

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



Mohd Sameer Malik, M. Kranti Kumar

**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, and high initial investment, among others. This research investigates the significance of automated construction progress monitoring, examines the factors that influence its adoption, and provides 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 significant role in employment, infrastructure development, and economic growth, has experienced both remarkable growth and persistent difficulties. However, historically, this industry has been growing with inefficiencies, delays, and cost overruns, prompting research into innovative technologies to address these issues. Construction projects are notorious for their inefficiencies, overruns, and delays [2]. 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.

Traditional methods of construction progress monitoring, which often rely on manual data gathering and subjective assessments, have limitations that hinder 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].

Automated construction progress monitoring involves integrating various technologies to acquire, process, and analyse data related to construction activities in real-time. These technologies work together to give helpful 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 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 capture photographs, videos, and data from various perspectives, providing a comprehensive view of the construction site.
- **Cameras and Video Surveillance:** Surveillance cameras are used to monitor construction activities and collect visual data. This technology enhances site security, facilitates project progress documentation, and supports 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 enable project managers and stakeholders to remotely access real-time data and reports, facilitating 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.

Manuscript received on 15 March 2024 | Revised Manuscript received on 20 March 2024 | Manuscript Accepted on 15 April 2024 | Manuscript published on 30 April 2024.

\*Correspondence Author(s)

**Mohd Sameer Malik**, Post Graduate Student, Department of Architecture, School of Planning and Architecture, Vijayawada (A.P), India. E-mail: [ar.sameermalik@gmail.com](mailto:ar.sameermalik@gmail.com)

**Dr. M. Kranti Kumar\***, Assistant Professor, Department of Architecture, School of Planning and Architecture, Vijayawada (A.P.), India. E-mail: [kranti.myneni@spav.ac.in](mailto:kranti.myneni@spav.ac.in), ORCID ID: [0000-0002-0753-5636](https://orcid.org/0000-0002-0753-5636)

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an [open access](https://creativecommons.org/licenses/by-nc-nd/4.0/) article under the CC-BY-NC-ND license <http://creativecommons.org/licenses/by-nc-nd/4.0/>

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

- **Building Information Modelling (BIM):** BIM technology enables the creation of digital models that represent the entire construction process. BIM can be integrated with monitoring systems to compare the as-designed model with the as-built structure, enabling quality control and progress tracking.
- **Augmented Reality (AR) and Virtual Reality (VR):** These technologies provide immersive experiences for visualising projects and making informed decisions. They enable stakeholders to navigate construction projects and identify potential issues virtually.
- **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.

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

Automated construction progress monitoring involves the use of numerous sensors, data analytics tools, and information technologies to continuously gather, process, and analyse data related to construction activities. This method provides real-time visibility into the status, quality, and safety of construction projects. By doing so, it gives project managers, contractors, and stakeholders the information they need to make timely decisions, allocate resources efficiently, and mitigate risks [7]. As the construction industry undergoes digital transformation, automated monitoring systems have become a vital 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 using progress monitoring. For a construction project to be successful, tracking and updating construction progress is one of the most critical but crucial components [8]. While inefficient progress monitoring techniques can result in project delays, efficient tactics enable timely remedial actions for projects that are impacted. Thus, developing a workable monitoring strategy is crucial for ensuring the effectiveness of data collection and reducing the likelihood of error. Currently available digital monitoring technologies help users resolve 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]. This research attempts to provide a thorough examination of the factors that influence automated construction progress monitoring. By identifying and

understanding these factors, construction professionals can navigate the complexity of establishing automated monitoring systems. This knowledge will not only enhance the adoption and integration of new technologies but also contribute to achieving the underlying objective of improving the overall efficiency, productivity, and sustainability of construction projects in the 21<sup>st</sup> century.

**Significance:** The importance of automated construction progress monitoring research cannot be overstated in addressing major industry concerns. While automated construction progress monitoring has proven to offer significant benefits worldwide, its successful deployment in India presents a unique set of challenges and opportunities. The country's diversified technical environment influences these factors, including cultural attitudes towards technology, socioeconomic issues, and the regulatory structure that governs construction projects. Understanding and analysing these factors is critical for ensuring the successful adoption and implementation of automated monitoring systems in India, which will enhance project efficiency, inform decision-making, and foster the overall 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 influential elements, can substantially benefit construction stakeholders, economies, and communities that depend 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 involves collecting structured data and identifying factors influencing the implementation of automated construction progress monitoring through 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 to automated monitoring systems.



- **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 the accuracy of firm 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 most tremendous significance. The factors with the most excellent 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 practices 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 practices for addressing the identified factors and maximising the implementation of automated monitoring systems.

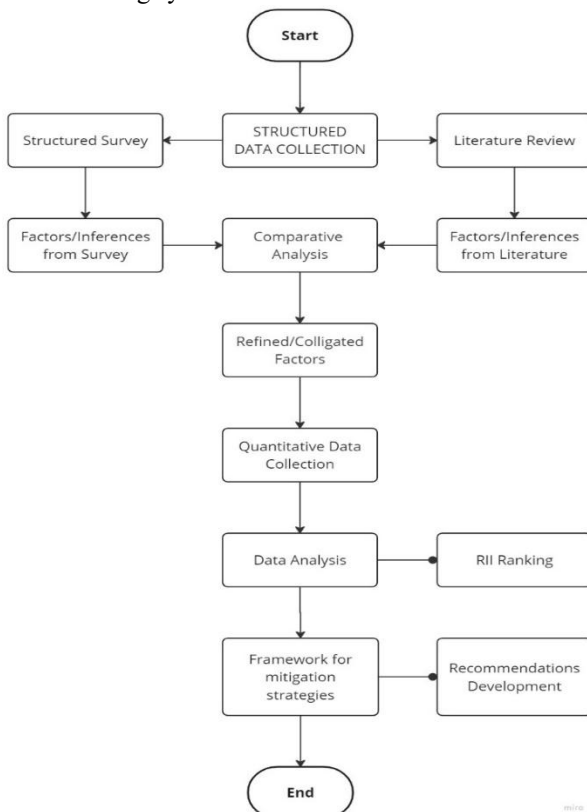


Figure 1: Methodology Diagram

### 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 make necessary corrections quickly. Finding a feasible monitoring strategy is therefore crucial to ensuring the effectiveness of data collection and lowering the possibility of inaccuracy. These days, modern digital monitoring technologies help users overcome 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]. Regarding automated construction progress monitoring, researchers have identified several 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 augmented reality (AR). However, nine of the technologies above—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 such as computer vision (CV) and machine learning (ML) have been found to complement the previously described technologies, producing more precise results.

Numerous research studies have identified the prerequisites and practical aspects, with a focus on individual monitoring systems. Nevertheless, little research has been conducted on the automated construction progress monitoring process using digital technology to identify key areas and practical implementation constraints. The studies for building progress monitoring were reviewed using scientometrics 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 examined the impact of automated progress monitoring techniques on the three primary project performance indicators: cost, time, and quality. Furthermore, the benefits of automatic progress tracking were confirmed for an 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].



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

To give confidence to stakeholders, however, factors influencing the implementation of automated monitoring and emphasising technology features for enhanced comprehension must be examined. The conducted research has identified multiple aspects, including project success, as well as significant factors influencing the evolution of the automated industry. 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 promptly and accurately be aware of the project's status. They should be informed about whether the project is proceeding according to schedule, budget, quality standards, and safety precautions. The progress control helps to effectively recognise the present as-built status of a construction project, detect differences between as-built and as-planned progress, and 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]. Although progress monitoring is crucial, the traditional approach can be challenging due to its high cost, inefficiency, time-consuming nature, low quality, infrequent updates, inability to facilitate timely management actions, and complexity. 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 is automatically gathered, additional data must be manually obtained. To increase productivity, they proposed a framework for semi-automated project monitoring and control. The framework's ultimate objective was to integrate data acquired manually and automatically seamlessly.

## A. Construction Progress Monitoring

Construction progress tracking, also known as construction progress monitoring, serves as a project's roadmap 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—is provided by effective progress monitoring. This includes whether we are on track, on budget, and achieving quality standards. To enable decision-makers to identify problems, allocate resources sensibly, and maintain project momentum for 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 relies on manual data collection methods, including 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 the 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 challenging to identify and handle concerns quickly [7]. Delayed understanding of project developments may result in delayed response times, hindering the ability to minimise risks and address emerging 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 cooperation can lead to misunderstandings and delays [2]. 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 collection. The need for physical presence creates issues related to travel limitations 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 poses a threat to 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. Utilising technology to support progress monitoring, these strategies were categorised into six primary 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:



Conventional ICT encompasses email, multimedia tools, interactive voice response (IVR), handheld computers (such as Personal Digital Assistants or PDAs), and other 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:** These techniques involve the use of tags and codes that can be attached to various resources on-site and are primarily 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 examples of these technologies. Every tag operates on the principles of Automatic Identification and Data Capture (AIDC) [3]. It is essential to note that tag-based technologies are unable to work in conjunction 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 multiple 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 emerging field focuses on utilising visual inputs to extract 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, to identify and effectively exploit these, a thorough analysis is required. It is worth noting that several case studies have demonstrated the effective integration of appropriate technology into sites, and it has been found that time and cost overruns have been significantly reduced.

#### 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 specific technological infrastructure challenges. To begin, internet connectivity is a significant challenge, particularly in remote construction sites where access to high-speed internet is often limited. Because of the dependency on real-time data transfer, robust and dependable internet connections are required for continuous monitoring [1].

Second, the availability and cost of modern hardware provide a significant challenge. The adoption of cutting-edge monitoring equipment often requires substantial 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 a careful evaluation of various cost-related aspects. The initial cost necessary to establish monitoring systems is a significant financial commitment. This includes the expenditures of procuring hardware, software, and other key components. The economic feasibility of this initial expenditure is an essential 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 correctly and perform optimally. These ongoing costs must be factored into the long-term budget to ensure the monitoring system remains functional. Software licence costs are another component of the financial environment. The use of complex monitoring software frequently requires license agreements, which add to the overall cost of deployment [7]. These fees, as well as potential scalability considerations, must be carefully evaluated and understood 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.

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

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 delicate balance to ensure financial viability.

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

The seamless integration of monitoring technologies into existing construction processes is critical to their effectiveness. Instead, technology should complement and enhance existing operations, rather than disrupting 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 essential 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.

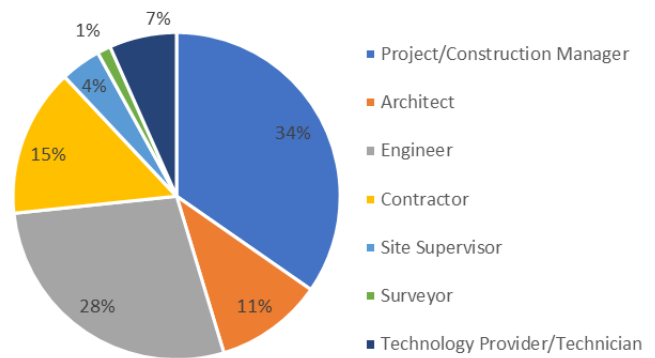


Figure 2: Distribution of the Respondents Across Various Roles

Figure 3 shows that the majority of respondents (48%) had 6-10 years of experience in the construction industry. 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 implementing Automated Construction Progress Monitoring. 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 comprised 12% of the sample, bringing seasoned expertise to the survey and potentially providing valuable insights into long-term trends and industry development.

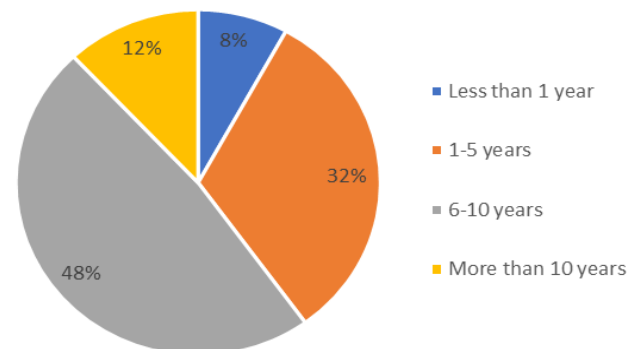
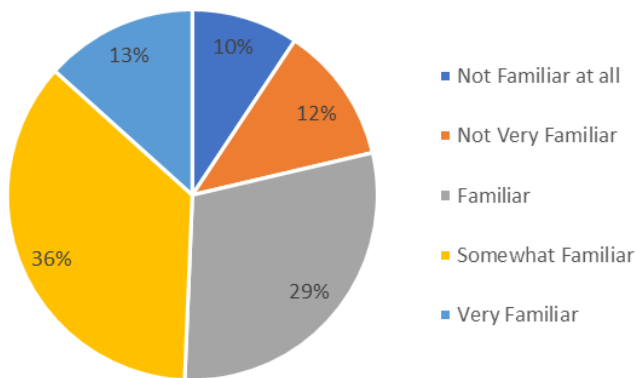


Figure 3: Distribution of Respondents' Experience Level

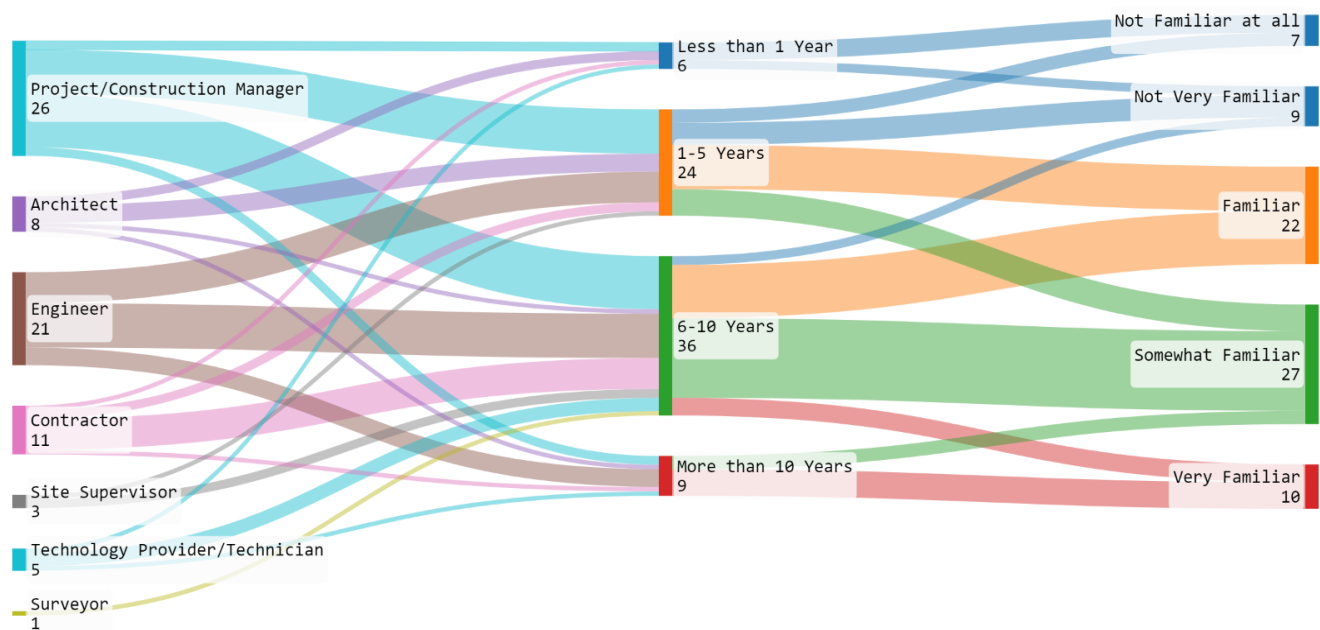
The familiarity of survey participants with Automated Construction Progress Monitoring varies depending on their level of exposure and understanding of the concept. While 36.00% of respondents reported being very familiar with Automated Construction Progress Monitoring, a sizable proportion (9.33%) reported being completely unfamiliar with it. 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.





**Figure 4: Distribution of Respondents' Familiarity with the Concept of Automated Construction Progress Monitoring**

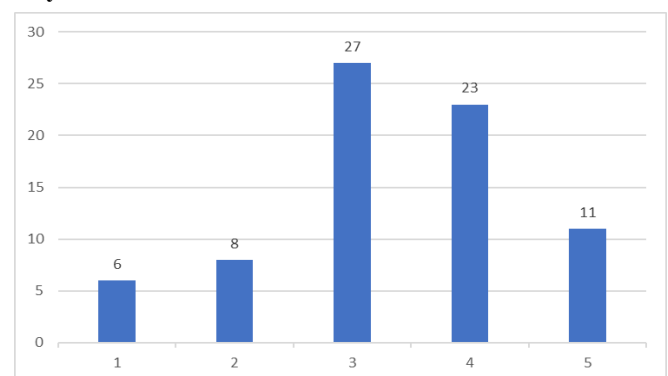
Figure 5 also shows a Sankey Diagram, which illustrates the complex relationship between respondent roles, the



**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 practices 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 six 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.

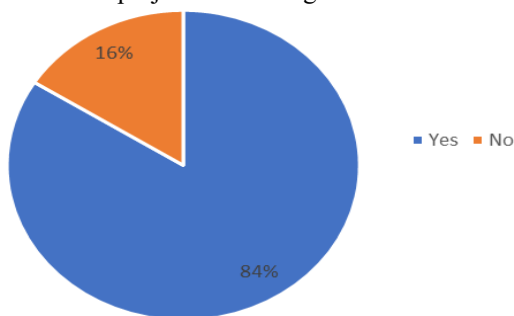


**Figure 6: Reliability of Manual Data Collection on Likert Scale (1-Not Reliable, 5- Completely Reliable)**

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.

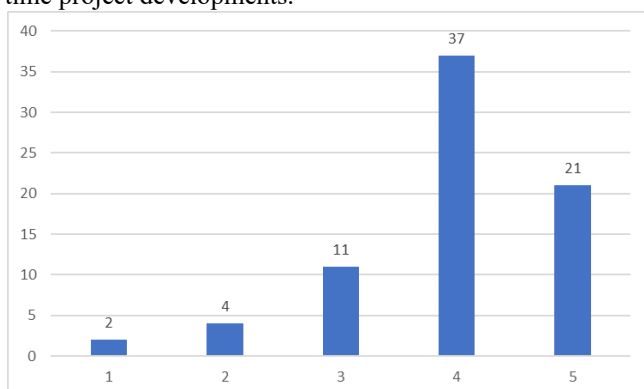
# Analysing Factors Affecting Implementation of Automated Construction Progress Monitoring in Indian Construction Industry

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.



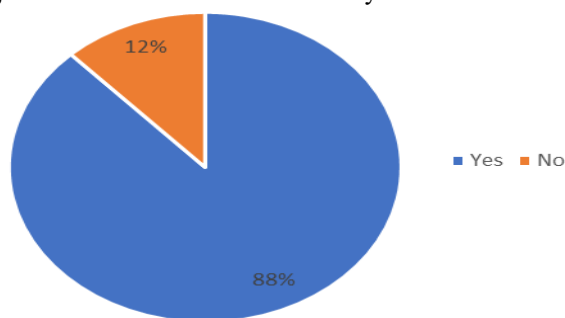
**Figure 7: Respondents Encountered Challenges in Manual Data Collection**

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.



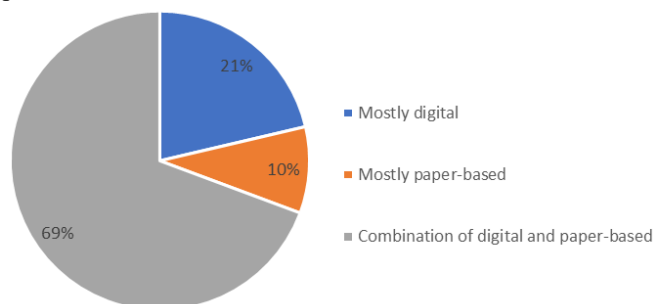
**Figure 8: Personnel Requirement to be Physically Present at the Site for Data Collection or Monitoring Activities**

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.



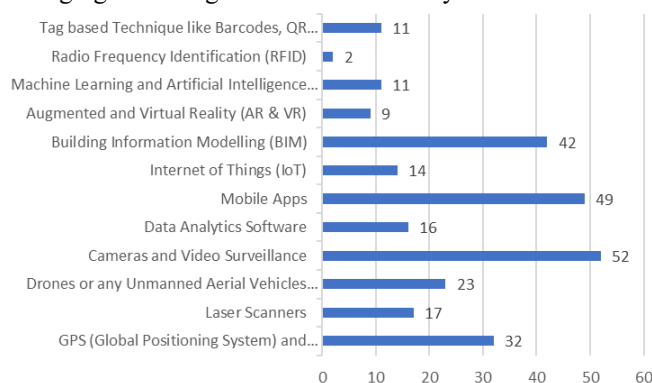
**Figure 9: Respondents Encountered Challenges for Travel Constraints and On-Site Dependencies**

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 offer benefits in terms of accessibility, organisation, and data retrieval, the continued reliance on paper-based documentation suggests a degree of inertia or difficulty 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 practices. 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, specific 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.

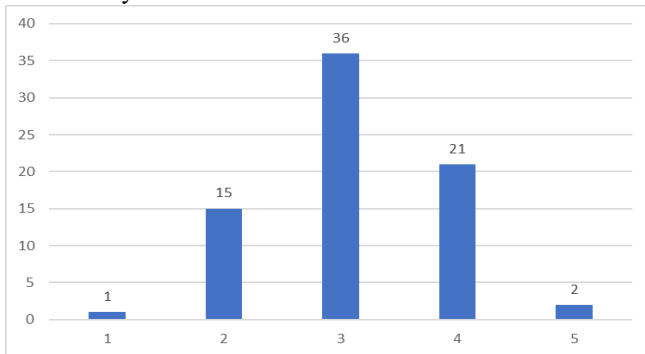


**Figure 11: Technologies Currently Being Adopted for Construction Project Monitoring Practices**

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

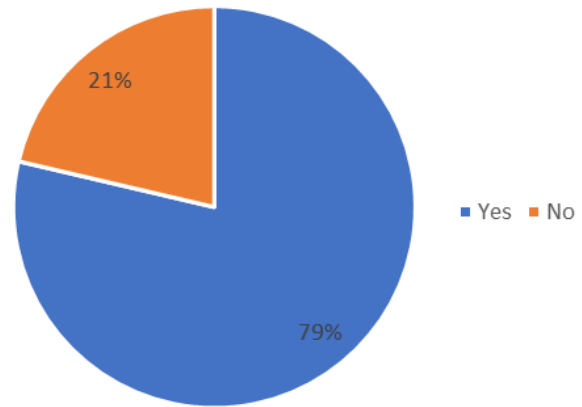


In particular, 48% of respondents rated real-time information availability as "average" (rated 3), while 20% rated it as "below average" (rated 2). On the extremes, only 2.67% rated it as "very poor" (rated 5), while 1.33% rated it as "excellent" (rated 1). These findings indicate that, while a significant 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 experiencing problems or difficulties due to 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 informed 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 inform strategies for enhancing project management practices, improving 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 helps determine 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 reactions, 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:

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

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	Number 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

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

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, which assess the perceived impact of various factors on the implementation of Automated Construction Progress Monitoring in the Indian construction industry, provide nuanced insights into the priorities, challenges, and considerations of industry professionals.

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, such as sensors, drones, and monitoring devices, in facilitating the effective implementation of Automated Construction Progress Monitoring. The emphasis on hardware availability emphasises the importance of access to modern technology solutions and the affordability of acquiring and deploying such equipment, which is 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, such as sensors, drones, and monitoring devices, in enabling the effective implementation of Automated Construction Progress Monitoring. The emphasis on hardware availability highlights the importance of having access to modern technology solutions, as well as the affordability of purchasing and deploying such equipment, both of which are necessary 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 implementing Automated Construction Progress Monitoring, 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 the implementation of Automated Construction Progress Monitoring, 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 incorporate 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 minor impact on the implementation of Automated Construction Progress Monitoring than other factors. While data security and regulatory compliance are unquestionably essential considerations, the findings suggest that they may not be perceived as immediate barriers or enablers to the adoption of Automated Construction Progress Monitoring by the surveyed sample. In summary, the detailed analysis of survey results reveals the multifaceted nature of the factors influencing the implementation of Automated Construction Progress Monitoring 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 essential 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.



#### D. Mitigation Strategies and Recommendations Development

Based on the research findings 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 This Technology.

To mitigate the impact of budget constraints, stakeholders should explore innovative financing models, such as public-private partnerships or leasing arrangements, to spread the upfront costs of hardware acquisition and implementation over a longer period. 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. Ultimately, awareness campaigns and capacity-building initiatives can cultivate a culture of innovation and technology adoption in the construction industry, encouraging stakeholders to view Automated Construction Progress Monitoring as a transformative tool for enhancing project efficiency, productivity, and sustainability. By implementing these mitigation strategies and recommendations, the construction industry can overcome barriers to the implementation of Automated Construction Progress Monitoring 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 practices, 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 practices 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, to drive the successful implementation of Automated Construction Progress Monitoring. 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.

#### DECLARATION STATEMENT

Funding	No, I did not receive.
Conflicts of Interest	No conflicts of interest to the best of our knowledge.
Ethical Approval and Consent to Participate	No, the article does not require ethical approval or consent to participate, as it presents evidence that is not subject to interpretation.
Availability of Data and Materials	Not relevant.
Authors Contributions	All authors have equal participation in this article.

#### REFERENCES

- Xue, J., Hou, X., & Zeng, Y. (2021c). Review of Image-Based 3D Reconstruction of Buildings for Automated Construction Progress Monitoring. *Applied Sciences*, 11(17), 7840. <https://doi.org/10.3390/app11177840>
- Alizadehsalehi, S., & Yitmen, İ. (2018b). A concept for Automated construction progress monitoring: Technologies adoption for benchmarking project performance control. *Arabian Journal for Science and Engineering*, 44(5), 4993–5008. <https://doi.org/10.1007/s13369-018-3669-1>
- Reja, V.K., Pradeep, M.S., & Varghese, K. (2022). A Systematic Classification and Evaluation of Automated Progress Monitoring



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

- Technologies in Construction. Proceedings of the ISARC. <https://doi.org/10.22260/isarc2022/0019>
4. Qureshi, A. H., Alaloul, W. S., Wing, W. K., Saad, S., Ammad, S., & Musarat, M. A. (2022). Factors Affecting the Implementation Process of Automated Construction Progress Monitoring. *Ain Shams Engineering Journal*, 13(6), 101808. <https://doi.org/10.1016/j.asej.2022.101808>
  5. Brilakis, I. K., & Soibelman, L. (2008). Shape-based retrieval of construction site photographs. *Journal of Computing in Civil Engineering*, 22(1), 14-20.
  6. Kopsida M, Brilakis I, Vela P. A review of automated construction progress and inspection methods. In: Proc. 32nd CIB W78 Conf. Constr. IT; 2015: pp. 421– 431.
  7. Pazhoohesh M, Zhang C. Automated construction progress monitoring using thermal images and Wireless Sensor Networks. In: Proceedings, Annu. Conf. - Can. Soc. Civ. Eng., 2015: pp. 593–602.
  8. Son H, Kim C. 3D structural component recognition and modelling method using colour and 3D data for construction progress monitoring. *Autom Constr* 2010;19(7):844–54. doi: <https://doi.org/10.1016/j.autcon.2010.03.003>.
  9. Alaloul WS, Qureshi AH, Musarat MA, Saad S. Evolution of close-range detection and data acquisition technologies towards automation in construction progress monitoring. *J Build Eng* 2021; 43:102877. doi: <https://doi.org/10.1016/j.job.2021.102877>.
  10. El-Omari S, Moselhi O. Integrating automated data acquisition technologies for progress reporting of construction projects. *Autom Constr* 2011;20 (6):699–705. doi: <https://doi.org/10.1016/j.autcon.2010.12.001>
  11. Qureshi, A. H., Alaloul, W. S., Wing, W. K., Saad, S., Musarat, M. A., Ammad, S., & Kineber, A. F. (2023). Automated progress monitoring technological model for construction projects. *Ain Shams Engineering Journal*, 14(10), 102165. <https://doi.org/10.1016/j.asej.2023.102165>

## AUTHORS PROFILE



**Mohd Sameer Malik**, an aspiring Project Manager and Architect, is currently pursuing a Master of Building Engineering and Management at the School of Planning and Architecture in Vijayawada, India. He holds a Bachelor's degree in Architecture from Dr. A.P.J. Abdul Kalam Technical University, Lucknow, which he graduated from in 2020. With two years of experience,

he excels in onsite execution, project coordination, and interior fitouts. His impactful roles include serving as a Research Fellow at the Mussoorie Dehradun Development Authority and as an Architect at Sustainable Alternatives, where he has made significant contributions to projects such as the Pradhanmantri Sangrahalaya and Vision Doon 2040. His research interests lie in the areas of digital transformation in the construction industry and innovative project management strategies. He has published research papers in reputable journals, including those from the Springer Nature Group, and contributed to scholarly discussions in these domains.



**Dr. M. Kranti Kumar** is currently an Assistant Professor at the School of Planning and Architecture, Vijayawada, Andhra Pradesh, India. He received B.Arch. Degree from JNTU, Hyderabad, Telangana, India in 2001. He pursued a Master's degree (M.Sc. in Construction Management) from the University of South Bank, London, in 2003, and completed a doctorate from the School of Planning and Architecture, Vijayawada. He

is also a member of the Council of Architecture and a Fellow member of the Indian Institute of Architects. He has 23 years of industrial experience and 14 years of academic experience. He has over 20 publications, presented at many international conferences, and has areas of interest in construction management and daylighting as part of his research.

**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)/ journal and/or the editor(s). The Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP) and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.