

SOCIAL SUSTAINABILITY AND HUMAN-CENTERED LEAN PRACTICES IN MODULAR AND OFF-SITE CONSTRUCTION

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ABSTRACT

This paper investigates how Lean Management principles influence social sustainability and human-centered practices in Modular and Off-Site Construction (MOC), highlighting both positive and context-dependent interactions. Using a mixed-method approach combining systematic literature review, NVivo-assisted coding, expert interviews, and quantitative validation, the study examines key social dimensions including workforce well-being, communication, inclusivity, safety, and working conditions. Quantitative results (Cronbach's Alpha = 0.944; Mean Score = 4.11) confirm the significance of the social dimension within Lean–Sustainability integration. Findings indicate that Lean principles such as *Respect for People* and *Continuous Improvement* foster collaboration, empowerment, and safety culture, while practices such as Just-in-Time may introduce trade-offs if not adapted to modular workflows. The results are synthesized into a conceptual, expert-validated framework, operationalized through a dual-impact analytical matrix capturing positive, negative, and context-dependent interactions. The study highlights the importance of context-sensitive Lean implementation and provides practical guidance for balancing efficiency and workforce well-being in industrialized construction environments.

KEYWORDS

Modular Off-Site Construction (MOC), lean management, social sustainability

INTRODUCTION

Lean thinking, originally developed in manufacturing, has been increasingly adopted in the Architecture, Engineering, and Construction (AEC) industry as a means to enhance value delivery, reduce variability, and improve process efficiency (Koskela 1993; Womack and Jones 1997). In the context of Modular and Off-Site Construction (MOC), Lean principles offer significant potential to support industrialized production systems through improved coordination, waste reduction, and continuous improvement (Cherrafi et al. 2016). However, unlike traditional project-based construction, MOC represents a broader transformation toward industrialized construction, characterized by standardized processes, integrated supply chains, and Design for Manufacture and Assembly (DfMA) approaches. This shift requires a more

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systemic and context-sensitive application of Lean principles, rather than their direct transfer from conventional construction settings (Gbadamosi et al. 2019; Montazeri et al. 2025). Despite this alignment, the implementation of Lean in MOC remains uneven and fragmented, particularly due to inconsistencies in supply chain integration, varying levels of digitalization, and differences between factory-based production and on-site assembly environments. These challenges highlight the need to better understand how Lean principles operate within industrialized construction systems and how their impacts extend beyond operational performance (Cherrafi et al. 2016; Martínez-Jurado and Moyano-Fuentes 2014). While Lean has been widely associated with improvements in productivity, cost efficiency, and environmental performance, its relationship with the social dimension of sustainability remains insufficiently explored. Social sustainability, in this study, is primarily examined from an internal organizational perspective, focusing on workforce-related factors such as employee well-being, safety, communication, working conditions, and skills development (Galuppo et al. 2014; Gladwin et al. 1995). However, broader aspects such as inclusivity, diversity, equity, and accessibility (IDEA) are increasingly recognized as critical components of sustainable industrialized construction and are therefore incorporated into the analytical perspective of this research.

Central to this discussion is the concept of human-centered Lean, which builds upon the foundational Lean principle of *Respect for People* and extends it to emphasize worker well-being, empowerment, inclusivity, and participatory decision-making. In MOC environments, where production processes are tightly coordinated and often time-sensitive, the human dimension becomes a critical enabler of both operational performance and sustainability outcomes (Bhattacharya and Ramachandran 2021; Cherrafi et al. 2016).

This study adopts a human-centered interpretation of Lean Construction, grounded in the principle of *Respect for People* and extended to the context of Modular and Off-Site Construction (MOC). Within this perspective, Lean is not only viewed as an efficiency-driven approach but also as a socio-technical system that shapes workforce conditions and organizational dynamics. Accordingly, the study develops a conceptual framework, operationalized through a dual-impact analytical matrix, which systematically maps the positive, negative, and context-dependent social outcomes of Lean practices in MOC. The framework is primarily descriptive and diagnostic rather than predictive, providing structured insights into how Lean tools influence social sustainability and under what conditions trade-offs may emerge.

To address the identified gaps, this study systematically examines how Lean practices influence social sustainability within MOC, considering both their positive contributions and potential trade-offs. Specifically, the research pursues two objectives:

1. To evaluate the positive, negative, and context-dependent impacts of Lean practices on key social sustainability metrics in MOC.
2. To identify the Lean practices that most effectively support human-centered and socially sustainable outcomes across modular construction processes.

By adopting this dual-impact perspective, the study contributes to a more balanced understanding of Lean–Sustainability integration and provides a structured analytical basis for aligning Lean implementation strategies with human-centered and socially sustainable construction practices.

LITERATURE REVIEW

Modular and Off-Site Construction (MOC) represents a shift from traditional construction toward industrialized production systems, where key activities are transferred from on-site locations to controlled manufacturing environments. This transition has been associated with improvements in productivity, reduced delays, and lower material waste (Bhatia et al. 2023;

Wang et al. 2020). In parallel, Lean Management, originating from the Toyota Production System, focuses on eliminating non-value-adding activities and maximizing value creation (Ohno 2008; Womack and Jones 1997). Despite this alignment, the application of Lean principles in MOC remains uneven, often constrained by supply chain fragmentation, coordination challenges, and limited standardization (Pan and Pan 2023).

The relationship between Lean and sustainable development (SD) has been widely explored, particularly in relation to economic and environmental performance. Lean practices contribute to waste reduction, resource optimization, and operational efficiency (Khodeir and Othman 2018). However, certain techniques introduce trade-offs: Just-in-Time (JIT) may increase transport-related emissions due to more frequent deliveries (Caldarelli et al. 2022), while poorly implemented Value Stream Mapping (VSM) can negatively affect performance (Belekoukias et al. 2014). Nevertheless, Lean adoption in MOC has demonstrated benefits such as reduced material waste and improved energy efficiency (Nahmens and Ikuma 2012).

In contrast, the social dimension of sustainability remains comparatively underexplored. Issues such as workforce well-being, safety, ergonomics, and communication are often overlooked despite their importance in achieving comprehensive sustainability (Batwara et al. 2023). Lean has historically been associated with a worker-oriented philosophy (Sugimori et al. 1977), and its effectiveness is closely linked to employee engagement and high-involvement practices (Hopp and Spearman 2021). From this perspective, Lean contributes to social sustainability through improved working conditions and organizational practices, often framed within internal corporate social responsibility (Sánchez-Hernández et al. 2021). Lean practices act as the operational mechanisms through which these outcomes are realized (Amrani and Ducq 2020). Tools such as 5S, Kaizen, VSM, and Poka-Yoke have been shown to enhance workplace organization, safety, and process reliability, while supporting continuous improvement and employee involvement (Naeemah and Wong 2022; Singh et al. 2020). However, their effects are not uniformly positive and vary depending on implementation context. While MOC is often described as a shift toward factory-based production, it more broadly reflects a systemic transformation involving supply chain integration, digitalization, and Design for Manufacture and Assembly (DfMA). These factors shape the conditions under which Lean practices are applied and influence their social implications. In this study, the manufacturing environment is considered as a primary analytical boundary, given its direct impact on workforce conditions, safety, and communication dynamics.

Despite these insights, limited research has systematically examined the social impacts of individual Lean tools or their potential trade-offs within MOC contexts (Naeemah and Wong 2022; Tasdemir et al. 2020). This study addresses this gap by focusing on corporate social sustainability aspects well-being, safety, ergonomics, and inclusivity while acknowledging that broader dimensions such as diversity and community impact fall beyond the present scope. The research therefore evaluates Lean practices from a social sustainability perspective and identifies those most effective across different phases of the MOC process.

METHODOLOGY

This study adopts a mixed-method research design to examine how Lean Management (LM) influences social sustainability in Modular and Off-Site Construction (MOC). The research focuses on the social dimension, analyzing both positive and negative interactions between Lean practices and social sustainability metrics.

The methodology follows a sequential mixed-method approach, integrating qualitative and quantitative analysis to develop and validate a dual-impact analytical matrix **Error! Reference source not found.** Data from the Systematic Literature Review (SLR) informed the interview design, while NVivo coding provided the link between qualitative findings and quantitative validation. A total of 13 experts participated in both interviews and survey validation, ensuring

consistency across phases. The classification of impacts (+/–/±) was based on triangulation of coded evidence, frequency patterns, and expert consensus. Duplicate records were removed through a two-step screening process, and data saturation was achieved after the thirteenth interview.

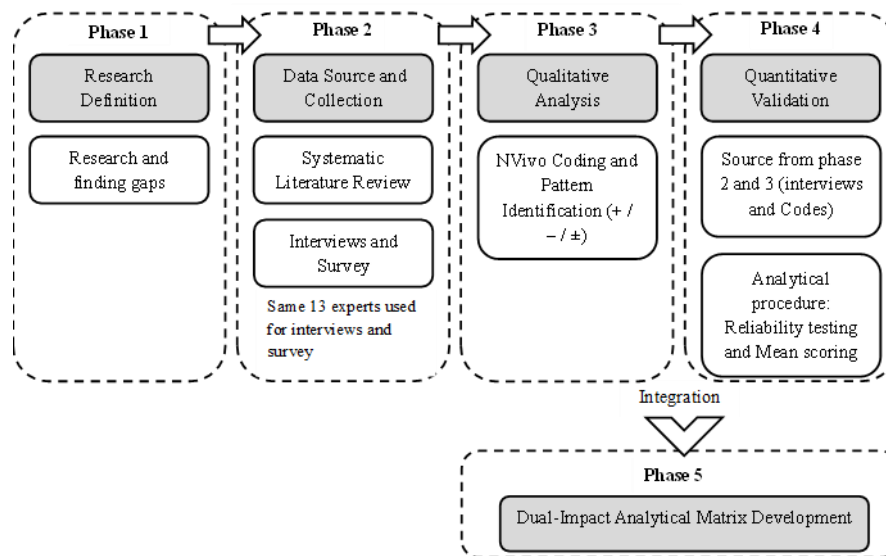


Figure 1: Sequential mixed-method research design

PHASE 1 – RESEARCH DEFINITION

The study examines how Lean principles, particularly *Respect for People* and *Continuous Improvement*, influence workforce well-being, safety, communication, inclusivity, and working conditions in MOC. The research builds on prior findings identifying the social dimension as the most significant sustainability pillar (MS = 4.11; $p = 0.00232$) (Rasouli 2025), and adopts a dual-impact perspective.

PHASE 2 – DATA SOURCE AND COLLECTION

The dataset originates from a broader research project and integrates three complementary sources of evidence: systematic literature review, expert interviews, and survey-based evaluation.

Systematic Literature Review (SLR)

A systematic literature review was conducted using Scopus and Web of Science, following PRISMA guidelines. The search was based on the following Boolean expression:

“Lean Construction” OR “Lean Management”) AND (“Sustainability” OR “Sustainable Development”) AND (“Modular Construction” OR “Off-Site Construction” OR MOC)

After screening and eligibility assessment, 71 peer-reviewed articles (2004–2024) were selected. Duplicate records across databases were identified and removed through a two-step screening process. Bibliometric analysis using VOSviewer identified research trends, recurring keywords, and gaps, particularly the limited attention to social sustainability and the lack of focus on dual (positive/negative) impacts of Lean practices.

Expert Interviews and Survey

A total of 13 experts from academia, manufacturing, and construction management were purposively selected based on their expertise in Lean and/or modular construction. The sample size aligns with accepted ranges for mixed-method studies (10–15 participants) and achieved thematic saturation. Each expert participated in a semi-structured interview (30–60 minutes),

and a structured survey questionnaire. The use of the same participants in both phases ensured consistency and enabled direct integration between qualitative insights and quantitative validation. The survey instrument asked participants to evaluate the influence of Lean tools on 16 sustainability sub-metrics across economic, environmental, and social dimensions using a five-point Likert scale (1–5).

For this paper, only the five social sustainability metrics are considered: Employee skills (training and learning), Organizational influence, Relationships and communication, Safety and health, Working conditions

PHASE 3 – QUALITATIVE ANALYSIS (NVIVO CODING)

Qualitative analysis was conducted using NVivo 14, combining data from literature and interview transcripts. The coding framework was derived from the thematic structure developed in the broader research. The analysis followed established procedures Dransfield et al. (2004) and included: word frequency analysis and matrix coding queries. This phase identified relationships between Lean practices and social sustainability metrics. Lean tools such as Kaizen, 5S, Visual Management, Last Planner System, Kanban, and Just-in-Time (JIT) were analyzed in relation to social outcomes. Coding outputs were categorized into: Positive interactions (e.g., improved collaboration, safety, empowerment), Negative interactions (e.g., workload pressure, coordination stress), Context-dependent interactions ($\pm$).

These results formed the analytical basis for constructing the dual-impact matrix in Figure 2. Blue coded references in the matrix denote positive interactions such as improved collaboration and empowerment; orange coded references capture negative effects like workload intensity, time pressure, or logistical inefficiencies when Lean tools are not adapted to modular workflows.

MATRIX SOCIAL SUSTAINABLE IMPACTS VS LEAN PRACTICES	Employee skills (Training and Learning)				
	Influence on the Organization Relationships and communication Safety and Health Working conditions				
5S	0	2	2	4	2
IPD (Integrated Project Delivery)	0	0	2	0	0
JIT	0	1	1	3	1
Kaizen	0	1	2	7	2
Kanban	0	1	1	1	1
Last Planner	0	4	1	5	3
Lean Project Delivery System	0	0	1	0	0
Poka Yoke(Error proofing)	0	1	1	4	1
Pull strategy	0	0	2	0	0
Six Sigma	1	2	1	2	1
SMED	0	0	1	1	1
Target Value Design	0	0	1	0	0
Visual Management(Andon Line)	0	1	2	3	3
VSM	0	-1	1	3	2
SOCIAL					

Figure 2: Matrix coding query for social metrics of SD vs most effective lean tools by NVivo 14.

PHASE 4 – QUANTITATIVE VALIDATION

Quantitative validation was performed to ensure the reliability and consistency of expert evaluations and to statistically support the relationships identified in the qualitative phase.

Data Source

The dataset is based on the same 13 experts, ensuring continuity between qualitative and quantitative stages.

Analytical Procedure

Quantitative analysis was performed using IBM SPSS Statistics v25, applying:

- Reliability Testing (Cronbach's Alpha): A threshold of 0.7 was adopted. The obtained value ($\alpha = 0.944$) confirms high internal consistency.
- Mean Scoring (MS): Used to determine the relative importance of sustainability metrics and associated Lean tools.

Integration of Qualitative and Quantitative Findings

Quantitative results were used to validate and reinforce patterns identified in NVivo coding. Specifically: NVivo analysis identified the direction and type of interactions (+/-/±) and survey results confirmed the consistency and relative importance of these interactions. This integration ensured that the final matrix is both empirically grounded and statistically supported.

PHASE 5 – INTERPRETATION AND MATRIX DEVELOPMENT

The final phase synthesizes qualitative and quantitative findings into a dual-impact analytical matrix, representing the interaction between Lean practices and social sustainability metrics. The matrix captures: positive contributions (e.g., communication, safety, empowerment), negative trade-offs (e.g., workload intensity, coordination stress under JIT) and context-dependent effects. The interpretation also incorporates human-centered dimensions, including Inclusivity, Diversity, Equity, and Accessibility (IDEA), and decision-support approaches such as Choosing by Advantages (CBA). This structured representation serves as a diagnostic and analytical tool to support context-sensitive Lean implementation in MOC.

RESULT

Building on the mixed-method design, the results provide integrated qualitative and quantitative evidence to examine how Lean practices influence social sustainability in Modular and Off-Site Construction (MOC). In alignment with the research objectives, the findings (1) evaluate the positive, negative, and context-dependent impacts of Lean practices on social sustainability metrics, and (2) identify the practices that most effectively support human-centered outcomes.

RELIABILITY OF THE DATASET

Cronbach's Alpha testing was conducted to assess the internal consistency of expert responses across sustainability metrics. The obtained value ($\alpha = 0.944$) exceeds the recommended threshold of 0.7 (Tavakol and Dennick 2011), confirming a high level of reliability.

This result validates the use of the dataset for subsequent analysis and supports the consistency of expert evaluations used to assess the influence of Lean tools on social sustainability.

IDENTIFICATION OF SOCIAL SUSTAINABILITY METRICS

NVivo coding analysis identified five key social sustainability indicators most relevant to Lean implementation in MOC. These indicators emerged as the most frequently referenced themes across both the 71 journal articles and 13 expert interviews, as presented in Table 1.

The results show that Safety and Health (17 references), Organizational Influence (14), and Relationships and Communication (10) are the most prominent dimensions through which Lean practices influence social sustainability. Rather than indicating overall dominance across all sustainability pillars, these findings highlight that Lean practices most directly manifest through

social mechanisms, particularly those related to coordination, safety culture, and organizational interaction. This supports the study's focus on the social dimension as a critical lens for understanding Lean implementation in MOC.

Table 1: Sustainable development indicators and aspects through MOC

Dimension	categories	Number of coding
Social Sustainability	Safety and Health	17
	Influence on the Organization	14
	Relationships and communication	10
	Working conditions	7
	Employee skills (Training and Learning)	3

DUAL-IMPACT ANALYSIS OF LEAN PRACTICES

To address the first research objective, a dual-impact analytical matrix was developed by integrating NVivo coding results with expert validation. This matrix systematically maps the positive (+), negative (−), and context-dependent ($\pm$) interactions between Lean practices and social sustainability metrics. Table 2 shows the dual-impact matrix. The results reveal that most Lean practices generate predominantly positive social outcomes, particularly those aligned with Lean's *Respect for People* principle. For example, practices such as Kaizen, 5S, Visual Management, and Last Planner System (LPS) consistently enhance communication, safety, and collaboration.

However, the findings also demonstrate that certain Lean tools produce negative or mixed effects, particularly when applied without adaptation to modular construction contexts. Tools such as Just-in-Time (JIT) introduce time pressure and coordination stress, while Value Stream Mapping (VSM) may challenge organizational structures depending on implementation conditions. These results highlight that Lean practices do not operate uniformly; instead, their social impacts are context-dependent, shaped by factors such as workflow stability, coordination requirements, and organizational maturity.

EVIDENCE-BASED VALIDATION OF IMPACT CLASSIFICATION

To strengthen the interpretive validity of the matrix, representative excerpts from expert interviews were used as evidence hooks supporting the classification of impacts. For instance, participants highlighted that:

“Just-in-Time (JIT) enhances coordination but can increase stress under variable flow conditions illustrating its dual nature. (Int.3)” Similarly, “Kaizen was described as empowering when team-led, but constraining when excessively formalized (Int.11)”

supporting its context-dependent classification. These examples demonstrate how expert insights directly informed the assignment of positive, negative, and mixed interactions, reinforcing the reliability of the dual-impact analytical matrix.

Table 2: Matrix: sustainable impacts vs. lean practices (social dimension)

Lean Practice	Employee Skills (Training & Learning)	Organizational Influence	Relationships & Communication	Safety & Health	Working Conditions
5S	+ Improves discipline and workplace training	+ Improves clarity and visual control	+ Improves communication via standardized layouts	+ Reduces accidents through orderly workspaces	+ Creates safer, more orderly workplaces
Kaizen	+ Promotes learning through continuous improvement	+ Increases empowerment and participation	+ Encourages teamwork and problem-solving	+ Improves safety through systematic problem-solving	± Improves ergonomics but may raise short-term workload
Visual Management (Andon)	+ Reinforces learning through visual feedback	+ Improves decision transparency	+ Enables real-time communication	+ Supports rapid hazard identification	+ Supports monitoring of work conditions
Last Planner System (LPS)	+ Encourages learning through collaborative planning	+ Strengthens coordination and commitment	+ Improves communication and trust	+ Reduces stress and accidents through stable workflows	+ Improves predictability and reliability
Just-in-Time (JIT)	– Limits training under time pressure	– Increases stress from tight schedules	– Raises coordination demands in unstable supply chains	– Increases safety risks during rushed operations	– Intensifies workload and reduces flexibility
Kanban	+ Enhances learning through workflow visibility	+ Encourages autonomy and self-management	+ Improves task coordination and information flow	+ Reduces overload and accident risk	+ Improves work rhythm and operator comfort
Poka-Yoke (Error Proofing)	+ Develops skills through error awareness	+ Promotes accountability and standardization	+ Clarifies process deviations	+ Prevents safety incidents	+ Reduces rework-related mental strain
Value Stream Mapping (VSM)	+ Strengthens process learning	± Clarifies roles but may challenge structures	+ Improves information flow	+ Identifies unsafe process steps	+ Supports ergonomic workflow planning
Integrated Project Delivery (IPD)	+ Promotes cross-disciplinary learning	+ Fosters shared responsibility and integration	+ Improves stakeholder communication	+ Enhances safety through coordinated design	+ Strengthens collaborative work culture
Choosing by Advantages & IDEA (Inclusivity, Diversity, Equity, Accessibility)	+ Encourages inclusive learning and skill development	+ Strengthens transparency, equity, and fairness	+ Builds respectful, trust-based communication	+ Enhances psychological safety	+ Supports inclusive, healthy workplaces

Note: Positive (+) indicates beneficial impacts; Negative (–) indicates adverse or trade-off impacts; ± indicates context-dependent effects.

IDENTIFICATION OF HUMAN-CENTERED LEAN PRACTICES

Addressing the second research objective, the results identify Lean practices that most effectively support human-centered and socially sustainable outcomes. Practices such as: Kaizen, LPS, and Visual Management emerged as the most supportive practices, enhancing empowerment, collaboration, transparency, safety, and team engagement. In contrast, time-sensitive practices such as JIT require careful contextual adaptation to avoid negative impacts

on worker well-being and organizational stability. The inclusion of IDEA (Inclusivity, Diversity, Equity, Accessibility) and Choosing by Advantages (CBA) further extends the analysis beyond traditional Lean tools, emphasizing the importance of inclusivity, fairness, and participatory decision-making in human-centered Lean implementation.

DISCUSSION

INTERPRETING LEAN'S INFLUENCE ON SOCIAL SUSTAINABILITY

The discussion aligns with the results, identifying the social dimension as a key enabler of Lean effectiveness in MOC. The framework is validated through expert consensus and remains conceptual; its context sensitivity is defined through differences between factory and on-site phases, flow variability, and coordination intensity. These conditions indicate where Lean tools require adaptation, and broader applicability claims are therefore moderated. The results indicate that Lean practices most consistently influence sustainability through social mechanisms, particularly safety, communication, and organizational interaction. This finding supports prior studies (Carvajal-Arango et al. 2019; Innella et al. 2019; Naeemah and Wong 2022), which associate Lean's *Respect for People* principle with improved workforce well-being and safety performance. However, the present study extends this understanding by demonstrating that these social factors function not merely as outcomes, but as structural enablers of effective Lean implementation in MOC. Practices such as *Kaizen*, *Visual Management*, and *Last Planner System (LPS)* foster participatory environments where workers actively contribute to process improvement, thereby strengthening coordination and reducing variability. This suggests that Lean performance in modular construction is inherently dependent on human-centered conditions, rather than solely on technical efficiency.

UNDERSTANDING NEGATIVE AND MIXED INTERACTIONS

The findings highlight the dual and context-dependent nature of Lean practices. Tools such as JIT and VSM, while improving flow and efficiency, may generate adverse outcomes if not adapted to modular contexts. JIT introduces time pressure and coordination demands under unstable flows, while VSM may disrupt organizational structures in fragmented systems.

These impacts are conditioned by factors such as production setting (factory vs on-site), workflow stability, and coordination complexity. This reinforces the need to adapt Lean tools to modular construction environments rather than directly transferring them from manufacturing.

THEORETICAL AND PRACTICAL IMPLICATIONS

The findings contribute to both theory and practice by advancing a human-centered and context-sensitive interpretation of Lean in MOC.

Human-Centered Lean Implementation:

Social sustainability emerges as a precondition for effective Lean implementation. Empowerment, communication, and inclusivity directly influence coordination and process reliability. Integrating IDEA and CBA extends Lean toward fairness and participatory decision-making.

Context-Sensitive Application of Lean Tools:

Tool effectiveness varies by environment. Collaborative tools such as *Kaizen* and *LPS* are more effective in on-site assembly, while process-control tools such as 5S and VSM are more suited to factory-based production.

Balancing Efficiency and Well-Being:

The dual-impact perspective highlights trade-offs between efficiency and workforce well-being. Overreliance on time-driven tools such as JIT may undermine safety and flexibility, positioning social sustainability as both an enabler and constraint in Lean implementation.

CONCLUSION

This study advances understanding of how Lean Management can support social sustainability in Modular and Off-Site Construction by adopting an explicitly human-centered perspective. Rather than treating social outcomes as secondary effects of efficiency-driven practices, the research demonstrates that social sustainability should be considered a core design parameter in Lean implementation for MOC. A key contribution of this work lies in recognizing the dual nature of Lean practices. While many Lean tools can enhance communication, safety, empowerment, and inclusivity when applied appropriately, others may introduce social trade-offs if transferred rigidly from manufacturing contexts to modular construction workflows. Acknowledging these trade-offs enables a more realistic and responsible approach to Lean–Sustainability integration and moves the discourse beyond predominantly positive or normative interpretations of Lean.

The proposed conceptual framework, operationalized through a dual-impact analytical matrix, provides a structured approach for aligning Lean tools with social sustainability objectives across different phases of the MOC process. By incorporating human-centered decision-support approaches such as Choosing by Advantages and IDEA, it supports more inclusive, transparent, and context-sensitive decision-making. This reinforces the view that workforce well-being, collaboration, and fairness are not constraints on Lean performance but enablers of sustainable modular production systems. From a practical standpoint, the findings suggest that practitioners should move away from uniform Lean deployment strategies and instead adopt phase-specific and socially informed implementations. Aligning Lean tools with organizational culture, production context, and workforce needs is essential for balancing operational efficiency with long-term social sustainability.

Despite these contributions, the study has several limitations. First, the findings are based on a relatively small sample of expert participants ($n = 13$), which, although sufficient for mixed-method validation and thematic saturation, limits generalizability. Second, the proposed framework is validated through expert judgment rather than empirical application in real-world projects and should therefore be interpreted as a conceptual and diagnostic tool. Third, the analysis focuses exclusively on the social dimension of sustainability, without explicitly integrating economic and environmental interactions within the same framework.

This work contributes a conceptual, expert-validated framework for analysing the social dimension of Lean practices in Modular and Off-site Construction. While not field-tested, the framework offers practical guidance for researchers and practitioners seeking to adapt Lean tools to human-centered and context-sensitive modular environments.

Future research should build on this work by empirically testing the framework across a broader range of modular projects, including longitudinal case applications, and by applying advanced analytical approaches such as Structural Equation Modelling (SEM) or Fuzzy DEMATEL to further explore causal relationships among the identified variables. Overall, this study underscores the importance of embedding social sustainability at the heart of Lean thinking to support more resilient, inclusive, and sustainable Modular and Off-Site Construction systems.

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