

Lean Construction 5.0

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Abstract

Lean Construction 5.0 is an advanced framework that merges traditional Lean principles with digital technologies and a humanistic approach. Its objective is to maximize efficiency, quality, and value in architecture and engineering projects, minimizing waste and promoting continuous improvement. This paradigm redefines value from the client's perspective and encourages collaborative workflows. Integrated with BIM, IoT, and AI, it optimizes scenario simulation and real-time project management. Furthermore, Lean 5.0 incorporates sustainability principles (carbon neutrality, circular economy) to reduce the environmental impact of construction. The Lean 5.0 methodology combines traditional Lean tools with digital technologies. Value Stream Mapping visualizes processes to eliminate non-value activities, while the 5S methodology organizes the workspace and reduces waste. The Last Planner System enables collaborative planning (pull planning), synchronizing just-in-time deliveries and minimizing rework. These tools, along with root cause analysis, improve team coordination. Furthermore, Lean 5.0 integrates BIM, IoT, and AI through Lean Digital platforms, facilitating 3D simulations and real-time monitoring. Recent results show quantifiable benefits of Lean 5.0. Projects with a strong Lean approach triple ($\approx 300\%$) on-time deliveries and double ($\approx 200\%$) the probability of meeting quality standards. Furthermore, project phase durations have been reduced by up to 30%, accelerating timelines and reducing costs. These advances are enhanced by incorporating BIM, IoT, and AI into construction management. Specialized platforms such as VisiLean integrate this data, reinforcing transparency and continuous improvement. Lean 5.0 also promotes sustainability through carbon-neutral practices and a circular economy. Overall, the Lean-Digital convergence drives more agile workflows, operational resilience, and greener construction. The adoption of Lean 5.0 is associated with cost and schedule reductions, and higher quality. Cases in Chile, Spain, and Brazil illustrate these benefits: for example, a Chilean company improved its operational management, a Spanish project was delivered a year ahead of schedule, and a Brazilian port optimized its logistics flow. The integration of Lean with BIM, IoT, AI, and digital platforms (Lean Digital, VisiLean) consolidates early deliveries and sustainability. Lean Construction 5.0 thus emerges as a rigorous and promising standard, harmonizing productivity, quality, and environmental responsibility in construction.

Keywords: Lean, Construction, Management

1. Introduction

Lean Construction 5.0 is an advanced framework that builds upon traditional lean construction principles by integrating modern technological advancements and a human-centric approach to enhance productivity, sustainability, and value creation in the construction industry. Originating from lean management practices, Lean Construction 5.0 aims to minimize waste, streamline processes, and foster continuous improvement across all project

phases, ultimately addressing both the digital and green transitions in construction practices [1,2]. This methodology is notable for its focus on collaborative strategies and innovative tools, such as Building Information Modeling (BIM) and the Internet of Things (IoT), which have transformed conventional construction methods into more efficient, adaptive systems capable of meeting contemporary challenges.

Central to Lean Construction 5.0 are key principles, including waste reduction, value definition, and continuous workflow optimization, which collectively work to elevate project outcomes. By establishing a clear understanding of value from the customer's perspective, this framework encourages stakeholders to focus on activities that enhance quality and eliminate inefficiencies, leading to superior project performance and client satisfaction [3-5]. Furthermore, the application of Value Stream Mapping and the Last Planner System empowers teams to identify non-value-adding activities, promote reliable workflows, and facilitate better coordination among project participants [4,6,7].

Despite its promising advantages, Lean Construction 5.0 faces challenges such as resistance to change, the need for extensive training, and the initial investment costs associated with adopting new practices. The cultural shift required for successful implementation can also present difficulties, as organizations must transition to a collaborative, transparent environment that supports continuous improvement [2,8,9]. Moreover, as the construction landscape evolves amid economic fluctuations and unexpected global events, the adaptability of lean methodologies remains critical for long-term success and resilience in the industry.

In summary, Lean Construction 5.0 represents a significant evolution in construction practices, merging traditional lean principles with modern technological solutions and a focus on human-centric design. This innovative approach aims to address pressing industry challenges, improve operational efficiencies, and foster a sustainable and resilient construction ecosystem that meets the demands of today's society [10,11].

- **Principles of Lean Construction 5.0**

Lean Construction 5.0 integrates principles from lean management to enhance productivity, minimize waste, and foster a human-centric approach within the construction industry. This innovative framework aims to create more value using fewer resources while addressing both digital and green transitions in construction practices [1,2]. The following core principles define Lean Construction 5.

- **Waste Reduction**

Lean Construction 5.0 focuses on identifying and eliminating various forms of waste, which can include time, materials, and effort. This principle encompasses not only physical waste but also inefficiencies in processes that hinder productivity. Key strategies for waste reduction involve streamlining material transportation, managing surplus inventory effectively, and minimizing movement and waiting times onsite [12,13]. By fostering a culture of waste awareness, teams can significantly enhance performance and stakeholder satisfaction [12].

- **Continuous Improvement**

Continuous improvement is a cornerstone of Lean Construction 5.0, encouraging teams to adopt a mindset geared towards innovation and efficiency. This principle involves regularly assessing processes, identifying variances, and implementing

solutions to enhance performance over time. The goal is to create an environment where incremental improvements are made consistently, leading to sustainable progress and increased value generation [4,13].

By applying these principles, Lean Construction 5.0 seeks to transform traditional construction methods into more efficient, sustainable, and human-centric practices that better meet the evolving demands of the industry and society at large.

- **Defining Value**

The first principle involves understanding and defining what constitutes value from the customer's perspective. This requires identifying the specific needs and preferences of clients, which may extend beyond mere functional requirements to encompass desired quality, timing, and cost outcomes [3,4]. Establishing clear value definitions allows teams to focus their efforts on activities that enhance quality and eliminate waste [14].

- **Value Stream Mapping**

Value stream mapping (VSM) is a crucial tool in Lean Construction 5.0 that visually represents the sequences of activities involved in delivering a product or service. By mapping the value stream, teams can assess which activities add value and which do not. This evaluation helps identify and eliminate non-value-adding steps, thus enhancing overall efficiency and cost-effectiveness [15,16].

- **Continuous Workflow**

Creating a continuous workflow is essential for optimizing construction processes. This principle emphasizes the need for seamless transitions between different stages of construction to minimize delays and interruptions. By establishing pull planning and ensuring that all necessary resources are available just-in-time, teams can maintain a steady workflow that maximizes productivity and minimizes waste [4,16].

- **Historical Context**

Lean construction, which draws heavily from the principles established in lean manufacturing, has its roots in a long history of process optimization and value creation. Although its modern implementation is often attributed to the methodologies popularized by Toyota in the late 20th century, the foundations of lean thinking can be traced back centuries, reflecting a cumulative evolution of ideas across various cultures and industries.

- **Early Contributions to Lean Thinking**

The origins of lean principles can be linked to several historical milestones that emphasized the importance of efficiency and standardized processes. For instance, by 1765, French general Jean-Baptiste de Gribeauval recognized the significance of standardized designs and interchangeable parts for battlefield repairs [17]. This idea laid groundwork for later advancements in manufacturing practices. Further developments occurred in the early 19th century, when Marc Brunel in England devised a series of machines to produce identical wooden items for the Royal Navy, exemplifying an early form of process flow in manufacturing [17].

Despite these earlier contributions, it was not until the early 20th century that lean principles began to coalesce into a recognizable framework. Henry Ford is often credited with integrating the entire production process at his Highland Park plant in 1913, where he married interchangeable parts with standard work and moving conveyance to establish what he termed "flow production" through the moving assembly line [18]. This revolutionary approach not only transformed the automotive industry but also set the stage for future innovations in lean thinking.

- **Development of Lean Construction**

Lean construction emerged in the late 20th century as a specific application of lean principles to the construction industry. With traditional construction methods often plagued by inefficiencies, high costs, and delays, lean construction sought to eliminate waste and maximize value throughout the entire project lifecycle [19]. The implementation of lean principles in construction involves a focus on customer value, waste elimination, and continuous improvement, mirroring the foundational ideas of lean manufacturing [4,14].

As the construction industry evolved, researchers like Professor Lauri Koskela and Glenn Ballard played pivotal roles in formalizing lean construction concepts, emphasizing the need for a systematic approach to project management that incorporates operational research and practical development [7,20]. This culminated in the identification of key lean principles that have become essential for effective project delivery, including defining value, mapping the value stream, and creating flow [3,21].

- **The Fusion of Lean and Technology**

The continuous advancement of technology has further influenced the evolution of lean construction. The recent concept of Lean Construction 4.0 represents a fusion of lean principles with the digital transformations sweeping through the industry, highlighting the necessity for construction practices to adapt and evolve in response to technological progress [22]. This evolution reflects a broader trend across industries, where lean methodologies are increasingly integrated with modern technological solutions to improve efficiency and enhance value creation [19,23].

- **Key Concepts**

Lean Construction 5.0 is an advanced iteration of Lean principles applied to the construction industry, emphasizing efficiency, waste reduction, and value creation throughout the project lifecycle. The core concepts of Lean Construction 5.

- **Last Planner System**

The Last Planner System (LPS) is a pivotal tool within Lean Construction that promotes collaborative planning and enhances workflow predictability. Developed by Glenn Ballard and Greg Howell, the LPS focuses on empowering those closest to the work—typically foremen or leads—to make decisions and commitments regarding task execution [4,6].

Establish Reliable Workflows: By ensuring that the right resources and information are available when needed, LPS minimizes disruptions and bottlenecks during construction [4,24].

Enhance Coordination: Regular meetings and communication among team members help identify constraints and address them proactively, leading to more effective scheduling and planning [4].

Support Continuous Learning: As workflows become more predictable, teams can learn from past experiences and improve future project planning and execution [6].

- **Lean Principles**

The framework of Lean Construction is built around five key principles that guide decision-making and project execution:

Value: Identify what is truly valuable to the customer and focus on delivering that value throughout the project [5].

Value Stream: Map out all the steps involved in delivering the product or service to eliminate non-value-adding activities[5].

Flow: Ensure that work processes are uninterrupted and that tasks transition smoothly from one phase to another, facilitating a continuous workflow [5].

Pull: Implement a system where work is initiated based on demand, preventing overproduction and reducing excess inventory [8,5].

Perfection: Commit to continuous improvement by constantly refining processes to reduce waste and enhance value delivery [5].

- **Pull Planning and Scheduling**

Pull planning involves starting with the desired project outcome and working backward to establish the necessary steps to achieve that goal. This technique emphasizes identifying key handoffs and ensuring that work is initiated based on actual demand rather than arbitrary schedules. By focusing on pull rather than push, teams can significantly reduce waste and enhance productivity [4,25].

- **Value Engineering**

Lean Construction also integrates principles of value engineering from the project initiation stage. This approach aims to improve communication between project owners and construction teams, leading to more efficient planning and control systems [26]. Value engineering emphasizes the importance of aligning project goals with customer expectations, which is essential for delivering high-quality outcomes.

- **Continuous Improvement**

A hallmark of Lean Construction is its commitment to continuous improvement. This ongoing effort involves regularly reviewing processes, soliciting feedback, and implementing changes that drive efficiency and enhance value delivery [25]. Techniques such as workforce training and development further support this aim, fostering a culture of learning and adaptation within construction teams [4,27].

➤ Digital Technologies and Smart Construction Practices

• Introduction to Digital Transformation in Construction

The construction industry is undergoing a significant transformation driven by the adoption of various digital technologies. This shift, often referred to as Lean Digital Transformation, integrates Industry 4.0 principles with traditional construction methodologies to enhance efficiency, reduce waste, and improve project outcomes [10,28]. Central to this transformation are technologies such as Building Information Modeling (BIM), the Internet of Things (IoT), and Artificial Intelligence (AI), which collectively enable smarter construction practices and operational efficiencies [2,29].

• Role of Building Information Modeling (BIM)

BIM plays a critical role in the transition to digital construction. It provides detailed 3D models of projects, facilitating better collaboration among stakeholders and streamlining workflows [28,30]. By engaging key trade partners early in the design process and employing advanced scheduling techniques like critical path method (CPM), BIM helps optimize project timelines and enhance overall project delivery [1]. The integration of BIM with lean construction principles allows for more effective waste management and resource allocation, promoting a culture of continuous improvement [29].

• The Internet of Things (IoT) in Smart Construction

IoT technology enables the construction industry to achieve real-time monitoring and management of project elements. By embedding sensors in materials, equipment, and structures, construction managers can gather valuable data on resource utilization, safety conditions, and project progress [2,28]. This data-driven approach not only enhances decision-making capabilities but also supports predictive maintenance, ultimately leading to improved efficiency and reduced downtime on construction sites [2,29].

• Artificial Intelligence and Machine Learning Applications

AI and Machine Learning (ML) are pivotal in driving innovations within Lean Construction 5.0. These technologies empower systems to analyze vast datasets, predict project delays, cost overruns, and identify potential design flaws, thus enabling more informed decision-making [2,10]. Additionally, AI can automate repetitive tasks and streamline processes, which significantly reduces human error and increases productivity throughout the project lifecycle [2,29].

• Robotics and Automation in Construction

The integration of robotics into construction practices represents a significant leap forward in automation. Collaborative robots (cobots) and drones can perform tasks that are dangerous or require high precision, thereby enhancing worker safety and efficiency [2]. Moreover, the use of automation in construction can lead to better quality control and faster project completion, aligning with the goals of Construction 5.0 to create more sustainable and effective building practices [2,29].

2. Methods

➤ Tools and Techniques

Lean construction employs a variety of tools and techniques designed to enhance efficiency, reduce waste, and improve workflow in construction projects. These methodologies aim to streamline processes, ensuring that each step adds value to the project while minimizing non-value-added activities.

• Value Stream Mapping

One of the primary tools in lean construction is Value Stream Mapping (VSM). This technique involves mapping out every step of the construction process, from design to delivery, to identify areas of waste and inefficiency [4,8]. By visualizing the entire workflow, teams can pinpoint activities that do not add value and subsequently eliminate them, thereby streamlining operations and enhancing cost-effectiveness [14]. For instance, in a residential construction project, VSM can reveal delivery issues that lead to excess storage needs, allowing teams to adjust timing and improve workflow efficiency [8].

• 5S Methodology

The 5S methodology is another valuable tool in lean construction. It focuses on organizing and maintaining a clean, efficient workspace. The five steps (Sort, Set in order, Shine, Standardize, and Sustain) encourage teams to create an environment that minimizes waste and enhances productivity [31]. Implementing 5S leads to better inventory control, improved quality of work, and decreased construction time and costs [32].

• Last Planner System

The Last Planner System (LPS) is another critical technique used in lean construction. This approach focuses on collaborative planning and scheduling, enabling teams to achieve a continuous flow of work processes. By involving all stakeholders in the planning phase, LPS helps ensure that everyone is aligned with project goals, reducing disruptions and delays [3,7]. LPS has been particularly effective in enhancing project efficiency and reducing costs by minimizing rework and optimizing resource allocation [3].

• Just-in-Time Delivery

Just-in-Time (JIT) delivery is a logistical strategy integral to lean construction. This method ensures that materials are delivered precisely when needed, preventing overstocking and potential damage [14]. By synchronizing material deliveries with project timelines, JIT delivery contributes to waste reduction and maintains a smooth workflow, which is essential for meeting customer expectations and project deadlines [3].

• Root Cause Analysis

Root Cause Analysis (RCA) techniques, such as the 5 Why Analysis, are employed to identify and address underlying issues affecting project performance. By systematically asking "why" problems occur, teams can uncover root causes and implement corrective actions to prevent recurrence [33]. This method fosters

a culture of continuous improvement, essential for sustaining lean construction practices.

3. Results and Discussion

➤ Applications

- **Integration of Advanced Technologies**

Lean Construction 5.0 emphasizes the incorporation of advanced technologies such as Building Information Modeling (BIM), Artificial Intelligence (AI), and the Internet of Things (IoT) to enhance efficiency and sustainability in construction processes.

These technologies facilitate real-time data sharing and decision-making, thereby transforming traditional construction methodologies into more agile and responsive systems [2,28]. For instance, BIM provides digital documentation of construction facilities, streamlining communication among stakeholders and supporting a collaborative project environment [30,34].

- **Sustainability and Circular Economy**

One of the primary applications of Lean Construction 5.0 is its focus on sustainability. The framework promotes the adoption of carbon-neutral practices and the circular economy, which emphasizes reusing, repurposing, and recycling resources to minimize waste and environmental impact [10,35]. Construction stakeholders are increasingly aware of the need to not only consider the operational phase of buildings but also to enhance the sustainability of the construction processes themselves.

This shift reflects a broader societal commitment to addressing climate change and resource depletion [2,32].

Enhancing Resilience

Lean Construction 5.0 also addresses the critical need for resilience in the face of disruptions such as economic downturns or natural disasters. By implementing strategies that build "anti-fragile" organizations, construction firms can better anticipate and respond to crises, ensuring stable and sustainable performance [35].

This resilience is achieved through improved visibility across supply chains, enabling project teams to adapt swiftly when faced with unforeseen challenges [30,34].

- **Collaborative Approaches**

The framework encourages the adoption of collaborative approaches within project teams through tools like the Last Planner System and Integrated Project Delivery. These methodologies foster a culture of teamwork and shared responsibility, allowing for more efficient resource management and improved project outcomes [2,30,34]. Additionally, the trend of "connected construction" promotes enhanced collaboration among stakeholders, which is crucial for navigating the complexities of modern construction projects [2,28].

- **Human-Centric Focus**

Finally, Lean Construction 5.0 advocates for a human-centric approach, where technology complements rather than replaces

human skills. By empowering human operators with actionable insights derived from data analytics, the construction industry can achieve mass customization and tailored production workflows, ultimately enhancing both job satisfaction and project efficiency [35,36]. This focus on human capital ensures that the industry is not only more efficient but also more inclusive and responsive to the needs of its workforce.

4. Conclusions

- **Benefits**

Lean Construction 5.0 offers a multitude of advantages that enhance efficiency, reduce costs, and improve overall project outcomes.

- **Enhanced Safety**

Safety is a critical component of Lean Construction. The methodology scrutinizes every task for value, leading to the identification and mitigation of potential risks. This proactive approach contributes to safer job site conditions, minimizing the likelihood of accidents and ensuring a productive work environment [3].

- **Improved Project Outcomes**

One of the primary benefits of Lean Construction is the enhancement of project outcomes through better planning and scheduling. Case studies demonstrate that projects employing Lean principles often complete faster and with higher quality, leading to increased client satisfaction. Research indicates that projects utilizing high lean intensity are three times more likely to finish ahead of schedule and twice as likely to meet or exceed quality expectations [8,37].

- **Cost Efficiency**

Lean Construction emphasizes waste reduction, which directly correlates to better cost control. By streamlining processes and reducing inefficiencies, organizations can lower project costs significantly. Reports suggest that general contractors applying Lean methodologies have reduced project realization phases by up to 30% [13,38]. Additionally, the focus on value stream mapping helps identify and eliminate unnecessary expenditures, further boosting profitability [14].

- **Employee Satisfaction and Collaboration**

The collaborative nature of Lean Construction fosters an environment where employees feel more engaged and satisfied with their work. Greater stakeholder satisfaction results from transparent processes and the successful outcomes of Lean projects. Employees and trade contractors are often more inclined to embrace continuous improvement when they experience the benefits of working in a Lean framework [13].

- **Environmental Sustainability**

Lean Construction aligns with contemporary sustainability goals by minimizing waste and reducing energy consumption. The integration of smart technologies in construction practices not only enhances production efficiency but also supports environmental preservation, thereby meeting evolving regulatory standards and

addressing the concerns of increasingly mindful consumers [2,11].

- **Challenges**

Lean construction, while offering numerous benefits such as improved efficiency and reduced waste, faces several persistent challenges that hinder its widespread adoption in the construction industry.

- **Resistance to Change**

One of the primary obstacles to implementing lean construction is the resistance to change among teams and management. Many individuals are accustomed to traditional methods and may be hesitant to adopt new practices that lean construction demands [8]. Overcoming this resistance requires not only a commitment to change but also effective communication about the advantages of lean methodologies [1].

- **Training and Education**

Proper training and education are critical to the successful implementation of lean construction principles. Teams unfamiliar with these strategies may struggle to adopt them without extensive guidance, and the time and resource investment required for training can be significant [8,39]. Additionally, if team members are not adequately trained, there is a high likelihood that they will revert to conventional solutions, negating the benefits of lean practices [9].

- **Initial Investment Costs**

The initial costs associated with adopting lean practices can pose a significant barrier to entry for many companies. These costs may include expenses related to training programs, necessary tools, software, and consulting services [8,9]. While these initial investments are often offset by long-term savings, the upfront financial burden can deter companies from making the transition to lean construction.

- **Cultural Shift**

Implementing lean construction requires a fundamental shift in organizational culture towards collaboration, transparency, and continuous improvement. Fostering such an environment can be a complex and gradual process [8,2]. It involves instilling a mindset of continuous improvement and encouraging teams to engage in open dialogue about variances and potential inefficiencies in their workflows [4].

- **Adaptability and Market Dynamics**

The construction industry is also challenged by the need for adaptability to dynamic market conditions, including economic fluctuations and unexpected events like global pandemics. As the construction landscape evolves, businesses must remain flexible and responsive to these changes, which can complicate the implementation of lean practices [2].

- **Case Studies**

Lean Construction 5.0 has been implemented across various sectors and regions, demonstrating its versatility and effectiveness in

addressing the challenges within the construction industry. Below are several notable case studies that illustrate the application and benefits of Lean methodologies.

- **Applications**

- **International Milan, Italy**

A boutique law firm in Milan initiated a lean transformation aimed at streamlining processes to enhance client service and improve team efficiency [40]. This case underscores the adaptability of Lean principles beyond traditional construction settings.

- **Botswana**

In Botswana, a company focusing on vehicle conversion adopted lean thinking to boost its capacity and manage rising demand effectively. Their journey exemplifies how lean can drive significant operational improvements in manufacturing contexts [40].

- **Netherlands**

A Dutch hospital collaborated with its laundry supplier to transition their relationship from a client-supplier dynamic to a partnership. By solving shared problems through Lean methods, they improved operational efficiencies and strengthened their partnership [40].

- **Construction Specific Examples**

- **Chile**

A construction company in Chile embarked on a lean journey in 2018, transforming its workplace culture and improving site operations [40]. This transformation shows how lean practices can enhance construction project management and worker engagement.

- **Norwegian Furniture Manufacturer**

Haugstad Mobel, a Norwegian furniture manufacturer, successfully transformed its corporate culture through Lean Thinking, achieving sustainable growth and operational excellence [40].

- **Spanish Construction Firm**

A construction company in Spain leveraged Lean Thinking to complete a challenging project a year ahead of schedule, demonstrating the capacity of Lean principles to drive project efficiency and timely delivery [40].

- **Port Terminal in Brazil**

A port terminal in Brazil utilized Lean methods to significantly enhance its road flow management, illustrating how logistics and operations can benefit from Lean strategies [19,40].

- **Methodological Implementations**

- **Daily Management at Manuelita Sugar Mill, Colombia**

At the Manuelita Sugar Mill in Colombia, the implementation of Daily Management practices improved leadership effectiveness and operational outcomes, addressing challenges related to siloed thinking and communication [40].

- **Lean Practices in Chinese Manufacturing**

An Esquel factory in Guilin, China integrated lean principles into

its processes, resulting in improved efficiency and environmental sustainability. This case highlights the potential of Lean practices in reducing waste and promoting a green approach in manufacturing [40].

➤ Educational Applications

• Lean Thinking in Education

A private engineering school adopted a Lean Thinking approach to its curriculum, which exemplifies how educational institutions can benefit from Lean principles by enhancing teaching efficiency and student engagement [40].

These case studies collectively illustrate the transformative power of Lean Construction 5.0 methodologies across various contexts, emphasizing continuous improvement, stakeholder collaboration, and operational efficiency.

• Future Directions

The future of Lean Construction is poised for significant transformation as the industry transitions towards Lean Construction 5.0. This evolution will necessitate a more sophisticated approach to address emerging social challenges and adapt to the rapid technological changes impacting the sector [29]. The integration of advanced digital technologies, including the Internet of Things (IoT), artificial intelligence (AI), and big data analytics, will play a crucial role in reshaping construction practices, aligning with the principles of Industry 4.0 and moving towards Industry 5.0 [10,11].

• Embracing Human-Centric Principles

One of the key tenets of Lean Construction 5.0 is the emphasis on human-centric design, which focuses on enhancing worker well-being and promoting collaboration between humans and machines. This shift underscores the importance of skilled labor in navigating complex construction environments and mitigating risks associated with automated systems [34,35]. As the construction industry continues to embrace advanced technologies, there will be a pressing need for workforce upskilling and reskilling to ensure that workers can effectively engage with these innovations while maintaining safety and productivity [2].

• Integration of Advanced Technologies

The future landscape of Lean Construction will be characterized by the increased adoption of technologies such as robotics, augmented reality, and cloud computing, aimed at improving project oversight and enhancing collaborative workflows [11,32]. Platforms like VisiLean are exemplifying how lean principles can be seamlessly integrated with these technologies, fostering transparency, efficiency, and a culture of continuous improvement within construction projects [34]. This strategic progression towards digital integration emphasizes the importance of aligning processes and tools to promote collaboration among various stakeholders, thereby reducing silos that have historically plagued the industry [19].

• Sustainability and Resilience

In addition to technological advancements, Lean Construction 5.0 will prioritize sustainability and resilience, aiming to create a construction ecosystem that is both adaptable and environmentally responsible. This involves adopting practices that minimize waste and maximize value throughout the construction lifecycle from design and construction to maintenance and recycling [11,20]. By focusing on sustainable methods, the industry can better meet the evolving demands of society and contribute positively to environmental conservation.

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