and data collection on construction sites.

Following closely behind is the factor "Budget Constraints," which received the second highest RII score. This finding highlights the financial implications of Automated Construction Progress Monitoring implementation, emphasising the importance of allocating adequate resources and investments to procure and deploy advanced monitoring technologies. Organizations seeking to implement Automated Construction Progress Monitoring may face significant budgetary constraints, limiting their ability to invest in hardware, software, training, and infrastructure upgrades required for success.

Furthermore, "Resistance to Technology Adoption" and "Integration with Existing Systems" were identified as critical factors influencing Automated Construction Progress Monitoring implementation, with relatively high RII values. These findings highlight the complex organisational dynamics and technological challenges that come with integrating new monitoring systems into existing workflows and cultures. Resistance to change, combined with the need to seamlessly integrate Automated Construction Progress Monitoring with legacy systems and processes, emphasises the importance of change management strategies and robust implementation plans in breaking down barriers and fostering stakeholder acceptance. Conversely, factors such as "Data Security and Privacy" and "Government Initiatives" received lower RII scores, indicating that respondents believe these aspects have a smaller impact on Automated Construction Progress Monitoring implementation than other factors. While data security and regulatory compliance are unquestionably important considerations, the findings indicate that they may not be perceived as immediate barriers or enablers to Automated Construction Progress Monitoring adoption by the surveyed sample. In summary, the detailed analysis of survey results demonstrates the multifaceted nature of the factors influencing Automated Construction Progress Monitoring implementation in the Indian construction industry. While hardware availability, budget constraints, and resistance to technology adoption are the primary concerns, factors such as integration with existing systems, stakeholder readiness, and regulatory compliance all play important roles in determining the success of Automated Construction Progress Monitoring initiatives. These findings are useful for industry stakeholders, policymakers, and technology providers looking to accelerate the adoption and implementation of Automated Construction Progress Monitoring solutions in construction projects.

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D. Mitigation Strategies and Recommendations Development

Based on the findings of the research on factors influencing the implementation of Automated Construction Progress Monitoring in the Indian construction industry, several mitigation strategies and recommendations can be developed to address the identified challenges and facilitate the successful adoption of Automated Construction Progress Monitoring.

To begin, to mitigate the impact of budget constraints, stakeholders should look into innovative financing models such as public-private partnerships or leasing arrangements to spread the upfront costs of hardware acquisition and implementation over time. Furthermore, targeted government incentives and subsidies can encourage investment in Automated Construction Progress Monitoring technologies, lowering financial barriers for construction companies. To address resistance to technology adoption, comprehensive change management programmes should be implemented, including stakeholder engagement, training initiatives, and open communication, to foster buy-in and ensure a smooth transition to Automated Construction Progress Monitoring systems. Interoperability standards and modular solutions can help improve integration with existing systems by allowing for seamless integration with legacy software and workflows, reducing disruption and increasing usability.

Furthermore, collaboration among industry stakeholders, technology providers, and regulatory bodies is required to develop clear guidelines and standards for data security and privacy, ensuring compliance with relevant regulations, and instilling trust in Automated Construction Progress Monitoring systems. Finally, awareness campaigns and capacity-building initiatives can foster a culture of innovation and technology adoption in the construction industry, encouraging stakeholders to see Automated Construction Progress Monitoring as a transformative tool for improving project efficiency, productivity, and sustainability. By implementing these mitigation strategies and recommendations, the construction industry can overcome barriers to Automated Construction Progress Monitoring implementation and fully realise the potential of advanced monitoring technologies to drive progress and innovation in construction projects.

VI. CONCLUSION

In conclusion, this research paper has provided a thorough understanding of the current practises, challenges, and opportunities associated with construction project monitoring in the Indian construction industry. Key insights have been gained through a combination of survey findings, research results, and Relative Importance Index (RII) analysis into the factors influencing the implementation of Automated Construction Progress Monitoring systems, as well as the current state of technology adoption and operational practises within the industry. Several key findings emerged from a thorough analysis of survey data, literature reviews, and expert insights.

First, the study discovered a significant reliance on manual data collection methods, emphasising the need for more efficient and dependable monitoring solutions to improve project accuracy and timeliness. Budget constraints, resistance to technology adoption, and integration with existing systems were all identified as significant barriers to ACPM implementation. However, these challenges present opportunities for innovation and improvement. The study found widespread adoption of certain monitoring technologies, such as cameras, mobile apps, and Building Information Modelling (BIM), indicating a growing interest in using technology for project monitoring. Furthermore, the Relative Importance Index (RII) analysis identified hardware availability and budget constraints as critical considerations, emphasising the importance of overcoming financial barriers and promoting technological advancements.

The findings emphasise the importance of technological advancements, particularly in terms of hardware availability and cost, as well as overcoming budget constraints and resistance to technology adoption in order to drive successful Automated Construction Progress Monitoring implementation. Furthermore, the analysis emphasises the importance of seamless integration with existing systems, effective change management strategies, and proactive stakeholder engagement in overcoming barriers and increasing acceptance of monitoring technologies. Moving forward, the construction industry must prioritise investments in digital infrastructure, hardware, and software solutions to improve project monitoring capabilities, increase data accuracy and timeliness, and drive efficiency and innovation across construction projects. The industry can realise the full potential of automation by leveraging emerging technologies, cultivating an innovation culture, and addressing organisational and regulatory challenges. Overall, the study emphasises the importance of increasing ACPM adoption in India's construction sector to improve project efficiency, productivity, and sustainability. By addressing the identified challenges and implementing the recommended strategies, stakeholders can overcome barriers to ACPM implementation and fully realise the potential of advanced monitoring technologies in construction projects.

DECALARION STATEMENT

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Authors Contributions	All authors have equal participation in this article.

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