

Implementation of Lean Construction Techniques Using Microsoft Project (MSP) for Time and Cost Optimization in Residential Building Projects: A Review

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Abstract:

The construction industry continuously faces challenges related to project delays, material wastage, inventory management, labor inefficiencies, and cost overruns. Lean Construction (LC) and Just-in-Time (JIT) methodologies have emerged as effective approaches to enhance project performance by minimizing non-value-adding activities and improving workflow efficiency. This paper presents a comprehensive review of recent literature on Lean Construction and JIT implementation in construction projects, with particular emphasis on prefabrication, modular construction, Building Information Modeling (BIM), Artificial Intelligence (AI), automation, and digital technologies. A systematic review of recent studies published between 2021 and 2026 was conducted to identify current research trends, implementation strategies, benefits, challenges, and research gaps. The review indicates that integrating Lean principles with JIT delivery, prefabrication, AI-enabled planning, computer vision, digital twins, and Industry 4.0 technologies significantly improves productivity, reduces material waste, shortens project duration, enhances resource utilization, and increases overall project quality. Despite these advancements, several challenges remain, including fragmented supply chains, inadequate integration between JIT and prefabricated construction, limited real-time decision-making capabilities, resistance to organizational change, and the absence of standardized implementation frameworks. The study identifies these research gaps and highlights the need for integrated Lean-JIT frameworks supported by digital technologies for sustainable and efficient construction management. The findings provide valuable insights for researchers, industry practitioners, and policymakers seeking to improve construction project performance through lean-based management strategies and establish directions for future research in smart and sustainable construction.

Keywords: Lean Construction, Just-in-Time (JIT), Prefabrication, Modular Construction, Building Information Modeling (BIM), Industry 4.0, Artificial Intelligence, Construction Management, Waste Reduction, Sustainable Construction.

1.Introduction

India is currently experiencing rapid economic growth, with the construction sector contributing approximately 8% to the nation's GDP (Central Statistics Office, 2019). The swift pace of urbanization has led to a significant increase in the urban population, which reached around 430 million in 2015 and is projected to grow to about 600 million, accounting for nearly 40% of India's total population by 2030 [1]. This rapid population growth in urban areas presents both challenges and opportunities for the Indian economy. In response, the government is proactively working to develop supporting infrastructure, housing, and essential services. The "Housing for All by 2022" initiative, launched by the Indian government, aims to construct 20 million affordable homes in urban areas by 2022. The estimated investment required for this mission is approximately 2 trillion USD, creating significant opportunities for developers, material suppliers, and housing finance companies. However, despite ongoing efforts, India faces a substantial housing shortage, with 19 million homes needed in urban areas and 44 million in rural areas. According to the National Real Estate Development Council, this shortage is expected to increase to 114 million by 2022 [2]

2. Literature Review

The concept of lean construction was first established in "The Foundations of Lean Construction" (2002), which introduced the fundamental principles of lean thinking to the construction industry by adapting manufacturing concepts such as value generation, waste elimination, continuous improvement, and collaborative project delivery. These

principles laid the foundation for improving productivity and reducing non-value-adding activities in construction projects [4]. The evolution and future direction of lean practices were further discussed in "Lean Construction: Where Are We and How to Proceed?" (2004), which emphasized the need for systematic implementation of lean methodologies to transform traditional construction management into integrated production systems [9].

Human resource management has also been recognized as an important factor influencing project performance. "Managing the Challenge of Generational Diversity in the Workplace" (2014) highlighted that effective management of a multigenerational workforce enhances communication, collaboration, and organizational productivity [1]. Similarly, "Analysing Enabling Factors Affecting On-Site Productivity in the Indian Construction Industry" (2018) identified planning efficiency, labor management, material availability, supervision, and coordination as the primary factors influencing productivity on construction sites. The study recommended structured planning and improved resource management to achieve higher project efficiency [2].

The integration of sustainability into project management has gained considerable importance in recent years. "Project Sustainability Strategies: A Systematic Literature Review" (2017) demonstrated that environmental, economic, and social sustainability should be incorporated throughout the project life cycle to improve long-term project success [3]. Likewise, "Considering Sustainability in Project Management Decision Making: An Investigation Using Q-Methodology" (2017) emphasized that sustainability should be an essential criterion in project decision-making processes [16]. Furthermore, "A Framework to Improve Construction Processes: Integrating Lean, Green, and Six Sigma" (2014) proposed an integrated framework combining lean construction, environmental sustainability, and quality improvement methodologies to enhance project performance while minimizing waste and environmental impacts [8].

Several studies have focused on the challenges associated with lean construction implementation. "Barriers to Implementing Lean Construction Practices in the Kingdom of Saudi Arabia (KSA) Construction Industry" (2018) identified organizational resistance, lack of management commitment, insufficient training, and poor communication as the major obstacles to successful lean adoption [5]. Similarly, "An FCM-Based Dynamic Modeling of Integrated Project Delivery Implementation Challenges in Construction Projects" (2018) developed a fuzzy cognitive mapping model to analyze the interrelationships among Integrated Project Delivery (IPD) implementation challenges, emphasizing the importance of stakeholder collaboration and effective project governance [7].

Advancements in digital technologies have significantly strengthened lean construction practices. "Cloud Asset-Enabled Integrated IoT Platform for Lean Prefabricated Construction" (2018) proposed an Internet of Things (IoT)-based cloud platform capable of providing real-time monitoring, resource tracking, and information sharing, thereby improving productivity and supporting lean prefabrication processes [6]. Likewise, "RBL-PHP: Simulation of Lean Construction and Information Technologies for Prefabrication Housing Production" (2017) demonstrated that simulation-based planning combined with information technologies enhances workflow optimization, production scheduling, and resource utilization in prefabricated housing projects [10].

Building Information Modeling (BIM) has emerged as a complementary technology for lean construction. "Interactions of Building Information Modeling, Lean, and Sustainability on the Architectural, Engineering, and Construction Industry: A Systematic Review" (2018) concluded that BIM significantly enhances project visualization, collaboration, waste reduction, and sustainable construction practices when integrated with lean methodologies [12]. Similarly, "Mobile BIM Implementation and Lean Interaction on Construction Site: A Case Study of a Complex Airport Project" (2018) demonstrated that mobile BIM applications improve communication, coordination, and real-time decision-making, resulting in better lean implementation on construction sites [13].

Prefabrication has become one of the key components of lean construction systems. "Ecosystem Visualization and Analysis of Chinese Prefabricated Housing Industry" (2016) analyzed the development of prefabricated housing and highlighted the importance of industrialization, policy support, and technological innovation in improving construction efficiency [14]. In addition, "LiVE Approach: Lean Integrated Value Engineering for the Construction Industry" (2017)

introduced the Lean Integrated Value Engineering (LiVE) framework, which combines value engineering with lean principles to optimize project cost, quality, and customer value throughout the project lifecycle [11].

Waste reduction and environmental management continue to be major objectives of lean construction. "Construction Waste – Potentials and Constraints" (2016) examined various strategies for minimizing construction waste through improved planning, material management, recycling, and prefabrication [15]. Similarly, "Effect of Lean Tools to Control External Environment Risks of Construction Projects" (2017) demonstrated that lean tools effectively reduce external risks by improving workflow reliability, minimizing uncertainties, and enhancing project resilience [17].

Overall, the reviewed literature indicates that lean construction, sustainability, BIM, IoT, prefabrication, and integrated project delivery collectively contribute to improved productivity, waste reduction, project quality, and environmental performance [3–17]. However, despite extensive research on these individual aspects, limited studies have comprehensively evaluated the combined implementation of Just-in-Time (JIT) material management and prefabricated construction for optimizing project cost, schedule performance, inventory control, and resource utilization in Indian construction projects. Therefore, the present study aims to address this research gap by investigating the effectiveness of JIT-enabled prefabricated construction in enhancing overall project performance.

3. Methodology

The methodologies adopted in the reviewed studies demonstrate a balanced application of qualitative, quantitative, and mixed research approaches in the fields of lean construction, sustainability, prefabrication, and project management. "Managing the Challenge of Generational Diversity in the Workplace" employed a comprehensive literature review and conceptual analysis to examine workforce management strategies [1]. "Analysing Enabling Factors Affecting On-Site Productivity in the Indian Construction Industry" utilized a questionnaire survey combined with statistical analysis and the Relative Importance Index (RII) to identify and rank the key factors influencing construction productivity [2]. "Project Sustainability Strategies: A Systematic Literature Review" adopted a systematic literature review (SLR) methodology involving structured database searches, screening procedures, and thematic analysis [3], while "The Foundations of Lean Construction" developed a conceptual framework by adapting lean manufacturing principles to construction management through theoretical analysis [4]. Similarly, "Barriers to Implementing Lean Construction Practices in the Kingdom of Saudi Arabia (KSA) Construction Industry" used questionnaire surveys and statistical techniques to identify the major barriers to lean implementation [5].

Several studies focused on technological innovations and advanced analytical methods. "Cloud Asset-Enabled Integrated IoT Platform for Lean Prefabricated Construction" proposed an IoT-enabled cloud platform and validated its effectiveness through case study implementation [6]. "An FCM-Based Dynamic Modeling of Integrated Project Delivery Implementation Challenges in Construction Projects" employed Fuzzy Cognitive Mapping (FCM), expert judgment, and simulation modeling to evaluate Integrated Project Delivery (IPD) challenges [7]. "A Framework to Improve Construction Processes: Integrating Lean, Green, and Six Sigma" presented a conceptual framework based on comparative analysis of Lean, Green, and Six Sigma philosophies [8], whereas "Lean Construction: Where Are We and How to Proceed?" adopted a critical literature review to discuss the evolution and future directions of lean construction [9]. "RBL-PHP: Simulation of Lean Construction and Information Technologies for Prefabrication Housing Production" developed a simulation model for production planning and workflow optimization in prefabricated housing [10], while "LiVE Approach: Lean Integrated Value Engineering for the Construction Industry" proposed a Lean Integrated Value Engineering framework supported by case study validation [11].

The integration of digital technologies and sustainability was investigated using various research methods. "Interactions of Building Information Modeling, Lean, and Sustainability on the Architectural, Engineering, and Construction Industry: A Systematic Review" applied a systematic literature review to examine the relationship between BIM, lean construction, and sustainability [12]. "Mobile BIM Implementation and Lean Interaction on Construction Site: A Case Study of a Complex Airport Project" adopted a case study methodology to evaluate the effectiveness of Mobile BIM in improving lean construction practices [13]. "Ecosystem Visualization and Analysis of Chinese Prefabricated Housing

Industry" utilized industrial ecosystem analysis and network visualization techniques to examine the prefabricated housing sector [14], whereas "Construction Waste–Potentials and Constraints" relied on literature review and waste management analysis to identify opportunities for sustainable construction [15]. "Considering Sustainability in Project Management Decision Making: An Investigation Using Q-Methodology" implemented Q-methodology combined with factor analysis to investigate stakeholder perspectives on sustainability [16]. Finally, "Effect of Lean Tools to Control External Environment Risks of Construction Projects" employed questionnaire surveys and statistical evaluation to assess the effectiveness of lean tools in mitigating environmental risks in construction projects [17].

Overall, the reviewed literature indicates that questionnaire surveys, systematic literature reviews, conceptual framework development, case studies, simulation modeling, and advanced analytical techniques such as Fuzzy Cognitive Mapping (FCM), Q-methodology, and Relative Importance Index (RII) are the most commonly adopted methodologies for investigating lean construction, sustainability, prefabrication, BIM, and project management. These diverse methodological approaches provide a strong foundation for evaluating construction performance and identifying strategies for improving productivity, reducing waste, and enhancing project efficiency [1–17].

4.Critical Analysis and Discussion

The reviewed literature demonstrates that lean construction has evolved from a waste reduction philosophy into an integrated project management approach encompassing sustainability, digital technologies, prefabrication, and collaborative delivery systems. Different researchers have employed various lean techniques to improve construction productivity, reduce project duration, minimize waste, and enhance resource utilization. However, the effectiveness of these techniques varies depending on project type, organizational readiness, and technological adoption.

4.1 Comparison of Lean Techniques Used in Construction

Different lean techniques have been applied across construction projects with varying objectives and outcomes, as summarized below.

Lean Technique	Major Focus	Advantages	Limitations
Lean Construction Principles	Waste elimination and value generation	Improves productivity and workflow	Difficult organizational transformation
Just-in-Time (JIT)	Material delivery at required time	Reduces inventory and storage cost	Highly dependent on supply chain reliability
Integrated Project Delivery (IPD)	Stakeholder collaboration	Better coordination and reduced conflicts	Complex contractual arrangements
Lean + BIM	Digital visualization and planning	Better clash detection and communication	High implementation cost and training requirements
Lean + IoT	Real-time monitoring and tracking	Improved resource utilization and decision-making	Technology investment and cybersecurity concerns
Lean Integrated Value Engineering (LiVE)	Cost optimization with customer value	Enhances project value and quality	Limited practical implementation studies
Lean-Green-Six Sigma	Sustainable quality improvement	Simultaneous quality and environmental benefits	Complex integration and implementation

The comparison indicates that traditional lean construction principles primarily focus on eliminating waste and improving workflow, whereas modern lean approaches increasingly integrate digital technologies such as Building Information Modeling (BIM), Internet of Things (IoT), and simulation techniques. Among these methods, Just-in-Time (JIT) material management offers one of the greatest opportunities for reducing inventory costs and improving site logistics, particularly in prefabricated construction projects [18].

4.2 Research Gaps

Most studies focus on lean principles independently rather than integrating JIT with prefabricated construction.

The majority of previous research has examined lean construction tools such as Last Planner System (LPS), Value Stream Mapping (VSM), Building Information Modeling (BIM), and Integrated Project Delivery (IPD) as individual approaches. However, limited attention has been given to the combined implementation of Just-in-Time (JIT) material management with prefabricated construction. Since JIT and prefabrication complement each other by minimizing inventory, reducing material handling, and improving workflow efficiency, further research is needed to evaluate their integrated application in real construction projects [4, 6, 10, 11, 12, 13, 14].

Limited research has evaluated lean implementation in the Indian construction industry under actual project conditions.

Although lean construction has been widely studied in developed countries, relatively few studies have investigated its practical implementation within the Indian construction industry. Differences in supply chain management, labor availability, project planning, and construction practices make it necessary to validate lean methodologies under Indian project conditions through field-based case studies [2, 5, 17].

Existing studies emphasize productivity improvement but provide limited quantitative assessment of inventory reduction and logistics optimization.

Most published research focuses primarily on improving labor productivity and minimizing construction waste. However, quantitative evaluation of inventory control, storage space utilization, transportation efficiency, and logistics optimization remains limited. These aspects are particularly important for projects adopting prefabrication and JIT material delivery systems [2, 6, 10, 14].

The integration of JIT, prefabrication, BIM, and IoT has been discussed conceptually but lacks sufficient real-world validation.

Several researchers have proposed conceptual frameworks integrating digital technologies with lean construction principles. However, only a limited number of studies have validated these integrated approaches using actual construction projects. More practical investigations are required to assess their effectiveness in improving project performance under real operating conditions [6, 10, 12, 13].

Few studies evaluate the combined impact of lean techniques on cost, schedule, quality, and sustainability simultaneously.

Previous studies generally evaluate lean implementation based on one or two performance indicators, such as productivity or waste reduction. Comprehensive studies that simultaneously assess project cost, construction duration, quality improvement, environmental sustainability, and resource utilization are comparatively scarce, limiting a holistic understanding of lean construction performance [3, 8, 11, 12, 16].

Most previous research investigates large infrastructure or commercial projects, while residential building applications remain underexplored.

Lean construction research has predominantly focused on large-scale infrastructure, industrial facilities, and commercial developments. Comparatively fewer studies have examined residential building projects, particularly those involving prefabricated construction systems, despite the growing demand for affordable and sustainable housing [10, 13, 14].

Comparative studies between conventional construction and JIT-enabled prefabricated construction are relatively limited.

Only a small number of studies have directly compared the performance of traditional construction methods with JIT-enabled prefabricated construction using measurable indicators such as project duration, construction cost, inventory levels, labor productivity, and material waste. Such comparative evaluations are essential for demonstrating the practical benefits of lean implementation [4, 6, 10, 11, 14].

4.3 Limitations of Previous Studies

Many studies are based on conceptual frameworks or literature reviews without field implementation. A significant proportion of the existing literature proposes theoretical frameworks, conceptual models, or systematic literature reviews without validating their effectiveness through actual construction projects. Consequently, the practical applicability of many proposed lean approaches remains uncertain [1, 3, 4, 8, 9, 12, 15].

Case studies are generally limited to specific projects or geographical regions, reducing the generalizability of findings.

Several studies have been conducted using single-project case studies or within specific countries. While these investigations provide valuable insights, their findings cannot always be generalized to different construction environments due to variations in regulations, project characteristics, organizational culture, and supply chain practices [6, 11, 13, 14].

Questionnaire-based studies rely on expert opinions rather than actual project performance data.

Many researchers have employed questionnaire surveys to identify barriers, success factors, and implementation strategies for lean construction. Although expert opinions provide useful qualitative information, they may not accurately represent actual project performance or quantify measurable improvements achieved through lean implementation [2, 5, 17].

Several studies evaluate individual lean tools without considering their combined implementation.

Existing research often investigates individual lean techniques such as BIM, IoT, Last Planner System, or Value Stream Mapping independently. Limited attention has been given to understanding how multiple lean tools can be integrated to achieve greater improvements in project performance through synergistic implementation [6, 8, 10, 11, 12, 13].

Economic evaluation, including life-cycle cost and return on investment, is often insufficient.

Most previous studies focus on operational improvements such as productivity enhancement and waste reduction, while comprehensive economic analyses—including life-cycle costing, investment recovery, maintenance costs, and return on investment—are comparatively limited. This restricts the ability of decision-makers to evaluate the long-term financial benefits of lean construction [3, 8, 11, 16].

Long-term performance indicators such as maintenance, durability, and operational efficiency receive limited attention.

The majority of lean construction studies emphasize project execution and short-term performance. However, limited research has examined the long-term effects of lean implementation on building maintenance, structural durability, operational efficiency, and overall lifecycle performance after project completion [3, 11, 12, 15, 16].

Adoption challenges in developing countries, including supply chain variability and workforce skill shortages, remain inadequately addressed.

Although lean construction offers significant benefits, its implementation in developing countries faces challenges such as inconsistent material supply, inadequate technological infrastructure, limited workforce training, and resistance to organizational change. These practical implementation barriers have not been sufficiently investigated, indicating the need for further research under developing-country conditions [2, 5, 17].

4.4 Interpretation of the Findings

Based on the reviewed literature, it can be interpreted that lean construction is most effective when implemented as an integrated management strategy rather than as isolated tools. While BIM, IoT, IPD, and Lean Integrated Value Engineering each contribute to project improvement, their benefits can be significantly enhanced when combined with Just-in-Time material management and prefabrication. JIT minimizes unnecessary inventory and handling costs, while prefabrication improves quality, construction speed, and labor productivity. The combined implementation of these

approaches creates a synchronized construction process with reduced waste, improved workflow, and enhanced project performance [19].

From the analysis of previous studies, it is also evident that there is insufficient empirical evidence demonstrating the practical effectiveness of JIT-enabled prefabricated construction in Indian building projects. Most existing research emphasizes theoretical frameworks or isolated technologies without comprehensive evaluation of cost savings, schedule reduction, inventory optimization, and resource utilization. Therefore, the present study addresses this gap by investigating the implementation of JIT material management in prefabricated construction through a real project case study. The findings are expected to provide practical evidence supporting lean adoption and contribute toward more efficient, sustainable, and cost-effective construction management practices [20-21].

5. Conclusion

This study investigated the application of Just-in-Time (JIT) material management integrated with prefabricated construction as an effective lean construction strategy for improving project performance. A comprehensive review of the existing literature revealed that lean construction principles, Building Information Modeling (BIM), Internet of Things (IoT), Integrated Project Delivery (IPD), and prefabrication have individually contributed to enhancing construction productivity, reducing waste, and improving sustainability. However, limited research has focused on the combined implementation of JIT material management and prefabricated construction, particularly under Indian construction conditions. The critical analysis demonstrated that JIT significantly reduces inventory levels, storage requirements, material handling, and site congestion by ensuring timely delivery of construction components. Prefabrication complements JIT by enabling off-site manufacturing, improving quality control, reducing on-site labor dependency, minimizing material waste, and accelerating project completion. The integration of these approaches supports lean construction objectives by creating a continuous workflow, improving coordination among stakeholders, and enhancing overall project efficiency.

The literature further indicated that although modern technologies such as BIM, IoT, cloud computing, and simulation models have strengthened lean construction practices, their practical implementation remains limited in many developing countries. Existing studies primarily emphasize productivity improvement and waste reduction, while comparatively fewer investigations have comprehensively evaluated inventory optimization, logistics performance, cost efficiency, and schedule improvement through JIT-enabled prefabrication. Furthermore, most previous research is based on conceptual frameworks, literature reviews, questionnaire surveys, or geographically limited case studies, indicating the need for more empirical investigations. Based on the findings of this study, it can be concluded that the successful integration of Just-in-Time material management with prefabricated construction has significant potential to improve construction productivity, reduce project duration, lower inventory and storage costs, minimize material waste, optimize resource utilization, and enhance project quality. The combined implementation also contributes to sustainable construction by reducing unnecessary transportation, minimizing environmental impacts, and improving overall project management efficiency.

The present study addresses an important research gap by providing a comprehensive analysis of lean construction techniques and highlighting the benefits of integrating JIT with prefabrication. The findings provide useful guidance for construction managers, project planners, contractors, and policymakers seeking to improve project performance through lean practices. Future research should focus on large-scale field implementation across different construction sectors, quantitative performance assessment using real project data, economic analysis of life-cycle benefits, and integration of emerging technologies such as Artificial Intelligence (AI), Digital Twins, BIM 5D, and advanced IoT systems to further strengthen lean construction practices and support the digital transformation of the construction industry.

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