A Lean Construction-Based Evaluation of Prefabrication System Benefits in Modern Construction Projects

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ABSTRACT

This study evaluates the benefits of prefabrication systems in modern construction projects through the lens of lean construction. It addresses persistent inefficiencies in conventional construction, including delays, cost overruns, material waste, quality inconsistencies, safety risks, and poor workflow coordination. A quantitative research methodology, underpinned by a positivist philosophy, was adopted, using a descriptive cross-sectional survey design. Data were collected from 100 built-environment professionals in the Ghanaian construction industry, including contractors, consultants, project managers, quantity surveyors, architects, engineers, site supervisors, and client representatives. A structured questionnaire measured respondents' perceptions of prefabrication typologies, adoption factors, project delivery roles, performance relationships, and key benefits. The findings reveal that hybrid, modular, structural, and panelised prefabrication systems are the most recognised forms. Technological advancement, labour skills, economic considerations, regulatory frameworks, sustainability concerns, supply chain readiness, risk management, and stakeholder collaboration were identified as major factors influencing adoption. The results further show that prefabrication significantly enhances efficiency, quality, cost minimisation, faster project completion, waste reduction, safety performance, human error reduction, and project predictability. The study concludes that prefabrication supports lean construction principles by reducing waste, improving production flow, maximising value, and promoting sustainable project delivery.

Keywords: Prefabrication systems; Lean construction; Modern construction projects; Project delivery performance; Sustainable construction.

INTRODUCTION

The construction industry is under increasing pressure to deliver projects that are faster, safer, cost-efficient, environmentally responsible, and better aligned with client expectations (Firoozi *et al.*, 2024). In this context, prefabrication has emerged as a strategic approach to modern construction, in which building components, elements, or modules are produced in controlled off-site environments and then transported and assembled on site (Tavares *et al.*, 2024). Its relevance has grown as construction firms seek alternatives to conventional site-based methods that are often affected by delays, labour inefficiencies, weather disruptions, material waste, quality inconsistencies, and safety risks. Prefabrication is therefore not only a technological innovation but also an industrialised project delivery system that integrates design coordination, production planning, logistics, and site installation to improve project performance (Shibani et al., 2021). Recent advances in construction technologies, digital design, and automated production have further increased the practical value of prefabrication in modern projects (Jadhav et al., 2023).

Existing studies show that prefabrication can reduce dependence on on-site labour, shorten project duration, improve quality control, and minimise material waste (Legmpelos et al., 2013; Abanda et al., 2017). It also supports sustainability by reducing site disturbance, improving resource efficiency, and enabling more predictable construction outcomes (Wu et al., 2021). However, despite these recognised benefits, the literature remains fragmented in its systematic explanation of how to evaluate them through a lean construction lens. Much of the existing research discusses prefabrication benefits separately. At the same time, limited attention is given to how lean principles such as waste minimisation, value maximisation, flow improvement, continuous improvement, and collaborative planning can provide an integrated basis for assessing prefabrication performance (Koskela and Howell, 2002).

Against this backdrop, this study aims to evaluate the benefits of prefabrication systems in modern construction projects using lean construction as the theoretical foundation. The study contributes theoretically by linking prefabrication performance to lean construction thinking, practically by identifying value-adding benefits for project delivery, and managerially by supporting evidence-based decisions regarding the adoption of off-site construction. Lean construction theory is appropriate because it emphasises waste reduction, production flow, value creation, and continuous improvement in project delivery (Ibrahim *et al.*, 2025).

The remainder of this paper is structured into four sections: a literature review establishing the theoretical and empirical foundations; a methodology outlining the research design; findings and discussion of the results; study implications for policy, research, and practice; and, finally, conclusions.

LITERATURE REVIEW

Conceptualization of Prefabrication Systems in Modern Construction Projects

Prefabrication systems in modern construction projects refer to the production of building components, elements, or modules in a controlled off-site environment before their transportation and assembly on the project site. This concept is closely linked to off-site and modular construction, in which construction activities are partially transferred from the traditional site environment to factory-based production settings (Tavares *et al.*, 2024). In modern construction, prefabrication is increasingly understood as an industrialised project delivery approach that integrates design coordination, material production, logistics, and site installation to improve efficiency, quality, sustainability, and cost performance (Shibani et al., 2021). Its growing relevance is associated with advancements in construction technologies and materials, digital design processes, and the increasing demand for faster, more reliable project delivery (Jadhav et al., 2023).

Conceptually, prefabrication improves construction performance by reducing reliance on labour-intensive, weather-sensitive site activities. By manufacturing components off-site, contractors can minimise on-site labour requirements, reduce delays, and accelerate construction timelines (Legmpelos et al., 2013). This allows site preparation and component production to occur concurrently, thereby shortening overall project duration compared with conventional construction methods (Abanda et al., 2017). Prefabrication also enhances precision and consistency because factory production enables better supervision, standardised processes, and improved quality control (Wu et al., 2021). The controlled production environment reduces defects, limits weather-related damage, and supports strict compliance with design and technical specifications (Li et al., 2018). Consequently, prefabricated structures are often associated with improved structural integrity, durability, and predictable performance outcomes (Boafo et al., 2016).

The concept of prefabrication is also strongly connected to sustainable construction. Off-site production can reduce material waste, site pollution, noise, and environmental disturbance compared with traditional construction processes (Yang et al., 2020). Its sustainability value is further strengthened when prefabricated systems incorporate renewable, reusable, or low-carbon materials and efficient production practices (Zhao et al., 2023). In addition, prefabrication offers practical solutions to housing shortages and affordability challenges, particularly in urban areas where rapid delivery of quality buildings is required (Yu et al., 2020). Through standardised production and reduced construction time, prefabricated housing can lower delivery costs and improve access to affordable accommodation (Li et al., 2021). Its scalability also makes it suitable for emergency housing and disaster-response projects where speed and flexibility are essential (Zhao et al., 2018).

In modern construction projects, prefabrication is further supported by digital technologies such as Building Information Modelling, robotics, virtual simulations, and automated production systems. These technologies improve design accuracy, coordination, assembly planning, and project communication (Zhu et al., 2022). However, despite its benefits, prefabrication faces implementation barriers, including transportation difficulties, assembly complexities, regulatory constraints, resistance to change, and compatibility challenges with existing infrastructure (Zhang et al., 2019; Liu et al., 2020). Therefore, the effective conceptualisation of prefabrication requires collaboration among government, industry, and academia, supported by innovation, policy development, technical capacity, and supply chain integration (Hou et al., 2021).

Lean Construction Theory as the Theoretical Lens for Prefabrication Performance

The lean construction theory examines how the construction industry has been suffering enormously from a serious drawback: “Waste” (Senaratne and Wijesiri, 2008). Eliminating waste in a process is one of the top priorities in lean construction theory (Mao and Zhang, 2008). In general, project managers interpret waste as physical construction waste, which dominantly includes material losses. Despite extensive research on safety in the construction industry, incidents remain one of the industry's main problems. The mortality rate is about five times the average of other industries (Murie *et al*., 2007). Various research studies on lean construction in different countries show that the successful application of lean principles in construction can improve the cost structure (Salem *et al.,* 2006). Lean construction and simulation have been used to improve construction processes, such as housebuilding (Yu *et al*., 2009). Lean construction aims to improve construction operations by minimising waste and maximising value (Bertelsen et al., 2004). Prefabricated building construction is a key manifestation of the modernisation of the construction industry, capable of reducing costs and increasing work efficiency (Hamid *et al*., 2017). Koskela and Howell (2002) presented a new conceptualisation of Project Management theory, demonstrating the shortcomings of existing planning, execution, and control paradigms as advocated by contemporary Project Management theory and arguing that its constructs are insufficient to manage project-based production systems. Senaratne and Wijesiri (2008) underscore the detrimental impact of waste on project performance. By reducing waste, construction projects can achieve greater efficiency and cost-effectiveness. Salem *et al.* (2006) demonstrate the importance of maximising value through lean principles, emphasising the optimisation of resource utilisation and project outcomes. Ballard and Howell (2003) advocate the Last Planner System to foster continuous improvement in construction projects.

Murie *et al*. (2007) highlight the persistent safety challenges facing the construction industry and the potential of lean practices to mitigate risks and enhance safety performance. By fostering collaboration between owners, designers, contractors, and suppliers, lean practices facilitate the integration of diverse perspectives and expertise, leading to more efficient project delivery and improved outcomes (Koskela and Howell, 2002). Therefore, the collaborative planning and scheduling in construction projects focuses on increasing efficiency and reducing waste (Ballard,

2000). The developing leaders who embody Lean principles and practices foster a culture of continuous improvement and empower teams to achieve excellence. (Liker, 2004). The fundamental principle of Lean Construction Theory emphasises valuing and empowering workers, fostering collaboration, and creating a supportive work environment. (Liker, 2004). The method for synchronising production rates with customer demand to ensure a steady flow of work and minimise waste. (Ballard, 2000). The strategy for minimising inventory and reducing waste is to deliver materials and resources to the construction site exactly when they are needed. (Liker, 2004). Overall, lean construction aims to increase productivity, profits, and innovation in the industry by minimising waste (Aziz *et al*., 2013).

Benefits of Prefabrication Systems in Modern Construction Projects

Prefabrication offers numerous benefits, especially in enhancing efficiency and minimising costs (Hong *et al*., 2018). However, by constructing components off-site in a controlled environment, projects can be completed faster than traditional on-site construction methods (Boyd *et al*., 2013). This streamlined approach reduces the potential for delays caused by weather conditions or other on-site challenges (Heaton *et al.,* 2022). Furthermore, the simultaneous progression of component manufacturing and site preparation can accelerate project timelines, ultimately reducing labour expenses (Forbes *et al*., 2010). The enhancement of quality and precision is another significant advantage of prefabrication (Marfo *et al.*, 2025; Zhong *et al.,* 2017). Therefore, producing building components in a factory setting enables rigorous quality control, ensuring that each piece meets exact specifications (Colledani *et al*., 2014). However, this level of accuracy is often difficult to achieve in on-site construction, where variables such as human error and environmental factors can adversely affect the final product. Additionally, prefabrication minimises material waste through precise cutting and assembly, promoting more sustainable construction practices (Wasim *et al.,* 2022).

The safety improvements are a crucial benefit of prefabrication, as factory environments are typically safer than construction sites (Fard *et al*., 2015). In general, workers in a controlled setting face fewer hazards, such as heavy machinery, heights, and unstable conditions, which reduces the risk of injury (Hsiao *et al.*, 2001). The repetitive nature of tasks in a factory setting also leads to increased proficiency and fewer accidents. Moreover, the on-site assembly of prefabricated components often requires less time and fewer workers, further decreasing the potential for accidents and enhancing overall site safety (Fard *et al*., 2015). However, environmental benefits are also associated with prefabrication (Tumminia *et al.,* 2018). The controlled factory environment enables the use of energy-efficient processes and sustainable materials, thereby reducing the carbon footprint (Nota *et al*., 2020). Additionally, by minimising material waste and optimising resource use, prefabrication supports environmentally friendly construction practices (Navarro *et al*., 2019). The reduced on-site construction time also lessens the impact on the surrounding environment, leading to less disruption and a smaller ecological footprint (Guerlain *et al*., 2019).

Factors Influencing the Realization of Prefabrication Benefits

The adoption of prefabrication in the construction industry is influenced by a multitude of factors, spanning technological, economic, regulatory, environmental, and social dimensions. Technological advancements play a pivotal role in driving the uptake of prefabrication methods (Jin *et al.,* 2020). However, innovations such as building information modelling, advanced manufacturing techniques, and automation have significantly enhanced the efficiency, precision, and scalability of prefabrication processes (He *et al.,* 2021). These technological advancements enable greater customisation, faster production, and higher quality control in prefabricated construction, making it an increasingly attractive option for builders and developers (Agenda *et al*., 2016). The economic considerations are paramount in the decision to adopt prefabrication methods (Chen *et al.,* 2010). However, builders may weigh these initial costs against the long-term benefits of prefabrication, considering factors such as project scale, market demand, and financing options available (Navaratnam *et al.,* 2022). Government incentives, such as tax credits or grants for prefabrication projects, can further encourage adoption and help offset some financial barriers (Zolghadr *et al.,* 2022). Regulatory frameworks and building codes play a crucial role in shaping the landscape of prefabricated construction (Imrie *et al*., 2011).

Variations in regulations across regions and jurisdictions can hinder the adoption of prefabrication, as builders navigate differing standards for design, manufacturing, transportation, and installation (Imrie et al., 2023). In addition, harmonising building codes and streamlining approval processes for prefabricated components can facilitate smoother integration into construction projects and encourage broader adoption of off-site manufacturing methods (Lopez *et al*., 2022). Environmental sustainability is an increasingly influential factor driving the adoption of prefabrication in the construction industry (Wu *et al.,* 2021). The prefabricated construction has the potential to reduce material waste, minimise site disturbance, and lower carbon emissions compared to traditional on-site methods (Thomsen *et al*., 2022). By optimising material use, recycling waste, and incorporating energy-efficient designs, prefabrication aligns with the broader goals of sustainable development and green building practices (Adio *et al.,* 2014). The growing awareness of environmental impacts and regulatory requirements for sustainability certification further incentivises the adoption of prefabrication methods (Zhou *et al.,* 2019). The industry culture and attitudes towards innovation play a significant role in shaping the adoption of prefabrication (Liu *et al.,* 2017). The traditional construction practices and entrenched norms may create resistance to change, particularly among older generations of builders and contractors (Liao *et al*., 2018). The need for social distancing, supply chain disruptions, and

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labour shortages has underscored the advantages of off-site manufacturing and modular construction techniques (Yang *et al*., 2021). However, prefabrication offers greater control over working conditions, reduced reliance on on-site labour, and enhanced project resilience to future disruptions (Ghosh *et al*., 2021). Market demand and client preferences also influence the uptake of prefabrication in the construction industry. Clients increasingly value speed, cost certainty, and quality assurance in construction projects, driving demand for off-site manufacturing solutions (Zolghadr *et al.,* 2023). In addition, prefabrication offers shorter project timelines, reduced construction costs, and greater predictability in project outcomes, aligning with client expectations for efficiency and value (Chen *et al.,* 2023). By delivering projects faster and to a higher standard of quality, prefabrication methods can enhance client satisfaction and competitiveness in the marketplace (Mostafa *et al.,* 2020).

Supply chain dynamics and material availability are critical considerations for prefabricated construction (Arshad *et al*., 2022). Prefabrication reduces the need for on-site labour; however, it also requires specialised skills in manufacturing, logistics, and assembly (Legmpelos *et al.,* 2013). Moreover, attracting and retaining talent in the construction industry, particularly amid demographic shifts and evolving workforce preferences, can affect the scalability and sustainability of prefabrication initiatives (Agenda *et al.,* 2016). The risk management and liability considerations play a crucial role in the adoption of prefabrication methods. Builders must assess and mitigate risks associated with design errors, transportation challenges, and installation complexities inherent in off-site manufacturing processes (Lambert *et al.,* 2017). However, prefabrication offers potential benefits for quality control and project predictability; it also introduces new risks and uncertainties that builders must address (Bodaghi *et al.,* 2020). The effective coordination among architects, engineers, manufacturers, contractors, and clients is critical to integrating prefabrication seamlessly into construction projects (Mostafa *et al*., 2020). In general, the adoption of prefabrication in the construction industry is influenced by a complex interplay of technological, economic, regulatory, environmental, and social factors (Yuan *et al*., 2023).

METHODOLOGY

This study employed a quantitative research methodology to evaluate the benefits of prefabrication systems in modern construction projects through a lean construction lens. The quantitative approach was considered appropriate because the study sought to measure construction professionals' perceptions of prefabrication benefits and statistically describe the extent to which prefabrication contributes to efficiency, quality, cost minimisation, waste reduction, safety improvement, project delivery performance, and sustainability outcomes. Since the study focused on measurable variables, structured responses, and numerical patterns, the quantitative methodology provided an objective and systematic basis for analysing the role of prefabrication in improving the performance of modern construction projects.

The positivist research philosophy underpinned the study. Positivism assumes that research phenomena can be objectively observed, measured, and explained using empirical data and statistical analysis. This philosophical position was suitable for the present study because the benefits, roles, influencing factors, and project delivery outcomes associated with prefabrication systems can be operationalised into measurable constructs. By adopting positivism, the study reduced excessive reliance on subjective interpretation and strengthened the reliability, objectivity, and replicability of the research process. It also enabled the researcher to conclude observable data generated from construction professionals with practical knowledge of prefabrication and modern project delivery.

A descriptive survey research design was employed for the study. The descriptive design was used to examine the types of prefabrication systems recognised within the construction industry, the factors affecting their use, their roles in construction project delivery, their relationship with project performance, and their key benefits. This design was suitable because the study aimed to present a clear empirical picture of how prefabrication systems are perceived and applied in construction practice. The study also employed a cross-sectional survey design, in which data were collected from respondents at a single point in time. This approach was appropriate because it enabled the researcher to capture current professional views on prefabrication systems and their contribution to lean-oriented construction outcomes such as waste minimisation, value creation, improved workflow, quality enhancement, and production efficiency.

The study was conducted within the Ghanaian construction industry, with particular attention to professionals involved in building project planning, design, supervision, cost management, site coordination, and project delivery. Ghana was considered an appropriate context because the construction industry continues to face challenges, including cost overruns, delays, material waste, quality inconsistencies, labour inefficiencies, and weak project control. These challenges make prefabrication and lean construction highly relevant as alternative approaches for improving construction productivity and sustainability. The target population comprised built environment professionals, including contractors, consultants, project managers, quantity surveyors, architects, engineers, site supervisors, and client representatives. These professionals were selected because their technical expertise and project experience positioned them to provide informed responses on prefabrication systems and their benefits in modern construction projects.

The sample size for the study was one hundred respondents. This sample size was considered adequate for a quantitative survey and suitable for generating meaningful descriptive statistical evidence. A probability sampling approach was adopted to enhance representativeness and reduce sampling bias. Where professional categories were identifiable, stratified random sampling was used to ensure that different groups within the built environment profession were fairly represented. Respondents were then selected from the relevant professional strata to ensure that the views captured reflected diverse experiences across construction practice. The use of 100 respondents also provided a manageable yet sufficient dataset for analysing professional perceptions of prefabrication benefits in the study context.

Primary data were collected using a structured questionnaire. The questionnaire was designed to generate standardised, comparable, and quantifiable responses from the selected respondents. It was organised into sections that reflected the study's main concerns. The first section captured respondents' demographic and professional information, including professional role, years of experience, organisational type, and level of involvement in construction projects. The second section examined the types of prefabrication systems used or recognised in the construction industry, including hybrid prefabrication systems, panelised systems, modular systems, structural prefabrication systems, sub-assemblies and components, and kits of parts. The third section assessed factors affecting the use of prefabrication systems, such as technological advancement, economic considerations, regulatory frameworks, environmental sustainability concerns, industry culture, market demand, supply chain dynamics, risk management, collaboration, and labour skills. The fourth section measured the roles and benefits of prefabrication systems in project delivery, including efficiency, quality, sustainability, design flexibility, innovation, resilience, cost minimisation, faster completion, delay reduction, material waste minimisation, safety improvement, and human error reduction.

A five-point Likert scale was used to measure respondents' level of agreement with each questionnaire item. The use of a Likert scale was appropriate because it enabled professional perceptions to be converted into measurable numerical data. This also supported the systematic ranking and comparison of responses across the study's key variables. Before the main survey, the questionnaire was reviewed to ensure clarity, relevance, and alignment with the study aim. Items were developed from the study objectives, lean construction theory, and existing literature on prefabrication systems, off-site construction, modular construction, and construction project performance.

The collected data were coded and analysed using the Statistical Package for the Social Sciences. Descriptive statistics, specifically frequencies and percentages, were used to summarise response distributions and identify dominant patterns within the dataset. This approach was appropriate because the study examined construction professionals' recognition of prefabrication systems, the factors influencing adoption, the roles in project delivery, and the perceived benefits. The analysis enabled the study to identify the most recognised prefabrication systems, major adoption factors, key contributions to project delivery, and principal benefits associated with prefabrication.

The questionnaire items were derived from the study objectives, lean construction theory, and relevant literature on prefabrication, off-site construction, modular construction, and construction project performance.

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The instrument was reviewed for clarity, relevance, and alignment with the study variables. Validity and reliability considerations were addressed by ensuring that the items measured the intended constructs and generated consistent responses.

The findings were interpreted in relation to lean construction principles, including waste reduction, value maximisation, workflow improvement, quality control, safety enhancement, and continuous improvement. Ethical considerations were observed throughout the study. Participation was voluntary; respondents were informed about the academic purpose of the research, and anonymity and confidentiality were maintained. No personal identifiers were disclosed, and the data were used solely for academic and research purposes. These procedures supported a systematic, transparent, and credible methodology for evaluating prefabrication benefits in the Ghanaian construction industry, using reliable survey evidence.

RESULTS PRESENTATION

Table 1 presents respondents' views on the types of prefabrication systems used in the construction industry. The results show that hybrid prefabrication systems recorded the highest level of agreement, with 78.0% of respondents selecting scale 1, followed closely by modular prefabrication systems at 77.0% and structural prefabrication systems at 72.0%. This suggests that these systems are highly recognised and considered more prominent within modern construction practice. Panelised prefabrication systems also received strong support, with 63.0% selecting scale 1 and 27.0% selecting scale 2, indicating considerable industry awareness and application. Sub-assemblies and components recorded 58.0% on scale 1 and 28.0% on scale 2, showing moderate acceptance. Kits of parts had the lowest score on scale 1, although 55.0% still indicated strong recognition. Overall, the findings suggest that prefabrication in construction is dominated by hybrid, modular, structural, and panelised systems, while kits of parts remain comparatively less adopted.

Table 1: Types of Prefabrication Systems in the Construction Industry

Types of Prefabrication Systems	**1**	**%**	**2**	**%**	**3**	**%**	**4**	**%**	**5**	**%**
Hybrid Prefabrication Systems	78	78.0%	16	16.0%	1	1.0%	3	3.0%	2	2.0%
Panelised Prefabrication Systems	63	63.0%	27	27.0%	5	5.0%	3	3.0%	2	2.0%
Modular Prefabrication Systems	77	77.0%	13	13.0%	6	6.0%	3	3.0%	1	1.0%
Structural Prefabrication Systems	72	72.0%	18	18.0%	5	5.0%	4	4.0%	1	1.0%
Sub-Assemblies and Components	58	58.0%	28	28.0%	9	9.0%	2	2.0%	3	3.0%
Kits of Parts	55	55.0%	26	26.0%	13	13.0%	4	4.0%	2	2.0%

Source: Field Survey, 2026.

Table 2 presents the factors affecting the use of prefabrication systems in the construction industry. The findings show that technological advancement recorded the highest response on scale 1, at 71.0%, indicating that technological capacity is a major determinant of prefabrication adoption. Labour skills and workforce dynamics followed with 67.0%, suggesting that the availability of competent personnel strongly influences implementation. Economic consideration also recorded a high score of 66.0%, showing that cost, affordability, and investment requirements remain important decision factors. Environmental sustainability concerns, risk management and liability issues, and collaboration and coordination each accounted for 61.0%, reflecting their substantial influence on the use of prefabrication. The lack of a regulatory framework and market demand each accounted for 60.0%, indicating that policy support and client acceptance are also critical. Industry culture had the lowest scale-1 response rate at 51.0%, although it still shows moderate influence. Overall, the results suggest that the adoption of prefabrication is shaped by technological, economic, institutional, environmental, and workforce-related factors.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

Table 2: Factors Affecting the Use of Prefabrication Systems in the Construction Industry

Factors Affecting the Use of Prefabrication Systems	**1 F**	**1 %**	**2 F**	**2 %**	**3 F**	**3 %**	**4 F**	**4 %**	**5 F**	**5 %**
Technology Advancement	71	71.0%	18	18.0%	7	7.0%	3	3.0%	1	1.0%
Economic Consideration	66	66.0%	23	23.0%	6	6.0%	3	3.0%	2	2.0%
Lack of Regulatory Framework	60	60.0%	23	23.0%	12	12.0%	4	4.0%	1	1.0%
Environmental Sustainability Concerns	61	61.0%	29	29.0%	3	3.0%	5	5.0%	2	2.0%
Industry Culture	51	51.0%	32	32.0%	13	13.0%	3	3.0%	1	1.0%
Market Demand and Client Preferences	60	60.0%	26	26.0%	11	11.0%	1	1.0%	2	2.0%
Supply Chain Dynamics	58	58.0%	29	29.0%	6	6.0%	7	7.0%	0	0.0%
Risk Management and Liability Issues	61	61.0%	24	24.0%	10	10.0%	3	3.0%	2	2.0%
Collaboration and Coordination in the Industry	61	61.0%	26	26.0%	6	6.0%	5	5.0%	2	2.0%
Labor Skills and Workforce Dynamics	67	67.0%	21	21.0%	6	6.0%	2	2.0%	4	4.0%

Source: Field Survey, 2026.

Table 3 presents the roles of prefabrication systems in construction project delivery. The results show that ensuring efficiency recorded the highest response under scale 1, with 78.0%, indicating that respondents strongly recognise prefabrication as a major approach for improving project delivery speed, productivity, and resource utilisation. Ensuring quality followed with 74.0%, suggesting that prefabrication contributes to better artistry, standardisation, and quality control. Design flexibility also recorded a strong response of 69.0%, while sustainability and reduced unskilled labour on construction sites each recorded 67.0%. This implies that prefabrication improves environmental performance and reduces overreliance on on-site manual labour. Construction project resilience recorded 64.0%, while innovation recorded 61.0%, showing that prefabrication contributes to modernisation and adaptive project delivery. Collaboration among stakeholders recorded the lowest scale 1 response at 52.0%, although 35.0% selected scale 2. Overall, the findings indicate that prefabrication significantly improves efficiency, quality, sustainability, flexibility, resilience, innovation, and stakeholder coordination.

Table 3: Roles of Prefabrication Systems in Construction Project Delivery

Roles of Prefabrication Systems	**1 F**	**1 %**	**2 F**	**2 %**	**3 F**	**3 %**	**4 F**	**4 %**	**5 F**	**5 %**
Ensure Efficiency	78	78.0%	16	16.0%	3	3.0%	1	1.0%	2	2.0%
Ensure Quality	74	74.0%	19	19.0%	4	4.0%	2	2.0%	1	1.0%
Ensure Sustainability	67	67.0%	23	23.0%	6	6.0%	3	3.0%	1	1.0%
Reduced Unskilled Labour on Construction Site	67	67.0%	23	23.0%	5	5.0%	3	3.0%	2	2.0%

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Ensure Design Flexibility	69	69.0%	21	21.0%	7	7.0%	1	1.0%	2	2.0%
Enhances Construction Project Resilience	64	64.0%	27	27.0%	4	4.0%	4	4.0%	1	1.0%
Ensure Innovation	61	61.0%	27	27.0%	6	6.0%	3	3.0%	3	3.0%
Ensure Collaboration among Stakeholders	52	52.0%	35	35.0%	6	6.0%	5	5.0%	2	2.0%

Source: Field Survey, 2026.

Table 4 presents the relationship between prefabrication systems and project delivery in the construction industry. The results show that transformative impact recorded the highest response at scale 1, at 68.0%, indicating that respondents strongly perceive prefabrication as a major driver of improved project delivery. Enhanced energy performance followed at 63.0%, while production efficiency and standardisation each recorded 62.0%. This suggests that prefabrication contributes to better production control, improved energy performance, and more consistent construction outputs. Factory production and regulatory incentives each accounted for 61.0%, underscoring the importance of off-site production processes and supportive policy mechanisms in enhancing delivery outcomes. Risk mitigation, reduction of unskilled labour on construction sites, and traditional construction challenges each recorded 58.0%, showing that prefabrication helps address site-based inefficiencies and uncertainties. The streamlined process recorded 57.0%, still indicating strong recognition. Overall, the findings suggest that prefabrication positively influences project delivery through transformation, efficiency, standardisation, risk reduction, and improved performance.

Table 4: Relationship Between Prefabrication Systems and Project Delivery

Relationship Between Prefabrication Systems and Project Delivery	**1 F**	**1 %**	**2 F**	**2 %**	**3 F**	**3 %**	**4 F**	**4 %**	**5 F**	**5 %**
Transformative Impact	68	68.0%	26	26.0%	2	2.0%	3	3.0%	1	1.0%
Factory Production	61	61.0%	31	31.0%	3	3.0%	3	3.0%	2	2.0%
Streamlined Process	57	57.0%	27	27.0%	8	8.0%	5	5.0%	3	3.0%
Reduce Unskilled Labour on Construction Site	58	58.0%	25	25.0%	9	9.0%	6	6.0%	2	2.0%
Traditional Construction Challenges	58	58.0%	24	24.0%	10	10.0%	6	6.0%	2	2.0%
Efficiency in Production	62	62.0%	23	23.0%	5	5.0%	6	6.0%	4	4.0%
Risk Mitigation	58	58.0%	26	26.0%	7	7.0%	7	7.0%	2	2.0%
Enhanced Energy Performance	63	63.0%	23	23.0%	4	4.0%	6	6.0%	4	4.0%
Regulatory Incentives	61	61.0%	28	28.0%	3	3.0%	7	7.0%	1	1.0%
Standardization	62	62.0%	26	26.0%	5	5.0%	5	5.0%	2	2.0%

Source: Field Survey, 2026.

Table 5 summarises the benefits of prefabrication systems in the construction industry. The results show that enhancing efficiency received the highest response, at 73.0% on a scale of 1, indicating that respondents strongly view prefabrication as a major approach to improving construction productivity and workflow

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performance. Minimising cost followed at 65.0%, suggesting that prefabrication can support cost control through reduced waste, improved planning, and efficient resource utilisation. Increased proficiency was recorded at 64.0%, while minimising material waste and quality and precision each recorded 63.0%, demonstrating prefabrication's contribution to artistry, accuracy, and sustainable material management. Faster project completion was observed at 61.0%, while safety improvements were observed at 60.0%, indicating that prefabrication supports safer, quicker project execution. Reducing delays recorded 59.0%, and reducing human error recorded 56.0%. Overall, the findings indicate that prefabrication provides substantial benefits in efficiency, cost reduction, speed, safety, quality, waste minimisation, and construction accuracy.

Table 5: Benefits of Prefabrication Systems in the Construction Industry

Benefits of Prefabrication Systems	**1 F**	**1 %**	**2 F**	**2 %**	**3 F**	**3 %**	**4 F**	**4 %**	**5 F**	**5 %**
Enhancing Efficiency	73	73.0%	20	20.0%	2	2.0%	4	4.0%	1	1.0%
Minimizing Cost	65	65.0%	26	26.0%	4	4.0%	5	5.0%	0	0.0%
Faster Project Completion	61	61.0%	27	27.0%	7	7.0%	4	4.0%	1	1.0%
Reducing Delays	59	59.0%	31	31.0%	5	5.0%	4	4.0%	1	1.0%
Human Error Reduction	56	56.0%	32	32.0%	5	5.0%	7	7.0%	0	0.0%
Minimising Material Waste	63	63.0%	30	30.0%	2	2.0%	3	3.0%	2	2.0%
Safety Improvements	60	60.0%	27	27.0%	7	7.0%	5	5.0%	1	1.0%
Increased Proficiency	64	64.0%	27	27.0%	3	3.0%	4	4.0%	2	2.0%
Quality and Precision	63	63.0%	25	25.0%	7	7.0%	4	4.0%	1	1.0%

Source: Field Survey, 2026.

DISCUSSION OF RESULTS

The findings of this study provide strong empirical support for the growing relevance of prefabrication systems in modern construction project delivery. Across the five result areas, respondents consistently recognised prefabrication as a construction approach that improves efficiency, quality, sustainability, speed, cost control, safety, and project predictability. These findings align closely with the literature, which presents prefabrication as a transformative construction strategy that shifts substantial portions of construction work from unpredictable site environments to controlled factory settings (Ashcraft Jr et al., 2014). The discussion therefore shows that prefabrication is not merely a technical production method but a broader project-delivery innovation that influences construction processes, labour structures, risk management, stakeholder coordination, and long-term sustainability outcomes.

The findings on the types of prefabrication systems used in construction reveal that hybrid prefabrication systems recorded the highest level of recognition, followed closely by modular, structural, and panelised systems. This indicates that industry respondents are more familiar with prefabrication approaches that combine off-site production with on-site flexibility. The dominance of hybrid systems is particularly significant because hybrid prefabrication allows construction projects to benefit from the precision and quality control of factory manufacturing while still accommodating the design adjustments and contextual demands of site-based assembly. This finding supports Luo et al. (2021), who argue that hybrid prefabrication combines off-site manufacturing and on-site assembly to produce structural frames, wall panels, and floor sections with improved precision, quality, and adaptability. It also supports the argument of Allen et al. (2019) that hybrid systems are particularly useful for projects requiring both standardisation and design flexibility. The high

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

uptake of modular prefabrication also reflects the growing acceptance of three-dimensional building modules as a means of reducing project duration, improving artistry, and enhancing construction productivity. This is consistent with Kamali et al. (2019), who note that modular construction allows complete building sections to be manufactured off-site while site preparation progresses concurrently.

The strong recognition of structural prefabrication systems further suggests that key structural components such as beams, slabs, columns, and panels are increasingly viewed as suitable for off-site production. This supports Navaratnam et al. (2019), who explain that structural prefabrication enhances precision, improves quality assurance, and reduces construction waste. Panelised prefabrication also received considerable support, demonstrating that flat components such as wall panels, floor panels, and roof sections are recognised for their ability to streamline on-site assembly and accelerate construction. Gibb et al. (2015) similarly observe that panelised systems support efficient construction through controlled production and rapid installation. However, the comparatively low recognition of kits of parts suggests that, although this system is acknowledged, it may not yet be widely applied or fully understood by industry practitioners. This may be due to limited supply chain maturity, lack of standardised assembly platforms, or inadequate technical capacity. The result therefore suggests that while prefabrication is gaining visibility, its adoption remains uneven across system types.

The findings on factors affecting the use of prefabrication systems show that technological advancement is the most influential factor. This result is important because prefabrication is highly dependent on technological capacity, including Building Information Modelling, digital design coordination, automation, advanced manufacturing, and precision logistics. The finding confirms the findings of Jin et al. (2020) and He et al. (2021), who argue that technological advancement enhances the efficiency, accuracy, scalability, and customisation of prefabricated construction. In practical terms, prefabrication cannot be fully implemented where digital design systems, factory production technologies, and skilled technical teams are weak. The high ranking in technological advancement, therefore, suggests that the industry views prefabrication as a technology-driven construction system rather than merely an alternative to traditional building methods.

Labour skills and workforce dynamics also emerged as major factors affecting the use of prefabrication. This finding supports Legmpelos et al. (2013), who observe that prefabrication requires specialised skills in manufacturing, logistics, installation, and assembly. Although prefabrication reduces dependence on large numbers of on-site workers, it increases demand for technically competent personnel who can manage factory production, digital modelling, quality checks, transportation, lifting, and on-site integration. The finding therefore indicates that workforce development is central to the adoption of prefabrication. Without adequate training and skills upgrading, prefabrication may face implementation challenges despite its recognised benefits. This is particularly relevant in developing construction markets where conventional site-based construction still dominates and technical training systems may not yet be fully aligned with industrialised building methods.

Economic considerations also received high levels of agreement, confirming that cost remains a critical decision factor in adopting prefabrication. Although the literature shows that prefabrication can reduce labour expenses, material waste, delays, and rework, the initial investment in production facilities, transport systems, design coordination, and skilled labour may be substantial (Chen et al., 2010; Navaratnam et al., 2022). The findings therefore reflect a balanced industry perception: respondents recognise the long-term cost advantages of prefabrication, but they also acknowledge that economic feasibility determines whether organisations can adopt it. This supports Mostafa et al. (2020), who argue that prefabrication becomes more attractive when clients and contractors can clearly link it to cost certainty, shorter project timelines, and improved value delivery.

The findings also show that environmental sustainability concerns, the regulatory framework, risk management, market demand, supply chain dynamics, and collaboration significantly influence the adoption of prefabrication. This demonstrates that prefabrication is shaped by a complex system of institutional, environmental, market, and project-level conditions. The strong response to environmental sustainability aligns with Wu et al. (2021) and Thomsen et al. (2022), who argue that prefabrication reduces material waste, minimises site disturbance, and promotes lower-carbon construction practices. Similarly, the importance of regulatory frameworks aligns with Imrie et al. (2011) and Lopez et al. (2022), who emphasise that building codes, approval procedures, and standards strongly influence the implementation of prefabrication. The moderate ranking of industry culture suggests that while cultural resistance exists, it may not be the strongest barrier compared with technology, skills, and economics. However, Liu et al. (2017) and Liao et al. (2018) caution that entrenched traditional practices can slow the adoption of innovation. Thus, changing attitudes within the construction industry remains necessary for scaling prefabrication.

The findings on the roles of prefabrication systems in construction project delivery show that efficiency had the highest level of agreement. This confirms the central argument in the literature that prefabrication enhances project efficiency by enabling concurrent site preparation and off-site component production (Bryde et al., 2013; Bassil et al., 2018). By reducing sequential construction activities, prefabrication shortens project duration and improves workflow coordination. This result is also consistent with Hong et al. (2018), who identify efficiency enhancement as one of the most important benefits of prefabrication. Respondents' strong recognition of efficiency suggests that prefabrication is valued primarily for addressing one of the most persistent weaknesses of traditional construction: low productivity and prolonged project timelines.

Quality also emerged as a major benefit of prefabrication systems. This finding aligns with Wu et al. (2021) and Smith (2019), who argue that factory-based production improves construction quality because components are produced under controlled conditions with standardised processes and quality checks. Unlike traditional site-based construction, where weather, site congestion, labour variability, and inadequate supervision can affect quality, prefabrication allows components to be manufactured to precise specifications. This explains why respondents strongly associated prefabrication with improved quality, precision, and standardisation. The finding also supports Zhong et al. (2017), who highlight the role of prefabrication in enhancing accuracy and reducing defects.

Sustainability and reduced reliance on unskilled labour were also strongly recognised as key benefits of prefabrication. The sustainability result aligns with Wang et al. (2017) and Gorgolewski et al. (2018), who explain that prefabrication reduces environmental impacts by minimising site waste, noise, material misuse, and construction disturbance. The finding on reduced unskilled labour supports Li et al. (2019) and Cheng et al. (2017), who argue that prefabrication reduces reliance on large volumes of on-site manual labour and shifts labour demand toward more organised factory-based and assembly-based tasks. This does not mean that labour becomes irrelevant; rather, it suggests that the labour structure shifts from informal, labour-intensive work to more technical, coordinated, and controlled forms of production. Therefore, prefabrication may contribute to workforce modernisation in construction.

The role of design flexibility also received strong agreement, showing that respondents do not perceive prefabrication as rigid or limited to repetitive building forms. This is important because one common criticism of prefabrication is that it may restrict architectural creativity. However, the literature increasingly challenges this assumption. Mostafa et al. (2020) and Luo et al. (2017) argue that advanced manufacturing technologies allow prefabricated components to be customised to meet project-specific design requirements. The findings therefore suggest that industry practitioners recognise the possibility of combining standardisation with design adaptability. This is particularly important for modern construction projects, where clients demand speed and cost certainty without sacrificing aesthetics or functional requirements.

The findings on the relationship between prefabrication systems and project delivery indicate that transformative impact received the most responses. This reinforces Ashcraft Jr et al. (2014), who describe prefabrication as a method that fundamentally alters traditional construction by shifting production logic from fragmented on-site activities to integrated off-site manufacturing and assembly. Respondents' perception of prefabrication as transformative indicates that it is understood as more than a productivity tool; it is seen as a project delivery model that restructures planning, design, procurement, manufacturing, logistics, installation, and quality assurance. Factory production, standardisation, production efficiency, and energy performance were also strongly recognised, confirming the literature's claim that prefabrication improves delivery through controlled production, repeatable processes, and performance-oriented building components (Zhang et al., 2021; Kamel et al., 2023).

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

The relationship between prefabrication and risk mitigation is also notable. Traditional construction is frequently affected by delays, design errors, labour shortages, weather disruptions, site accidents, and material waste. The findings indicate that respondents view prefabrication as a means of reducing these uncertainties. This supports Schuldt et al. (2021), who argue that prefabrication reduces exposure to site-based risks, including weather-related delays and accessibility problems. It also aligns with Bodaghi et al. (2020), who note that although prefabrication introduces new risks, such as transportation and installation complexity, it can improve project predictability when properly planned. Therefore, the relationship between prefabrication and project delivery is strongly mediated by planning, coordination, regulation, and technical competence.

The findings on the benefits of prefabrication systems further confirm the results from the earlier tables. Enhancing efficiency was the highest-rated benefit, followed by minimising cost, increased proficiency, material waste reduction, quality and precision, faster completion, safety improvement, delay reduction, and human error reduction. These findings strongly support the literature, which identifies efficiency, cost reduction, speed, quality, waste minimisation, and safety as the core advantages of prefabrication (Hong et al., 2018; Boyd et al., 2013; Zhong et al., 2017; Fard et al., 2015; Wasim et al., 2022). The high score for cost minimisation is particularly significant because it suggests that respondents associate prefabrication with better resource utilisation, reduced rework, lower waste, and improved labour productivity. This supports Bertram et al. (2019), who argue that prefabrication can reduce project costs by lowering on-site labour needs and improving production efficiency.

The strong recognition of waste minimisation and precision in quality demonstrates the sustainability and performance value of prefabrication. Guide Jr et al. (2000) argue that precise material planning in controlled production environments reduces excess material use and improves cost-effectiveness. Similarly, Liu et al. (2022) and Williams et al. (2018) indicate that factory-based quality control improves component fit, finish, and structural reliability. The finding on safety improvement is equally important, as it confirms Navaratnam et al. (2022) and Ahn et al. (2020), who argue that moving work from hazardous construction sites to controlled factory environments reduces accident exposure. This suggests that prefabrication contributes not only to productivity but also to occupational health and safety performance.

Overall, the results and literature collectively demonstrate that prefabrication systems provide a strong pathway for improving construction project delivery. The empirical findings confirm that hybrid, modular, structural, and panelised systems are the most recognised prefabrication typologies, while technological advancement, workforce competence, economic feasibility, regulation, sustainability, and stakeholder coordination shape adoption. The findings further establish that prefabrication improves efficiency, quality, flexibility, sustainability, resilience, innovation, cost control, speed, safety, waste reduction, and project predictability. However, the discussion also shows that the adoption of prefabrication is not automatic. Its success depends on supportive policy frameworks, digital capacity, skilled labour, supply chain readiness, early stakeholder collaboration, and industry willingness to shift from conventional practices to more integrated construction delivery systems. Therefore, prefabrication should be understood as both a construction technology and a strategic project delivery approach capable of addressing many of the inefficiencies associated with traditional construction methods. The literature reviewed supports these interpretations by showing that prefabrication improves efficiency, quality, sustainability, safety, cost performance, and delivery reliability when properly planned and coordinated.

CONCLUSION

This study concludes that prefabrication systems significantly improve modern construction project delivery when assessed through a lean construction perspective. Theoretically, the study contributes by linking prefabrication benefits to lean principles, including waste minimisation, value creation, workflow improvement, quality enhancement, safety performance, and project predictability. This positions prefabrication not merely as a construction technology but as a strategic project-delivery approach that supports lean-oriented performance improvement.

The findings show that hybrid, modular, structural, and panelised prefabrication systems enhance efficiency, quality, speed, cost control, sustainability, safety, material waste reduction, delay minimisation, and human error reduction. Unlike previous studies that often examine these benefits separately, this study integrates them into a lean construction framework. It provides empirical evidence from built-environment professionals in the Ghanaian construction industry. This makes the study particularly relevant to developing construction contexts where delays, cost overruns, poor coordination, and material waste remain major challenges.

Practically, the study implies that construction firms, policymakers, and professional institutions should promote digital construction technologies, technical training, standardised regulations, local manufacturing capacity, and stakeholder collaboration. These measures will support the wider adoption of prefabrication and improve the efficiency, sustainability, predictability, and value-driven project delivery.

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