IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 2, July 2025
Impact Factor: 7.67

Adopting Lean Construction in SMEs: A Narrative Review on Benefits, Barriers, and Practical Solutions

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Abstract: *Lean Construction (LC) has emerged as a transformative methodology to improve efficiency, reduce waste, and enhance sustainability in the construction industry. However, its adoption among small and medium-sized enterprises (SMEs) remains limited due to financial, organizational, and cultural barriers. This paper provides a comprehensive review of the challenges and opportunities associated with LC adoption in SMEs, drawing on key studies from diverse geographic and industrial contexts. In particular, this review highlights critical factors such as leadership commitment, employee resistance, limited resources, and the need for tailored training programs. Furthermore, this review also examines regional disparities in LC implementation emphasizing the influence of cultural and economic conditions on adoption rates. In addition, the role of digital tools, including Building Information Modeling (BIM), and the integration of LC with modular construction are explored as pathways to enhance SME adoption. Finally, this review proposes a blueprint for SMEs to adopt LC, structured into seven actionable phases: leadership commitment, baseline assessment, pilot implementation, scaling practices, leveraging technology, fostering continuous improvement, and addressing SME-specific challenges. This framework emphasizes low-cost Lean tools, participative leadership, and strategic partnerships to overcome resource and capacity limitations. In conclusion, this review underscores the potential for LC to revolutionize SME operations by fostering a culture of continuous improvement and collaboration. By adopting the proposed framework, SMEs can achieve significant efficiency gains and position themselves as competitive players in the construction industry while contributing to broader sustainability goals*

Keywords: Lean Construction, SMEs, adoption barriers, efficiency, sustainability, modularity, leadership

I. INTRODUCTION

Lean Construction (LC) is an innovative approach to managing and executing construction projects, drawing inspiration from the principles of lean manufacturing. At its core, LC aims to maximize value for customers while systematically minimizing waste across all stages of construction. Waste in this context extends beyond material excess to inefficiencies in time, effort, and financial resources.

The concept of applying lean-like practices to construction can be traced back to iconic projects like the construction of the Empire State Building in 1930–1931 [1]. Completed in a record 410 days, this project demonstrated remarkable efficiency, using techniques such as just-in-time delivery, worker specialization, and prefabrication. These practices reflect key lean principles, even though the term "Lean Construction" did not exist at the time. The project's success was a precursor to the systematic application of such principles in the construction industry.

The roots of lean thinking, however, are more closely associated with **Henry Ford**, whose innovations in automobile manufacturing, particularly the assembly line, emphasized flow optimization and waste reduction [2]. Ford's ideas laid the groundwork for lean manufacturing, which was later formalized in the **Toyota Production System (TPS)** by **Taiichi Ohno** and **Eiji Toyoda**[3]. The foundational concept of lean construction emerged from the Toyota Production

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System (TPS), which emphasized waste reduction, continuous improvement, and value maximization for the customer — principles that directly influenced Lean Construction. This system was introduced to the construction industry through Lauri Koskela's seminal report, *Application of the New Production Philosophy to Construction*, which highlighted the potential for applying lean principles to construction processes [4]. Koskela proposed a paradigm shift from a transformation-only view of production to one that integrates flow and value perspectives, thus redefining construction as a process-driven activity.

The formal establishment of lean construction occurred with the formation of the International Group for Lean Construction (IGLC) in 1993. This group provided a platform for researchers and practitioners to develop, test, and share lean construction practices globally. Glenn Ballard and Greg Howell, key proponents of lean construction, introduced the Last Planner System, a production planning approach that aligns with lean principles by reducing variability and improving workflow reliability [5], [6], [7].

Today, LC is increasingly recognized as a vital methodology for addressing persistent challenges in the construction industry, such as project delays, cost overruns, and quality issues. While large-scale construction firms were the early adopters of LC, its application in **small and medium enterprises (SMEs)** is gaining attention. SMEs, which operate under tighter budgets and resource constraints, have much to gain from the efficiency and adaptability of LC principles. This review explores the role and potential of Lean Construction in SMEs, focusing on its adoption, benefits, and barriers. By examining global trends, challenges, and practical solutions, this paper aims to provide actionable insights for SMEs to integrate LC effectively into their operations. The rest of the paper is organized as follows: Section 2 introduces principles of lean construction followed by its benefits in Section 3. We next discuss barriers to adoption of lean construction in SMEs in section 4 followed by its global adoption landscape in Section 5. In section 6, we provide an actionable blueprint for SMEs to adopt lean construction effectively into their operations, concluding with future directions in section 7.

II. PRINCIPLES OF LEAN CONSTRUCTION

Lean Construction (LC) builds upon the foundational principles of lean manufacturing [8], adapting them to the construction sector's unique complexities and challenges [4]. Figure 1 outlines different principles of lean construction and their interconnected relationships. While lean manufacturing focuses on creating value by minimizing waste in production lines, LC extends this philosophy to dynamic, project-based environments where variability and uncertainty are significant [5]. Unlike manufacturing's controlled environment, construction projects face distinctive challenges such as weather dependencies, site-specific conditions, and complex stakeholder relationships, necessitating a tailored approach to lean principles.

At the core of LC lies the principle of waste elimination, which has been adapted from manufacturing [3] to address construction-specific challenges [9]. The construction sector identifies seven primary forms of waste: defects, overproduction, waiting, non-utilized talent, transportation, inventory, and motion. These wastes manifest uniquely in construction contexts. For instance, defects in construction can have far-reaching consequences, as a poorly executed foundation may require complete demolition and rebuilding, impacting the entire project timeline and budget. Similarly, inventory management in construction presents unique challenges due to limited site storage and weather exposure risks. To address these wastes, construction firms employ tools such as Value Stream Mapping (VSM) [10] and process flow diagrams [11], adapted specifically for construction's dynamic environment.

Value generation and flow efficiency form another crucial principle of LC, emphasizing customer-centric construction practices [4]. In construction projects, value is defined through specific deliverables such as energy efficiency ratings, completion timeframes, and quality standards. Flow efficiency is achieved through various techniques adopted for construction's unique environment, including standardization of repetitive tasks and buffer management that accounts for weather delays and subcontractor availability. These approaches help maintain consistent workflow despite the inherent variability in construction projects.

Pull planning and Just-in-Time (JIT) production principles have been particularly refined for construction applications. The Last Planner System (LPS) exemplifies this adaptation [6], facilitating collaborative planning among various trades to create reliable workflows [7]. This system proves especially valuable in space-constrained environments where

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material delivery timing is crucial. For instance, in residential construction projects, materials are delivered based on installation sequence, minimizing on-site storage requirements and reducing the risk of material damage.

Continuous improvement represents a fundamental principle that fosters incremental learning and refinement within construction projects. This principle manifests through regular evaluation of processes, identification of inefficiencies, and implementation of corrective actions [12]. Construction teams typically implement this through daily huddles, post-phase reviews, and systematic documentation of lessons learned. These practices help build organizational knowledge and improve project delivery efficiency over time.

The principle of respect for people takes on particular significance in construction, where project success heavily depends on effective collaboration among diverse stakeholders [13]. This principle emphasizes worker empowerment, open communication, and trust-building among team members. In practice, this involves active involvement of craft workers in planning and problem-solving, regular safety meetings incorporating worker feedback, and development of strong relationships with suppliers and subcontractors.

Holistic integration of design and construction represents a more recent evolution in LC principles, particularly with the advent of digital technologies. Building Information Modeling (BIM) [14], Virtual Design and Construction (VDC), and digital collaboration platforms have enhanced the ability to integrate design and construction processes effectively. [15] This integration helps minimize conflicts between design intent and on-site realities, reducing rework and improving project outcomes. Target Value Design (TVD) further supports this integration by ensuring design decisions align with project value objectives from the outset.

These principles work synergistically in construction projects, with each principle supporting and enhancing the others. Waste elimination facilitates flow efficiency, while pull planning enables effective JIT delivery. The respect for people principle underpins continuous improvement efforts, and holistic integration supports value generation through better coordination. This interconnected implementation creates a comprehensive system for improving construction project delivery.For Small and Medium-sized Enterprises (SMEs) in the construction sector, these principles offer particularly relevant benefits [16]. Unlike large firms, SMEs often operate with constrained resources, making efficiency crucial for survival. The scalable nature of LC tools allows SMEs to implement these principles progressively, starting with basic techniques and advancing to more sophisticated approaches as capabilities grow. This graduated approach ensures sustainable adoption while maintaining operational efficiency. Furthermore, SMEs can leverage these principles to enhance their competitive position through reduced waste, improved project predictability, and stronger stakeholder relationships.

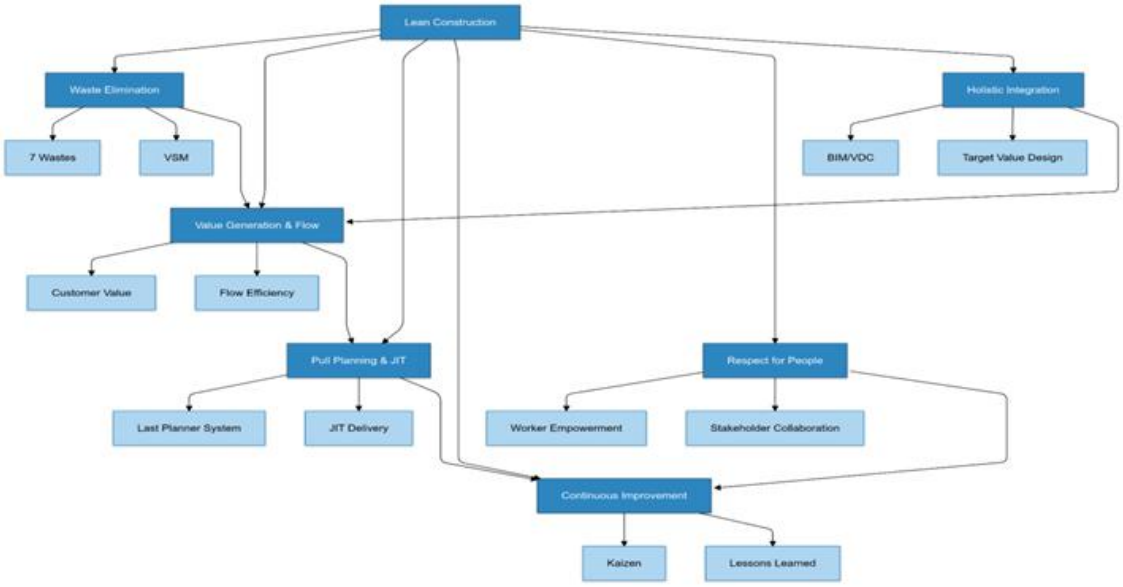

Figure 1. Illustration of the principles of Lean Construction for SMEs and their interconnected relationships

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III. PRINCIPLES OF LEAN CONSTRUCTION

Lean Construction (LC) principles offer SMEs significant advantages by promoting cost efficiency, improving project delivery, enhancing collaboration, increasing client satisfaction, and ensuring long-term competitiveness. By adopting LC, SMEs can address many of the common challenges they face in the construction industry, such as resource constraints, tight deadlines, and client demands for high-quality results. This section explores these benefits in detail, emphasizing how LC can transform construction practices within smaller firms.

A. Cost Efficiency

The evolution of waste reduction in construction

Waste reduction has long been a cornerstone of lean construction, driving innovations aimed at enhancing efficiency, minimizing resource consumption, and delivering value to stakeholders. Two critical frameworks underpinning these efforts are the Transformation-Flow-Value (TFV) theory and Just-in-Time (JIT) delivery systems. These frameworks complement each other, offering holistic perspectives on waste minimization through the integration of lean principles, process optimization, and advanced technologies.

TFV: A Holistic Framework for Waste Reduction

The **Transformation-Flow-Value (TFV)** theory of production has evolved significantly, reflecting a shift in how construction processes are conceptualized. Early contributions by Koskela et al. [17] highlighted the foundational differences between traditional "thing-based" and emerging "process-based" production paradigms. They argued that traditional approaches focused narrowly on inputs and outputs often fail to address inefficiencies inherent in construction workflows. In contrast, the process-based perspective emphasized the integration of transformation (resource conversion), flow (material and temporal dynamics), and value generation (customer-centric outcomes). Koskela et al. critiqued the inefficiencies of static management structures, advocating for dynamic, flexible systems that align work, flow, and value generation through distributed cognition and holistic control mechanisms.

Building on these ideas, Koskenvesa et al. [17] demonstrated the practical applications of TFV in construction site performance evaluations. Through case studies, they illustrated how traditional productivity models overlook non-value-adding activities, such as delays and inefficiencies. The TFV framework, by integrating transformation, flow, and value, identified waste sources that traditional methods missed. The study underscored the potential of TFV to enhance productivity, reduce variability, and optimize task execution, aligning seamlessly with lean principles.

More recently, Igwe et al. [18] investigated specific waste categories and their impact on TFV processes in the Nigerian construction sector. Their findings revealed the critical role of managing non-physical wastes like "Making-Do," "Waiting," and "Overproduction," which diminish productivity, inflate costs, and undermine value generation. They proposed adopting advanced management practices, such as Total Quality Management (TQM) and Building Information Modeling (BIM), to address these challenges. Collectively, these studies trace the evolution of TFV from a theoretical construct to a practical tool for identifying and mitigating inefficiencies in construction projects.

JIT: Targeting Waste in Logistics and Material Management

Parallel to the development of TFV, Just-in-Time (JIT) systems emerged as a complementary framework targeting waste reduction in logistics and material management. By focusing on delivering materials "just in time" for use, JIT minimizes inventory, reduces delays, and streamlines workflows, addressing key inefficiencies in construction supply chains.Si et al. [19] proposed a conceptual model for implementing JIT delivery in off-site construction (OSC). Recognizing the challenges of schedule variations and poor coordination, they introduced a data-sharing platform that facilitates real-time delivery adjustments through a dynamic compensation mechanism. This approach not only minimizes waste, such as excess inventory and delays, but also balances stakeholder interests, aligning with lean principles to enhance the efficiency and sustainability of OSC.Hussein et al. [20] extended these insights by identifying critical factors (CFs) for JIT implementation in Modular Integrated Construction (MiC). Using systematic reviews and meta-analysis, they emphasized the need for context-specific strategies, particularly in developing economies and

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complex supply chains. Their work highlighted JIT's potential to reduce timelines, optimize logistics, and enhance sustainability in diverse construction settings.

The integration of advanced technologies further transformed JIT practices, as demonstrated by recent research on Building Information Modeling (BIM). BIM supports JIT delivery by integrating with scheduling tools to generate precise material quantities and delivery schedules, reducing waste and delays. By enabling 4D visualization, BIM improves planning and coordination, eliminates inventory buffers, and fosters continuous improvement. These advancements underscore BIM's transformative role in modernizing JIT practices and making them indispensable for lean construction.

Integrating TFV and JIT: A Unified Approach to Lean Construction

The combined insights from TFV and JIT highlight their complementary roles in waste reduction. While TFV offers a theoretical foundation for understanding production inefficiencies across transformation, flow, and value, JIT provides a practical framework for optimizing logistics and material management. Together, they address waste at multiple levels—TFV targeting systemic inefficiencies in production processes and JIT focusing on the operational dynamics of material delivery.

The progression of research—from Koskela et al.'s foundational TFV theory (2007) to Koskenvesa et al.'s application of TFV [21], and the advancements in JIT frameworks and technologies by Si et al. [19], Hussein et al. [20], and BIM-integrated JIT systems—illustrates a continuous evolution in lean construction practices. This integrated approach not only enhances efficiency and sustainability but also positions the construction industry to meet the demands of modern projects with greater agility and precision.

Enhanced Resource Utilization

Enhanced resource utilization is a cornerstone of lean construction, focusing on maximizing the efficiency of materials, labor, machinery, and time while minimizing waste. This approach aligns closely with lean principles, which emphasize streamlined workflows, proactive planning, and collaboration among stakeholders. Key strategies include integrating early design-stage planning, prefabrication, just-in-time delivery, and efficient scheduling tools. Together, these methods aim to eliminate resource wastage, reduce lead times, and foster continuous improvement. By optimizing the use of resources, lean construction not only improves project timelines and costs but also supports sustainability and stakeholder value creation.

Boshner et al.[22] exemplify these principles through the Design for Construction (DFC) framework, showcasing the importance of aligning design and execution processes. Their case study demonstrated how prefabrication, standardized workflows, and just-in-time delivery reduced lead times and resource waste, enhancing stakeholder collaboration. Ramajogi et al. [23] expanded on these ideas by identifying inefficiencies in traditional practices, such as material wastage and labor mismanagement, and recommending modern tools like project scheduling software to streamline coordination. Together, these studies highlight the synergy between early planning, advanced tools, and collaborative execution. By implementing such strategies, lean construction achieves more efficient resource allocation, fostering productivity and sustainability across projects.

B. Improved Project Delivery

Improved Project Delivery Through Faster Completion Times

Early stakeholder involvement, particularly Early Contractor Involvement (ECI), is a strategic approach to enhance construction project outcomes by integrating contractor expertise during the design phase. This collaboration improves design quality, optimizes resource utilization, and minimizes delays caused by design revisions or material shortages. By engaging contractors early, projects benefit from practical insights on material selection, construction sequencing, and cost-effective strategies. ECI fosters better communication, aligns stakeholder objectives, and reduces overall project duration. However, its success depends on overcoming implementation challenges such as aligning stakeholder goals, navigating procurement regulations, and fostering a culture of collaboration.

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Song et al. [26] demonstrate the value of ECI through a combination of case studies and simulation modeling, showcasing significant reductions in project duration and man-hours. Their research highlights the importance of integrating contractor input to improve design quality and streamline scheduling. Wondimu et al. [27] expand on this by examining ECI in Norwegian public infrastructure projects, identifying various methods of implementation while addressing challenges posed by procurement directives. Their findings emphasize ECI's role in improving efficiency, reducing waste, and enhancing collaboration. Together, these studies advocate for broader adoption of ECI, offering valuable insights into its implementation and highlighting its potential to transform construction project delivery.

Higher Quality Outputs

Higher quality outputs in the construction industry are increasingly tied to the adoption of Lean Construction (LC) principles, which aim to improve efficiency, reduce waste, and foster continuous improvement. Rooted in Lean Production, LC emphasizes principles such as Kaizen (continuous improvement), collaboration, and waste minimization to enhance project outcomes. The integration of modern tools like Building Information Modeling (BIM) further amplifies these principles, offering real-time visualization, dynamic planning, and data-driven decision-making. However, successful implementation requires addressing challenges such as cultural resistance, resource constraints, and inconsistent practices, which can undermine the transformative potential of LC. Sustained improvements demand organizational commitment to training, standardization, and fostering a supportive culture.

Da et al. [28] explore the evolution of LC, emphasizing the critical role of education and collaborative learning in its sustained adoption. They highlight the need for industry-wide cultural shifts to ensure LC's long-term relevance. Guirriero et al. [29] extend this by illustrating how BIM integration enhances LC practices, showcasing tools like the Smart Construction Planner® to improve scheduling, material tracking, and site management. Amdal et al. [30] focus on the application of Kaizen in Norway's largest construction firms, identifying structured frameworks and knowledge-sharing mechanisms as pivotal for improving efficiency. Together, these studies present a comprehensive view of how Lean principles and modern tools can synergistically elevate construction quality, underscoring the importance of continuous learning, technology integration, and organizational flexibility in driving higher-quality outputs.

C. Enhanced Collaboration

Stronger Stakeholder Alignment Through Sustainable Lean Construction

Stronger stakeholder alignment is critical for achieving successful outcomes in construction projects, particularly when balancing efficiency and sustainability. Sustainable Lean Construction (SLC) integrates Lean Construction (LC) principles of waste reduction and process efficiency with Sustainable Construction (SC) goals of environmental stewardship and resource conservation. This alignment requires active stakeholder engagement to ensure that both economic and environmental benefits are prioritized. However, challenges such as cultural resistance, insufficient collaboration, and lack of commitment can hinder these efforts. Addressing these challenges requires frameworks that foster clear communication, shared goals, and a collective commitment to sustainable practices.

Abd et al. [31] emphasize the importance of stakeholder-driven approaches to implementing SLC in Malaysia. Their proposed model bridges the principles of LC and SC, focusing on reducing waste, enhancing resource efficiency, and maximizing project value. The study underscores that stakeholder engagement is vital to overcoming cultural and systemic barriers, advocating for improved communication and collaboration. This approach not only aligns diverse stakeholder interests but also sets the foundation for sustainable and efficient construction practices. By refining these strategies and incorporating empirical insights, SLC can serve as a robust framework for fostering stronger alignment and delivering holistic project success.

Post-Occupancy Evaluation: Enhancing Building Performance Through Feedback

Post-Occupancy Evaluation (POE) serves as a crucial feedback mechanism to assess how well buildings meet performance standards and occupant needs after occupancy. By addressing technical, functional, and socio-cultural aspects, POE provides actionable insights to improve building design, sustainability, and operational efficiency. It helps architects, facility managers, and stakeholders identify areas for refinement, ensuring that buildings adapt to evolving

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user requirements. However, challenges such as inconsistent methodologies, insufficient practitioner expertise, and stakeholder resistance often hinder the adoption and efficacy of POE. A comprehensive, inclusive approach is essential to overcome these barriers and realize POE's full potential in enhancing built environments.

Aliyu et al. [32] emphasize POE's role as a feedback tool, advocating for standardized, stakeholder-inclusive methods to address evaluation challenges and align buildings with user needs. Complementing this, Brioso et al. [33] propose integrating Building Information Modeling (BIM) and Geographic Information Systems (GIS) to enhance POE practices. Their spatial mapping method facilitates effective visualization and analysis of performance data, bridging gaps in traditional POE approaches. By combining quantitative and qualitative insights, this method improves stakeholder collaboration and fosters continuous improvement in building performance and occupant satisfaction. Together, these contributions highlight POE as a pivotal strategy for aligning building performance with sustainability and user-centric goals.

Integrated Design and Delivery: A Framework for Efficient and Value-Driven Construction

The Lean Project Delivery System (LPDS) redefines traditional construction approaches by prioritizing efficiency, collaboration, and value creation. Rooted in principles from the Toyota Production System, LPDS aligns project goals, processes, and constraints to deliver facilities that meet customer purposes while minimizing waste. It integrates innovative techniques such as target costing and set-based design, fostering iterative validation of business plans and stakeholder collaboration throughout the project lifecycle. By emphasizing continuous improvement and adaptive management, LPDS facilitates sustainable, cost-effective, and purpose-driven outcomes for construction projects.

Ballard et al. [34] provide foundational insights into LPDS, showcasing its application in design and definition phases to align ends and means effectively. Their case studies highlight LPDS's potential to enhance sustainability, reduce costs, and improve project outcomes. Forbes et al. [35] echo these advancements, emphasizing iterative design validation and cultural shifts necessary for lean success. Building on this foundation, Aslam et al. [36] propose integrating Virtual Design and Construction (VDC) with LPDS to address challenges like limited visualization and poor information flow. Their framework demonstrates synergies between VDC's technological capabilities and LPDS's lean principles, enabling enhanced productivity, waste elimination, and continuous improvement across all project phases. Together, these contributions underscore LPDS as a transformative approach for modern construction.

D. Increased Client Satisfaction

Increased Client Satisfaction through Enhanced Value Generation

Value generation is a cornerstone of Lean Construction (LC), aimed at aligning construction processes with client and societal expectations. By focusing on delivering optimal outcomes and minimizing waste, LC seeks to enhance client satisfaction while addressing broader environmental and social concerns. The concept of value in LC extends beyond meeting functional requirements, encompassing economic, social, and environmental dimensions to maximize overall project impact.

Salvatierra et al. [37] highlight the evolving definition of value within LC, emphasizing the need to integrate societal needs and sustainability into project objectives. They propose a model that expands value considerations to include global and social contexts, advocating for an industry-wide shift toward projects that contribute to social welfare while aligning with client goals. Musa et al. [38] examine the relationship between LC and Value Management (VM), emphasizing their shared focus on value delivery but contrasting their approaches. While VM often operates through targeted interventions during early project phases, LC provides a broader framework encompassing the entire project lifecycle. The paper proposes integrating LC's process-driven methodology with VM's strategic focus to create a cohesive system for value generation, enhancing project.

Flexible Response to Changes

The practice of deferring key decisions to the "last responsible moment" is another important feature of LC that contributes to greater flexibility. This practice enables SMEs to remain agile and respond to evolving client requirements without significant disruptions to the project. As construction projects often encounter unforeseen

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challenges or changes, being able to accommodate these adjustments without major delays or cost increases is a major benefit for SMEs. This flexibility helps ensure that the final product meets the client's expectations, even in the face of changes during the project lifecycle.

Vaagen et al. [39] propose an enhanced framework for Lean Project Delivery, embedding flexibility into the Last Planner System (LPS®) to better address uncertainties inherent in Engineer-to-Order (ETO) and construction projects. The framework incorporates planned adaptability in master planning, enabling teams to respond proactively to late-stage changes. Through Design Science Research and case studies, the study demonstrates how integrating flexibility reduces the time and cost implications of unforeseen changes, while also capturing opportunities from client-driven modifications. Paslawski et al. [40] explore similar themes in the context of ready-mix concrete delivery for road construction, introducing the RMCD4.0 method. By combining Lean Construction's waste-reduction principles with Agile Management's adaptability, and leveraging Construction 4.0 technologies like GPS tracking and wireless communication, RMCD 4.0 improves synchronization and efficiency. Case studies reveal productivity gains of up to 50%, illustrating the value of blending Lean stability with Agile flexibility.

E. Long-Term Competitiveness

Reputation Building

Consistently delivering high-quality projects on time and within budget enables small and medium-sized enterprises (SMEs) to establish a reputation for reliability and excellence, a crucial factor for securing new business opportunities in a competitive market. Lean Construction (LC) equips SMEs with tools to manage projects more effectively, build client trust, and strengthen their industry standing. Over time, SMEs leveraging LC principles can develop a robust brand identity that differentiates them from competitors and promotes growth through referrals and repeat business.

Ogunbiyi [41] highlights the role of LC in achieving not only operational efficiency but also sustainability goals. By integrating lean principles with sustainable construction practices in the UK, the study emphasizes the importance of waste reduction and enhanced efficiency as cornerstones of reputation building. The Lean Implementation Assessment Framework (LIMA) developed in the study provides contracting organizations with a roadmap to align lean methods with sustainable development, delivering economic, environmental, and social benefits. This alignment fosters client trust and reinforces the reputation of organizations as forward-thinking and responsible players in the construction industry.

By adopting LC practices and frameworks such as LIMA, SMEs can overcome barriers like resistance to change and resource constraints, ensuring continuous improvement in project delivery. This strategic approach not only enhances operational outcomes but also builds a strong foundation for long-term competitiveness through a well-established reputation for excellence and sustainability.

Sustainability and Innovation

In addition to enhancing operational efficiency, Lean Construction (LC) aligns closely with the construction industry's push toward sustainability. Core LC practices such as waste reduction, energy-efficient designs, and sustainable material sourcing enable SMEs to position themselves as forward-thinking, socially responsible entities. As sustainability becomes an increasingly critical criterion in construction projects, SMEs that adopt LC are better prepared to meet regulatory requirements, attract environmentally conscious clients, and contribute to a greener construction industry. Furthermore, LC's inherent focus on continuous improvement and innovation positions SMEs to stay ahead of industry trends, ensuring their long-term competitiveness.

Ogunbiyi et al. [41] explore the integration of lean techniques with sustainable construction practices in the UK, highlighting their shared goals of environmental stewardship and efficiency. Key benefits include improved corporate image, increased productivity, enhanced environmental quality, and alignment with customer expectations. The study identifies tools such as Just-in-Time (JIT), value analysis, and daily huddle meetings as instrumental in achieving these outcomes. Additionally, the synergy between lean and sustainability practices fosters value maximization, health and safety improvements, and waste reduction—critical aspects for SMEs aiming to build a reputation for sustainability and innovation.

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While the integration of lean and sustainability practices presents challenges, including resistance to change and knowledge gaps, the adoption of LC principles enables SMEs to achieve both operational excellence and environmental responsibility. By leveraging LC frameworks and tools, SMEs can demonstrate leadership in sustainable construction, differentiate themselves in a competitive market, and enhance their reputation as innovators committed to industry advancement.

F. Practical Evidence of Impact

The adoption of Lean Construction (LC) principles, particularly in small and medium-sized enterprises (SMEs), demonstrates tangible benefits through enhanced efficiency, reduced waste, and improved project outcomes. However, scalability and practical implementation remain challenges. Evidence from reviews and case studies provides insights into how SMEs can effectively adopt LC practices and scale their benefits.

Tezel et al. [16] and Matt et al. [42] conducted systematic reviews on the adoption of LC and Building Information Modeling (BIM) in SMEs. These studies reveal that while SMEs represent the majority of construction firms globally, they face significant barriers to adopting LC and BIM, including resource constraints, limited training opportunities, and insufficient stakeholder collaboration. The reviews highlight a research gap in SME-specific strategies and the combined application of LC and BIM, emphasizing the need for tailored approaches to address these challenges.

Training programs play a critical role in overcoming barriers to LC adoption. Martinez et al. [43] illustrate this through a case study on the design and implementation of a lean construction training program within a multinational organization. The program's success was attributed to its hands-on approach, live case studies, and participant-driven problem-solving, which fostered a culture of continuous improvement. However, balancing operational duties with training remains a challenge, emphasizing the need for sustained engagement and organizational commitment.

Further, the integration of LC principles with advanced technologies offers scalable solutions for SMEs. Cucuzza [44] introduces Lean Construction 4.0 (LC4.0), combining LC principles with Industry 4.0 technologies to address productivity challenges in the Architecture, Engineering, and Construction (AEC) sector. The framework includes tools like the LC4.0 Assessment for evaluating digital maturity and the Panelization Design Tool for optimizing offsite construction processes. Case studies, such as the Horizon 2020 BIM4EEB project, demonstrate the framework's scalability and potential for transforming SME operations through digitalization and automation.

These reviews and practical studies underscore the significant impact of LC on SMEs and provide a roadmap for overcoming barriers to adoption. Tailored strategies, comprehensive training programs, and leveraging advanced technologies enable SMEs to scale LC practices effectively, ensuring long-term competitiveness in the industry.

IV. BARRIERS TO ADOPTION

While the principles of Lean Construction (LC) offer significant potential to improve efficiency, reduce waste, and enhance value delivery, the widespread adoption of LC practices remains a challenge, particularly for small and medium-sized enterprises (SMEs). Despite its demonstrable benefits, including streamlined workflows and cost savings, LC adoption is often hindered by deeply entrenched organizational habits, cultural inertia, and systemic limitations within the construction industry. SMEs, which constitute a significant portion of the sector, frequently encounter unique constraints that magnify these challenges, such as limited financial and human resources, a reliance on traditional project management methods, and a focus on short-term outcomes over long-term process optimization. These factors are compounded by market dynamics and stakeholder misalignments that make it difficult to prioritize LC methodologies. Understanding these barriers is crucial to formulating strategies that facilitate the integration of LC principles and unlocking their transformative potential across the construction industry. This section explores the key organizational, cultural, and systemic obstacles SMEs face in adopting LC, while also outlining actionable recommendations to overcome these challenges and foster a more widespread implementation of Lean practices..

A. Organizational Barriers

The successful adoption of Lean Construction (LC) principles within small and medium-sized enterprises (SMEs) faces significant organizational challenges that stem from resistance to change, limited resources, and a lack of leadership and

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vision. These barriers, while interconnected, represent distinct obstacles that hinder the seamless integration of LC practices and require targeted strategies to overcome.

Resistance to Change

One of the most pervasive barriers to LC adoption is organizational resistance to change. SMEs often rely on traditional project management approaches that prioritize task-focused and cost-driven methodologies. Transitioning to LC requires a fundamental paradigm shift, which is frequently met with skepticism and reluctance, as these principles may initially appear disruptive to established workflows. Studies have highlighted that employees and managers within SMEs often lack adequate exposure to LC, further exacerbating resistance. Amade et al. [45] in their investigation of LC barriers in the Nigerian construction industry, underscored this resistance as a primary challenge. The study revealed that a lack of lean awareness, coupled with cultural and attitudinal issues, prevented organizations from embracing innovative workflows. Similarly, Moradi et al.[46] emphasized the role of organizational culture in enabling or hindering LC adoption. Their review found that insufficient awareness of LC principles and reluctance from top management significantly impeded implementation efforts.

Limited Resources

Resource constraints are another critical organizational barrier, particularly for SMEs operating with lean budgets and smaller teams. Implementing LC demands upfront investments in training, process redesign, and the acquisition of specialized tools. These commitments can be prohibitively expensive for resource-strapped organizations, especially when external expertise, such as consultants or trainers, is required. Sarhan et al. (2013) [47] identified insufficient financial resources as a key impediment to LC adoption in the UK construction industry, emphasizing the need for capacity building and financial support to bridge this gap. Similarly, Al Balkhy et al. [48] noted that inadequate training and poor stakeholder transparency compounded the issue, as SMEs often struggled to allocate funding to educational initiatives or collaborative efforts necessary for LC integration. These findings underscore the importance of designing cost-effective solutions and providing financial incentives to enable SMEs to overcome resource-related challenges.

Lack of Leadership and Vision

A third major organizational barrier is the absence of strong leadership and vision to champion LC as a long-term strategy. Transformational leadership plays a pivotal role in driving cultural shifts and fostering commitment to new methodologies. However, many SME leaders lack the awareness, conviction, or strategic insight to lead this transformation effectively. Huaman et al. [49] highlighted that the absence of leadership often results in inadequate empowerment of project teams and a lack of motivation to adopt LC principles. Without clear direction or support from top management, organizations struggle to align their goals with LC objectives, leading to fragmented efforts and ineffective use of lean tools. Similarly, Moradi et al. [46] and Sarhan et al. [47] emphasized that top management commitment is crucial for addressing structural and cultural challenges, fostering a lean mindset, and ensuring sustained implementation efforts.

Collectively, these organizational barriers form a significant impediment to the adoption of LC within SMEs. Overcoming these challenges requires a multi-pronged approach that includes raising awareness, fostering a culture of innovation, and equipping leaders with the skills and vision to drive LC integration. By addressing resistance to change, resource constraints, and leadership gaps, SMEs can unlock the transformative potential of LC and achieve significant gains in efficiency, cost savings, and value creation.

B. Organizational Barriers

Cultural factors represent a critical yet often underappreciated barrier to the adoption of Lean Construction (LC), particularly within small and medium-sized enterprises (SMEs). These factors primarily manifest as misalignment of stakeholder goals, reliance on traditional hierarchical structures, and a pervasive short-term focus that prioritizes immediate outcomes over long-term benefits. Together, these cultural dynamics create challenges in fostering the collaborative, forward-thinking mindset essential for the successful implementation of LC principles.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 2, July 2025
Impact Factor: 7.67

Misalignment of Stakeholder Goals

A core tenet of LC is the early and continuous involvement of all stakeholders, including contractors, clients, and subcontractors. This collaborative approach aims to ensure alignment on project objectives, enhance communication, and drive value creation throughout the construction lifecycle. However, SMEs often struggle to achieve this level of integration, particularly in multi-contractor projects where diverse priorities and perspectives can lead to conflicts. Traditional hierarchical structures and siloed decision-making exacerbate these challenges, creating barriers to achieving the alignment required for LC practices to flourish. Cano et al. [50] demonstrated the importance of stakeholder engagement in their study of LC implementation within a construction firm. Their findings emphasized that the process of adopting LC is not merely a one-time change but an ongoing, dynamic interaction involving actors both within the organization and with external partners. The successful implementation relied on balancing top-down strategic efforts with bottom-up engagement, highlighting the need for sustained collaboration among all stakeholders to overcome cultural barriers.

Short-Term Focus

In many SMEs, a short-term focus on immediate cost and schedule goals presents another significant cultural barrier to LC adoption. These organizations often prioritize achieving quick, tangible results, overlooking the long-term benefits that LC can provide, such as optimized workflows, enhanced efficiency, and value creation for clients. This short-termism is at odds with the holistic methodologies central to LC, which require a forward-thinking mindset to realize their full potential. Cano et al [50] also highlighted this tension, noting that the gradual diffusion of LC practices across their case study firm required a cultural shift from short-term tactical approaches to a broader strategic vision. This shift involved ongoing learning, adaptation, and the cultivation of a mindset focused on continuous improvement—a process that SMEs may find challenging without the right cultural foundation.

Addressing these cultural barriers necessitates a concerted effort to transform traditional mindsets and foster a culture of collaboration, innovation, and long-term thinking. SMEs must prioritize stakeholder engagement and encourage open communication across all levels of the organization. By aligning goals and fostering shared accountability, SMEs can create an environment conducive to the adoption of LC principles, ultimately unlocking their potential to enhance project outcomes and deliver greater value to clients.

B. Systemic Barriers

Systemic challenges, including limited access to training and knowledge, are particularly pronounced among SMEs. Awareness of LC frameworks, such as the Transformation-Flow-Value (TFV) theory and the Lean Project Delivery System (LPDS), is often minimal. Few training programs cater specifically to the unique constraints faced by smaller firms, leaving SMEs with limited resources to build LC expertise.

Market constraints further complicate adoption. Intense competition in the construction industry pressures SMEs to prioritize speed and cost efficiency over systemic process improvements. Moreover, clients may lack an understanding of or demand for LC practices, diminishing the incentives for SMEs to adopt them. The incompatibility of traditional tools and systems with LC principles also creates resistance. Many SMEs rely on outdated methods that are ill-suited for key LC practices, such as workflow visualization, continuous improvement, and just-in-time supply chains.

C. Recommendations to Overcome Barriers

Overcoming the barriers to Lean Construction (LC) adoption requires a systematic and multifaceted approach that addresses organizational, cultural, and systemic challenges. By leveraging leadership development, gradual implementation strategies, collaborative ecosystems, and targeted interventions, SMEs can build a foundation for sustainable LC practices and realize its transformative potential.

Leadership Development and Training

Strong leadership is a cornerstone of successful LC adoption. Training programs that emphasize transformational leadership can equip SME leaders with the skills needed to advocate for and implement LC effectively. Sarhan et al.

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(2013) underscore the importance of top management commitment in driving organizational change and fostering a culture that embraces Lean principles. Leadership training should include fostering a clear vision, effective communication strategies, and techniques to motivate teams toward long-term goals. These efforts can empower leaders to guide their organizations through the paradigm shift required for LC adoption.

Gradual Implementation

SMEs can benefit from a phased approach to LC implementation, focusing on specific tools and practices that yield immediate, measurable benefits. For instance, the adoption of the Last Planner System—a tool designed to improve workflow reliability and production control—can help SMEs achieve quick wins while building confidence in Lean methodologies. Gradual implementation also allows organizations to adapt LC practices to their unique operational contexts, reducing disruption and resistance to change.

Collaborative Learning Ecosystems

The creation of collaborative learning ecosystems can further support SMEs in their Lean journey. Partnerships with industry associations, government bodies, and academic institutions can facilitate resource-sharing and provide access to tailored training programs. Sarhan et al. [47] advocate for fostering relationships between stakeholders and adopting integrated project delivery systems to reduce fragmentation and adversarial relationships. By promoting knowledge exchange and collaboration, SMEs can overcome cultural barriers and align stakeholders toward shared goals.

Affordable Digital Tools and Technologies

Investing in affordable digital tools and technologies can empower SMEs to implement LC practices efficiently, even with limited resources. Digital platforms for project management, communication, and data analysis can streamline workflows and enhance transparency, reducing waste and improving decision-making. Government incentives or subsidized programs to promote digital transformation in SMEs can further ease the financial burden of adopting LC practices.

Building a Lean Culture

Addressing cultural barriers requires a shift toward collaboration, innovation, and long-term thinking. Sarhan et al. [47] emphasize the need for cultural change within the construction industry, advocating for less resistance to new methodologies and greater collaboration across teams. SMEs should prioritize fostering a Lean mindset at all organizational levels, encouraging open communication and shared accountability among stakeholders.

Flexible Procurement and Contract Systems

Traditional procurement and contract systems can hinder LC adoption by perpetuating adversarial relationships and siloed decision-making. Sarhan et al. [47] recommend adopting more flexible procurement strategies aligned with Lean principles, such as integrated project delivery systems. These systems promote cooperation, transparency, and shared risk, enabling stakeholders to work together more effectively.

By systematically addressing organizational, cultural, and systemic challenges, SMEs can unlock the full potential of LC. This adoption not only reduces waste and improves workflow reliability but also enhances value delivery to clients. In an increasingly competitive construction industry, embracing LC provides SMEs with a strategic advantage, positioning them for sustained growth and success.

V. ADOPTION OF LEAN CONSTRUCTION IN SMES: GLOBAL

Perspectives and Challenges

The adoption of Lean Construction (LC) principles by small and medium-sized enterprises (SMEs) in the construction sector has been a subject of growing research interest. While these principles have shown potential to improve efficiency and reduce waste, SMEs face unique challenges shaped by organizational, cultural, and regional contexts. This section explores these barriers and opportunities, structured into subsections for clarity.

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A. Challenges in Adopting Lean Construction in SMEs

Organizational Barriers

In Ghana, Ankomah et al. [51] highlighted that SMEs face significant constraints, including limited financial resources, insufficient organizational capacity, and deeply entrenched cultural mindsets resistant to change. Similar challenges were noted in New Zealand by Poshdar et al., [52] where only 3% of SMEs actively implemented Lean practices, despite broader awareness. The study identified internal resistance to change and poor communication of Lean's benefits as major roadblocks.

Singh et al. [53] identified managerial factors, such as the lack of leadership commitment, as critical barriers in India. Their multicriteria decision analysis revealed that a combination of resource scarcity, limited awareness, and complexity in implementing Lean further hindered adoption, keeping most companies at the early exposure stage rather than full implementation.

Cultural and Regional Barriers

Van et al. [54] explored the role of cultural dimensions in Lean leadership, particularly in the United States. The country's low power distance and high individualism facilitated leadership styles aligned with Lean practices, such as participative decision-making and employee empowerment. However, the high masculinity and performance-driven ethos often conflicted with Lean's relational and team-oriented aspects. Tailored leadership training programs were recommended to address these cultural nuances.

Globally, Hu et al. [55] observed that research on Lean implementation in SMEs has been predominantly concentrated in Western regions, including the US, Canada, and Europe. Developing economies in Asia and Africa remain underrepresented, despite facing distinct challenges such as financial constraints, infrastructure deficiencies, and limited access to Lean expertise. Regional variations in Lean practices also emerged, with Western SMEs focusing on internal operations and supply chain integration, while SMEs in developing regions struggled to overcome basic resource limitations.

B. Synergies Between Lean Construction and Emerging Approaches

Integration with Digital Tools

Daniel et al. [56] explored the intersection of LC with offsite construction (OSC), revealing growing interest in integrating these approaches to enhance sustainability and efficiency. Their bibliometric analysis highlighted the role of digital tools like Building Information Modeling (BIM) in driving Lean adoption. Despite advancements, the study pointed out limited interdisciplinary collaboration and the need for empirical case studies to assess the combined impact of LC and OSC. Shang et al. [57] delved deeper into the integration of BIM with Lean principles, categorizing barriers into supply chain, organizational, and project-specific factors. They emphasized the importance of government support, client engagement, and standardized regulations in overcoming these barriers. Addressing issues such as inadequate policies, resistance to change, and high implementation costs requires coordinated efforts across multiple stakeholders.

Alignment with Agile Project Management

Elseknidy et al. [58] investigated the challenges of Agile Project Management (APM) in sustainable residential construction, which shares principles with LC. Economic barriers, such as cost unpredictability and resource constraints, were found to be the most significant impediments, alongside social and cultural resistance. Limited training, poor communication, and mismatched client expectations further complicated APM adoption. These findings suggest parallels with LC adoption, reinforcing the need for tailored strategies to overcome similar barriers.

C. Regional Trends and Research Gaps

While Lean Construction research has grown steadily, regional imbalances persist. Daniel et al.[56] noted a concentration of research in countries like the US, Canada, and China, driven by the integration of sustainability practices and modular construction. However, Hu et al. [55] identified significant gaps in research from developing economies, particularly in Asia and Africa. The absence of context-specific studies limits the understanding of how

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Lean principles can be adapted to resource-constrained environments. Emerging themes identified by Daniel et al. [56] include the integration of LC with digital tools and sustainability practices, underscoring the potential for innovation. However, Van et al. [54]emphasized the importance of addressing cultural nuances in leadership and organizational behavior to maximize Lean's effectiveness in diverse contexts.

VI. BLUEPRINT FOR LEAN CONSTRUCTION ADOPTION IN SMES

Adopting Lean Construction (LC) in small and medium-sized enterprises (SMEs) requires a structured, phased approach tailored to their unique challenges. This blueprint outlines key stages for SMEs to integrate LC principles while addressing constraints like limited financial resources, cultural resistance, and operational scalability. Each stage builds on the next, ensuring a coherent and sustainable adoption process.

A. Establishing Leadership Commitment and Organizational Readiness

The cornerstone of any successful Lean implementation is strong leadership. SMEs should begin by designating a Lean Champion, ideally a senior leader, who can advocate for Lean practices and drive the cultural transformation needed for success. Leadership must communicate the benefits of LC clearly and consistently, ensuring that employees understand its value for both individual roles and organizational goals. Training programs are essential in this initial phase, providing employees with a foundational understanding of Lean principles like waste reduction, continuous improvement, and value maximization. Tools such as 5S, 5 Whys, and A3 problem-solving, as suggested by Ankomah et al. [51], can serve as accessible starting points that align with SMEs' limited resources. Leadership should also initiate efforts to address resistance to change by fostering an inclusive environment where employee feedback is encouraged.

B. Conducting a Baseline Assessment of Processes

Before implementing Lean practices, SMEs must understand their current operational inefficiencies. Conducting a thorough baseline assessment allows organizations to identify bottlenecks, sources of waste, and areas with the highest potential for improvement. Value stream mapping (VSM) is a particularly effective tool for this stage, enabling SMEs to visualize workflows and pinpoint inefficiencies. The assessment should focus on critical processes that directly impact project outcomes, such as procurement, scheduling, and resource allocation. This phase also provides an opportunity to set clear, measurable goals that align with organizational priorities. Key performance indicators (KPIs), such as cycle time, waste levels, and labor productivity, should be defined to track progress and demonstrate the value of Lean practices.

C. Launching a Pilot Project

The pilot phase allows SMEs to experiment with Lean principles on a smaller, manageable scale, reducing risk while building confidence in the approach. Selecting a project with clear deliverables and room for improvement is crucial. Low-cost tools like Kanban boards for workflow visualization and 5S for workspace organization can be implemented to achieve quick wins. By focusing on tangible improvements, such as reducing material waste or improving project timelines, SMEs can build momentum and garner employee support. Regular evaluation of the pilot project's outcomes using the pre-defined KPIs is critical. Insights gained during this phase should inform adjustments to the implementation strategy, ensuring that lessons learned are incorporated into future efforts. Transparent communication of the pilot's successes and challenges can help sustain organizational buy-in.

D. Scaling Lean Practices Across the Organization

Once the pilot project demonstrates the value of LC, SMEs can expand its principles to other areas of the organization. Scaling requires a strategic approach that prioritizes high-impact processes while maintaining flexibility to adapt to changing needs. Leadership must continue to play a central role, providing ongoing support and addressing any barriers to broader adoption. Change management becomes a critical component at this stage. Regular feedback loops, such as employee surveys and team workshops, ensure that the implementation aligns with organizational needs. As Van et al.

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[54] highlight, participative leadership styles are particularly effective in fostering collaboration and continuous improvement during this phase.

E. Leveraging Technology and Partnerships

Technology can significantly enhance the scalability of LC practices in SMEs. While initial efforts may rely on manual tools, gradual adoption of digital solutions like Building Information Modeling (BIM) can improve efficiency and decision-making. As Daniel et al. [56] suggest, integrating Lean principles with digital workflows and modular construction techniques offers substantial benefits in productivity and sustainability. Partnerships with industry associations, government programs, and Lean forums provide SMEs with valuable resources, such as training opportunities, case studies, and expert guidance. Collaborating with external stakeholders also helps SMEs stay informed about best practices and emerging trends, ensuring their Lean journey remains relevant and impactful.

F. Embedding a Culture of Continuous Improvement

Sustaining Lean practices requires a shift from project-based implementation to an organization-wide culture of continuous improvement. Kaizen events, which encourage team-driven innovation, play a vital role in keeping Lean principles at the forefront of daily operations. Leadership must also invest in targeted training programs for mid-level managers, ensuring they embody and promote Lean values. Regular benchmarking against industry standards and collaboration with external partners can further reinforce a culture of excellence. By aligning employee goals with organizational priorities, SMEs can ensure long-term engagement and commitment to Lean practices.

G. Addressing SME-Specific Challenges

To overcome challenges unique to SMEs, such as resource constraints and resistance to change, organizations must adopt innovative solutions. Low-cost Lean tools, government grants, and outsourced expertise can mitigate financial and capacity limitations. Emphasizing the tangible benefits of Lean through data-driven communication, such as improved productivity and reduced waste, helps address cultural resistance.

The phased approach outlined here provides SMEs with a practical and scalable framework for Lean Construction adoption. By starting small, leveraging early successes, and gradually expanding their efforts, SMEs can transform their operations, achieve significant efficiency gains, and position themselves as competitive players in the construction industry.

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Volume 5, Issue 2, July 2025
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International Journal of Advanced Research in Science, Communication and Technology
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Volume 5, Issue 2, July 2025
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