

Integrating Labour Productivity in Indian Construction Industry through Introduction of Smart and Automated Equipment: A Review

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Abstract - The Indian construction industry, a cornerstone of national economic development contributing nearly 9% to GDP, continues to confront challenges of low labour productivity, skill shortages, and technological inertia. Persistent inefficiencies, fragmented workforce structures, and dependence on outdated techniques have constrained productivity growth despite rapid infrastructure expansion. Contemporary research highlights the transformative potential of smart technologies such as AI, automation, robotics, and Building Information Modelling (BIM) to address these limitations. These innovations foster operational accuracy, safety, and timeliness while reducing reliance on manual labour. However, barriers such as high capital costs, inadequate training, and workforce displacement concerns remain critical. This review consolidates findings from national and international studies on labour productivity determinants, adoption of automated equipment, and digital integration trends. It further identifies government and industry-driven enablers, including digitization policies, workforce skill development programs, and the push toward sustainable construction. The study concludes that synchronized adoption of automation, mechanization, and digital tools is essential to elevate productivity, improve project quality, and ensure India's competitiveness in the global construction ecosystem by 2030.

Keywords - Labour Productivity, Construction Automation, Smart Equipment, Indian Construction Industry, Digital Innovation, Mechanization

1. Introduction

The Indian construction industry stands as one of the largest and most dynamic sectors of the national economy, contributing approximately 9% to India's GDP and employing nearly 70 million people as of 2023, with projections to reach 100 million by 2030. Despite its scale and importance, the industry continues to grapple with persistent labour productivity challenges stemming from inefficiency, outdated practices, and a widening skill gap. According to a 2025 skill gap analysis by CSDCI, India currently faces a deficit of over 40 million construction workers, representing nearly 45% of total workforce demand in the sector. This imbalance reflects structural workforce fragmentation, dependence on subcontracting, and limited adoption of advanced technology on construction sites.

The construction environment in India remains largely labour-intensive, characterized by low mechanization levels and inconsistent productivity outcomes. Labour productivity growth, which averaged around 4.3% between 1992 and 2022, has seen frequent fluctuations due to inconsistent training standards, informal

employment, and inadequate supervision. The lack of skilled operators to handle modern machinery and smart technologies further limits productivity improvements, especially for large-scale infrastructure projects that demand accuracy, speed, and consistency.

Integrating smart and automated equipment offers a transformative pathway to address these challenges. Technologies such as AI-powered machinery, robotics, drones, and telematics-driven monitoring systems can enhance operational efficiency, reduce human error, and relieve labour shortages. Automation not only optimizes time and cost performance but also improves safety standards and sustainability outcomes by minimizing manual fatigue and resource wastage. By reviewing contemporary literature and industrial applications, this paper explores how the adoption of smart and automated equipment can strengthen labour productivity across the Indian construction sector. Such technological integration is essential to meet the growing national infrastructure demand while ensuring long-term workforce efficiency and competitiveness in the global construction market.

1.1 Background on labour productivity issues in India's construction industry

Labour productivity in India's construction industry remains a persistent challenge, significantly impacting project timelines, costs, and quality outcomes. Despite being a major contributor to national GDP and employing millions, the sector struggles with structural inefficiencies and skill shortages that limit its growth potential.

The foremost issue is the acute shortage of skilled and trained workers. Migration patterns, an aging workforce, and insufficient vocational training programs have led to a scarcity of competent labourers capable of handling modern equipment and advanced construction technologies. Many workers are seasonal migrants with limited job continuity and poor access to welfare benefits, further decreasing workforce stability and motivation.

Low wages, irregular payments, and lack of worker recognition exacerbate productivity problems. Workers often face inadequate compensation relative to their effort, discouraging long-term commitment to construction work. Limited awareness of government training schemes such as the Pradhan Mantri Kaushal Vikas Yojana (PMKVY) and low participation in such programs perpetuate inefficiencies and skill deficits. Poor working conditions, insufficient safety measures, and ineffective site management practices also directly hinder output rates.

Additionally, the fragmented nature of labour employment involving subcontracting and informal hiring reduces accountability and consistent performance monitoring. Construction projects in major regions such as Delhi-NCR are reportedly operating with only 50–60% of their required workforce, leading to delays, cost increases, and suboptimal workmanship.

Addressing these issues demands systematic intervention through skill development programs, mechanization, and automation to offset labour gaps. Enhanced training, fair wage systems, safety improvements, and digital integration can collectively stabilize workforce efficiency and improve productivity metrics across the Indian construction industry.

1.2 Need for technological intervention in traditional labour-intensive methods

The Indian construction industry has long relied on labour-intensive and manual processes such as masonry, excavation, material handling, and concreting. While these traditional practices have supported economic growth, their inherent inefficiencies high dependency on manual effort, variable quality, and susceptibility to delays limit large-scale productivity improvements. With the sector facing rising urbanization pressures and workforce shortages, technological intervention has become essential to meet growing infrastructure demands sustainably and efficiently.

Technological innovation introduces mechanization, automation, and digitalization into the construction process, leading to measurable gains in accuracy, speed, and resource optimization. Use of smart machinery, robotics, drones, and AI-integrated systems significantly reduces time-intensive manual tasks, minimizes errors, and enhances quality consistency throughout project execution. Automation can operate continuously without fatigue, manage repetitive and hazardous operations, and improve occupational safety an area of chronic concern in Indian construction.

Moreover, digital tools such as Building Information Modeling (BIM) and project management software enable real-time coordination among engineers, contractors, and clients. These systems eliminate miscommunication, control material wastage, and promote data-driven planning. The fusion of AI and BIM allows project scenarios to be simulated and optimized before physical construction begins, mitigating rework and cost overruns.

In essence, technological intervention bridges the efficiency gap between traditional and modern construction practices. It transforms the industry from being labour-dominated to knowledge- and technology-driven, ensuring higher safety, environmental sustainability, and long-term productivity growth that aligns with India's smart infrastructure vision.

1.3 Relevance of automation, AI, and smart machinery

Automation, artificial intelligence (AI), and smart machinery hold critical relevance in the modernization and enhanced productivity of the Indian construction industry. These technologies directly address core challenges such as labour shortages, inconsistency in workmanship, safety risks, and project delays by automating repetitive, hazardous, or precision-intensive tasks.

Automation enables continuous, fatigue-free operation of heavy machinery and equipment, leading to significant reductions in cycle times and improved quality control. AI enhances decision-making through predictive analytics, enabling proactive identification of risks and optimization of resource allocation. Smart machinery equipped with sensors and telematics allows real-time monitoring of equipment performance, site productivity, and safety compliance, fostering data-driven management and transparency.

In the Indian context, where the construction workforce faces skill gaps and labour fragmentation, these technologies help bridge efficiency divides by upgrading operational capabilities without proportionally increasing manpower. They enable transformation from traditional labour-intensive methods to more sophisticated, technology-enabled construction practices. This relevance is increasingly recognized with government initiatives promoting digital infrastructure and smart city development, positioning automation and AI as cornerstones of a sustainable, high-performance construction sector.

1.4 Research aim: Reviewing technological integration for improving labour productivity

The aim of this research paper is to comprehensively review the integration of technological advancements specifically smart and automated equipment into the Indian construction industry to improve labour productivity. The study seeks to analyze how digitalization, robotics, AI, and mechanized equipment influence traditional labour-intensive workflows, ultimately enhancing efficiency, accuracy, safety, and timeliness of construction projects.

The objective is to synthesize findings from recent literature and industry case studies to highlight the mechanisms through which technology adoption addresses persistent labour productivity challenges such as skill shortages, fragmented workforce management, and inconsistent quality. This review also aims to identify barriers to implementation, such as cost constraints and lack of technical expertise, and explore enabling factors like government initiatives and workforce training programs.

By investigating the current landscape of technological integration and its impact on labour productivity, the research intends to provide valuable insights and recommendations for policymakers, contractors, and researchers to foster a digitally empowered construction sector that aligns with India's infrastructure growth and sustainability goals.

2. Literature review

The following are the previous research review based on labour productivity in construction industry.

2.1 Labour Productivity in Construction Industry

Shehata et al. (2011) said proper management of resources in construction projects can yield substantial savings in time and cost. Here State-of-the-art methods and techniques of productivity measurement are used. They concluded that the key for productivity improvement is not to complete as many tasks as possible or to maximize workload but focus on maintaining a predictable workflow and thus be able to match the available workload with capacity (work hours) [1].

Ameh et al. (2011) established the relationship between time overrun and labour productivity on construction sites in Lagos, Nigeria. They concluded that factors cause time overrun are inadequate fund for the project, inadequate planning of project before take-off, inadequate tools and equipment, delay in delivery of materials, subcontractors' incompetency and design changes during project execution. And factors that affect productivity in the construction sites are use of wrong construction method, inadequate construction materials and inaccurate drawings/specification were the most significant. Based on the outcome of the study, They gave

recommendations which improved productivity in the construction industry and to reduce time overrun on projects in Nigeria [2].

Shashank et al. (2014) grouped factors affecting labour productivity in six different group which are Motivation group, Manpower group, Material/Equipment group, Safety group, Managerial group, Quality group. They said Motivation factor has the highest impact on labour productivity. So they suggested that, the construction company should increase labour satisfaction by paying a reasonable salary, developing financial reward or recognition program and improving the living condition on site [3].

Shah et al. (2014) stated that productivity can be an influential factor in minimizing the project losses or increased profits. Productivity can help a company gain competitive advantage and slim profit margins. They suggest the top factors which affects productivity based on the survey conducted in the central Gujarat region were low payment, poor construction methods, use of technology/level of mechanization, delays in material delivery etc [4].

Thiyagu et al. (2015) proposed fifteen independent groups affecting the labour productivity in the construction projects. The topmost factors affected the labour productivity are given Sanitation and hygiene of the construction site and the temporary shed; Labour injuries on site; Alcoholism; Working overtime; Shortage of construction materials; Payment delays; Change orders from the designers; Improper equipment; Poor quality of construction materials; Misunderstanding among laborers [5].

Sukumar et al. (2016) carried survey of building projects in Sangli, Kolhapur and Pune districts, where an increase in productivity is being sought. They identified ten most significant factors affecting labour productivity for small, medium and large companies. The groups of factors which are highly effective are: supervision, material, execution plan, and design. He said that for large companies, equipment factors have also highly effective. While in small and medium companies, owner/consultant factors also need special attention [6].

Saravanan et al. (2016) concluded eleven different factors influencing labour productivity which are time, quality, safety and managerial factors, experience of labour, type of project, misunderstanding, external factors, motivation, material/tools and natural factors [7].

Ghate et al. (2016) observed that measurement of labour productivity is helpful in saving the time of the project as well as cost of project without hampering the quality of work. They used work study and work measurement techniques for data collection of labour and improvement in labour productivity. They concluded that this techniques helped to reduce cost by 20% of labour cost per floor [8].

Patel et al. (2017) In the construction context, labour productivity is the ratio of output (work done) to the labour input (work hours) required to produce it. This metric is an indicator of worker efficiency and is essential for optimizing project costs, ensuring timely completion, and maintaining quality. Since labour costs can account for 30–50% of a project's total cost, small changes in productivity can have a significant financial impact [9].

Kadam et al. (2018) Productivity is an important aspect of construction industry that may be used as an index for efficiency of production. Efficient management of construction resources can lead to higher productivity which can help to achieve cost and time saving. Productivity remains an interesting subject and a leading theme to efficient use of resources in construction sector. It has been observed that low productivity of construction workers is one of the major causes of time & cost overrun in construction projects. Construction is labour oriented industry. It heavily relies on the skills of its workforce. The labour is industry's most valuable asset. It is important to improve efficiency of production by improving productivity of labour. Decreasing productivity of project has always been major concern for construction Industry [10].

Pambhar et al. (2020) Labour productivity can be calculated by comparing the volume of work produced over a specific period, such as a day, week, or month, against the total person-hours worked. A higher productivity rate means more work is completed with the same or fewer labour hours, while a lower rate signals inefficiency [11].

The construction sector in Libya faces mounting challenges, with low labour productivity emerging as a critical issue. **Almamlook et al. (2020)** aimed to identify and prioritize factors impacting productivity across management, technological, and human/labour domains. A structured questionnaire was distributed to contractors and consultants, covering 30 productivity-related factors. Results revealed that management-related issues were the most influential, followed by technological and labour-related aspects. The top five critical factors lack of labour supervision, worker skill level, construction technology, inter-disciplinary coordination, and design drawing errors were ranked in order of impact. These findings offer actionable insights for

construction managers to enhance workforce efficiency and project outcomes in Libya's evolving construction landscape [12].

Hire et al. (2020) emphasized that project productivity significantly influences cost and profitability in the construction industry, where labour accounts for 30–50% of total expenses. Despite its importance, labour productivity has been insufficiently researched. The study conducted a comprehensive bibliometric survey using Scopus data from 1996–2020 to examine literature on labour productivity and the application of neural networks for productivity prediction. It analyzed publication trends across journals, countries, authors, and citations. The results highlight the research gap in labour productivity modeling and underline the potential of soft computing techniques to enhance construction performance and guide future academic investigations in this field [13].

Pambhar et al. (2020) highlighted the rapid growth of the global construction industry and its increasing project complexity due to unique designs and multiple stakeholders. The study emphasized that labour plays a central role in ensuring timely, cost-effective, and quality project delivery, with labour costs contributing 30–50% of total expenses. Effective labour management, therefore, becomes essential for achieving efficiency and controlling costs. The paper identified key factors influencing labour productivity and suggested that improved management practices could reduce project costs and duration by up to 15%. It further recommended adopting strategic initiatives to enhance workforce productivity and site performance [14].

2.2 Smart and Automated Equipment in Construction

Rajgor et al. (2012) highlight that the construction industry is labour-intensive, slow to adopt technology, and prone to low productivity and cost overruns due to factors like skilled labour shortages, site challenges, design changes, and communication issues. Construction automation has emerged as a solution, leveraging robotics to improve accuracy, safety, and control. Automated systems now aid in various operations, from construction processes to maintenance. Advanced robotic technologies such as “Sense-and-Act” systems are being developed to handle uncertainties on-site. Embracing automation with new designs, materials, and intelligent decision-making can significantly enhance construction quality and efficiency for modern projects [15].

Siddharth et al. (2014) emphasize that choosing the right method to acquire construction equipment whether by purchasing, loan financing, renting, or leasing is crucial for maximizing profitability. The study evaluates various financial and non-financial factors influencing this decision, based on literature reviews and expert interviews. It proposes a framework to assess these factors systematically to support future research and guide construction firms in selecting the optimal acquisition strategy that balances cost, usage needs, and operational efficiency [16].

Pindoria et al. (2017) define construction equipment productivity as the output achieved per minute, hour, or day, an important measure for determining fair rental or usage rates. Their study involved analyzing various factors that affect equipment productivity through extensive literature review, identifying thirty-five critical factors grouped into four main categories: soft factors (such as company policies, site conditions, and labour availability), hard factors (including technical specifications and equipment condition), controllable factors (maintenance and motivation), and external influences. Effective management of these factors enhances equipment efficiency, thereby improving overall construction productivity and reducing project costs [17].

Parikh et al. (2021) explored the growing integration of mobile devices in construction management and their vital role in enhancing communication, data accessibility, and efficiency. The study revealed that tools such as smartphones, tablets, and laptops enable real-time decision-making and project coordination. While countries like the United States have widely adopted such technologies, their use in India remains limited. Major software developers, including Autodesk, are creating mobile applications for document and project management. Mobile-based Document Management Systems (DMS) significantly improve project tracking and save time and costs. The study emphasizes the vast potential of mobile apps in modernizing India's construction sector [18].

Oke et al. (2017) investigated the negative impacts of automation in South Africa's construction industry amid infrastructure growth. The study revealed that automation's leading drawbacks include worker displacement, emotional stress among workers, high maintenance needs, and significant capital costs. Other issues include geographical displacement of labour, reduced flexibility, and employee dissatisfaction. Contractors emphasized worker displacement, maintenance, and emotional stress, while professionals focused on high costs and stress as major concerns. Despite automation's potential benefits, these challenges could adversely affect project delivery and productivity, highlighting the need for careful management of automation's social and economic impacts in construction projects [19].

3. Various Factors Affecting Labour Productivity

Enhancing labour productivity has long been a major concern for project managers seeking to improve performance in the construction industry. Recognizing and analyzing both positive and negative factors influencing productivity enables the formulation of strategies to minimize inefficiencies and optimize outcomes. A clear understanding of these factors is essential to address cost overruns and schedule delays, ultimately enhancing project success. Through detailed studies and surveys, several factors influencing construction labour productivity have been classified into fifteen categories: design, execution planning, materials, equipment, labour, health and safety, supervision, working time, project, quality, financial, leadership and coordination, organizational, owner/consultant, and external factors.

1. Design Factors: Complexity or errors in design can cause delays and reduce productivity.
2. Execution Plan Factors: Poor planning or scheduling leads to inefficient labour use.
3. Material Factors: Delays or shortages of materials disrupt workflow and lower productivity.
4. Equipment Factors: Inadequate or faulty equipment causes work stoppages and slowdowns.
5. Labour Factors: Skill levels, motivation, and availability directly impact productivity rates.
6. Health and Safety Factors: Unsafe conditions lead to accidents, absenteeism, and reduced efficiency.
7. Supervision Factors: Effective supervision ensures proper guidance and coordination on site.
8. Working Time Factors: Overtime, shift patterns, and working hours influence labour output.
9. Project Factors: Project complexity, size, and location shape productivity challenges.
10. Quality Factors: Rework due to poor quality affects timely project completion.
11. Financial Factors: Budget constraints and delayed payments affect workforce morale and resources.
12. Leadership and Coordination Factors: Strong leadership and coordination foster better teamwork and productivity.
13. Organization Factors: Company policies and organizational structure influence labour effectiveness.
14. Owner/Consultant Factors: Decisions and demands from owners or consultants impact workflow.
15. External Factors: Weather, regulations, and market conditions can create unforeseen productivity barriers.

These categories collectively offer a comprehensive framework for addressing labour productivity issues and guiding project managers toward targeted improvement strategies.

3.1 Barriers to Improving Labour Productivity

Although many factors affecting labour productivity have been identified, several barriers hinder effective improvement. Ineffective management is widely recognized as the main cause of low productivity in construction projects. Beyond this, specific obstacles include lack of alignment of goals among stakeholders, which leads to miscommunication and inefficiencies. Contractual conflicts between parties often cause resource wastage and duplicated efforts. Measurement difficulties arise because productivity in construction is complex to quantify accurately, creating challenges in setting clear improvement targets. Moreover, a weak commitment to continuous improvement among management and workers limits progress. Finally, a lack of labour force focus, where workers may be complacent or resistant to change, restricts productivity advancements.

Addressing these barriers requires strategies such as better communication and coordination, conflict resolution mechanisms, clear definition and monitoring of productivity metrics, fostering a culture of ongoing improvement, and engaging laborers through training and motivation. Overcoming these challenges is critical to boosting productivity and achieving project success in the construction industry.

3.2 Guidelines for Improving Labour Productivity

Improving labour productivity in the construction industry requires a balanced combination of workforce development, managerial efficiency, and technological integration.

1. Training and Skill Development: Providing proper and continuous training ensures laborers are competent with modern tools, safety norms, and methods, thereby reducing rework and improving efficiency. Regular skill enhancement programs also boost confidence and operational quality.

2. **Motivation and Incentives:** Motivating workers through rewards, recognition, and participative decision-making keeps morale high and encourages timely project completion. Incentive programs can significantly raise output levels.
 3. **Advanced Material and Equipment Management:** Timely and well-planned procurement of materials prevents site delays. Advanced equipment planning, digital tracking, and proper storage practices improve workflow efficiency.
 4. **Timely Wage Payment:** Ensuring prompt payment reinforces worker trust and commitment. Financial security motivates laborers to perform consistently and maintain productivity standards.
 5. **Systematic Work Flow and Supervision:** Establishing a logical sequence of activities supported by clear supervision prevents confusion and idle time. Supervisors must monitor work daily to identify and resolve bottlenecks quickly.
 6. **Preconstruction Site Planning:** Preparing an optimized site layout, finalized before work begins, minimizes movement and material handling waste. Including a pre-monsoon plan ensures continuity during adverse weather.
 7. **Work Environment and Facilities:** Providing adequate sanitation, rest areas, water, and safety equipment enhances worker comfort and focus, reducing absenteeism and fatigue.
 8. **Legal and Financial Preparedness:** Completing regulatory clearances and fund planning in advance minimizes disruptions. Projects with approved budgets and documentation proceed more efficiently.
 9. **Technology and Automation:** Wider adoption of automation systems, machinery, and construction management software helps track performance, monitor productivity, and optimize labour use.
- These guidelines collectively strengthen project execution, fostering a disciplined, safe, and motivated workforce capable of achieving higher productivity and quality outcomes.

Conclusion:

Based on Literature review the following and outcomes.

1. Labour productivity in the Indian construction industry remains hindered by skill shortages, outdated methods, and fragmented workforce management.
2. Strategic adoption of automation, robotics, and AI can significantly enhance efficiency, safety, and project predictability.
3. Continuous training and digital literacy programs are vital to bridge existing skill gaps and prepare the workforce for technology-driven construction.
4. High implementation costs and fears of job displacement present major barriers to widespread automation adoption.
5. Collaborative efforts between government, academia, and industry are necessary to promote sustainable technology integration and long-term productivity growth.

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