Enhancement of Quality Management Through Lean in Sri Lankan Construction Industry

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ABSTRACT

Quality management remains a critical concern in the construction industry of developing countries, where inefficiencies, rework, and inconsistencies in quality practices negatively impact project outcomes. Although lean construction features prominently in the global literature, the rigorous integration of lean principles into quality management frameworks remains underexplored. While lean construction is widely recognised for enhancing process efficiency and value delivery, its integration with quality management, particularly through structured frameworks, has received limited attention in the Sri Lankan context. This study addresses this gap by investigating how lean can be applied to enhance quality management in Sri Lankan construction organisations. Guided by a pragmatic research philosophy, this study employed the Delphi technique involving experts with expertise in lean construction and quality management. Data was analysed using NVivo through directed content analysis.

The study identified lean-related quality process areas and performance indicators based on established literature and expert judgement. The validated indicators were organised into four core process areas: continuous improvement, benchmarking, standardisation, and error detection and prevention. A total of 22 performance indicators corresponding to these areas were confirmed through expert consensus. The findings show strong alignment with established lean concepts such as Kaizen, the Plan Do Check Act cycle, standard work, and quality at source. The results also reflect local priorities such as proactive error management and regulatory alignment, emphasising the need for contextual adaptation. The study extends lean quality theory to a new geographic setting, offers a practical framework for Sri Lankan construction organisations, demonstrates the methodological value of the Delphi approach in data-limited contexts, and supports societal goals by promoting more reliable and accountable construction practices. These contributions advance understanding and implementation of lean-based quality management in emerging construction sectors.\

KEYWORDS: *Construction Quality Management, Construction, Lean Construction, Construction Dynamics*

INTRODUCTION

Lean Construction (LC), adapted from lean manufacturing, represents a paradigm shift in the construction industry aimed at minimizing waste, enhancing value, and improving overall process efficiency through continuous improvement and stakeholder collaboration (Khan et al., 2024; Koskela, 2000). As construction projects face increasing demands for timely delivery, cost-effectiveness, and consistent quality, the integration of lean principles has gained global traction. Tools and techniques such as the Last Planner System, 5S, visual management, and value stream mapping have been widely recognized for their potential to improve process flow, reduce rework, and enhance construction quality (Salem et al., 2005; Aziz & Hafez, 2013).

Quality management in construction is a critical dimension that ensures project outputs meet client expectations, regulatory requirements, and performance standards (Alsharef et al., 2024). However, quality failures remain a recurring issue, particularly in developing economies where project environments are often characterized by fragmented processes, poor communication, and reactive management strategies (Love et al., 2018). Within this context, the degree to which lean principles are embedded in an organization's culture and operational systems plays a vital role in determining the effectiveness of quality-related outcomes. High levels of lean integration are typically associated with a proactive quality culture, emphasizing defect prevention, continuous monitoring, and systematic improvement rather than corrective actions after problems arise (Nesensohn et al., 2015; Marhani et al., 2012).

In Sri Lanka, the construction industry has begun exploring lean practices, although adoption remains at a relatively early stage (Ranadewa et al., 2021). Empirical studies suggest a growing awareness of lean principles but also highlight gaps in practical implementation and strategic integration with quality management systems (Senaratne & Wijesiri, 2008; Jayanetti et al., 2024). The limited application of lean construction tailored to the Sri Lankan context emphasise a critical research gap, particularly in understanding how lean can be incorporated to address persistent quality challenges. Despite growing global evidence on the role of lean practices in improving construction quality, there is limited empirical research examining how lean, contributes to construction quality management in the Sri Lankan context. Existing literature seldom addresses the operational realities, fragmented processes, and quality-related challenges specific to

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developing construction sector. This study addresses this gap by exploring how lean can be effectively used to enhance quality management in Sri Lankan construction organizations through the identification of relevant process areas and performance indicators. The present study aims to investigate how quality management can be enhanced through lean within Sri Lankan construction organizations. Specifically, it seeks to identify key process areas (KPAs) that reflect lean attributes relevant to quality, define performance indicators (PIs) associated with these KPAs, and explore how these can be operationalized to drive quality improvements in practice. A qualitative, three-round Delphi method is employed to achieve expert consensus, supported by NVivo-based content analysis for thematic synthesis. The findings are expected to contribute to the development of a structured, context-sensitive framework that integrates lean and quality management, offering both theoretical insight and practical value to the Sri Lankan construction sector.

The paper begins with an introduction and literature review, followed by a Delphi-based methodology. Key findings on process areas and performance indicators are presented, discussed in relation to existing literature, and summarized through theoretical, practical, methodological, and societal contributions, concluding with implications for future research.

LITERATURE REVIEW

Lean Construction and Quality Management

Lean Construction (LC) originates from the principles of lean manufacturing, focusing on maximizing value for the client while minimizing waste throughout the construction process (Aslam et al., 2024; Koskela et al., 2002; Ballard & Howell, 2003). By applying tools such as the Last Planner® System, 5S, visual management, and value stream mapping, LC enables improved planning, flow, and coordination across project phases. These tools foster collaboration, reduce variability, and support a culture of continuous improvement, which are all foundational to high-quality project delivery (Salem et al., 2005; Aziz & Hafez, 2013). Globally, LC has been credited with improving cost performance, reducing delays, and enhancing quality outcomes on complex construction projects.

Quality management in construction encompasses planning, assurance, and control measures to ensure projects meet predefined standards, client requirements, and performance expectations (Alsharef et al., 2024). Traditional quality control approaches in construction often emphasize inspection and correction rather than prevention and system optimization. Lean contributes to reversing this trend by embedding a proactive, process-driven approach to quality (Hamzo Khan et al., 2024). Organizations with higher lean maturity levels often integrate quality checks within standardized workflows, enabling early detection of issues and continuous refinement (Nesensohn et al., 2015; Salem et al., 2005). As lean implementation matures, firms tend to exhibit improved quality metrics, including reduced defect rates, enhanced documentation, and better stakeholder satisfaction.

Quality Management in Construction Through Lean Integration

Lean construction supports quality improvement by fostering structured problem-solving, standardization, and real-time monitoring of performance (Gartoumi et al., 2024). Techniques such as root cause analysis, visual management, A3 thinking, and kaizen promote transparency and accountability in day-to-day operations (Salem et al., 2005). As organizations mature, their quality systems shift from reactive to predictive models, with built-in quality controls embedded into production processes. This enables the prevention of errors before they occur and promotes a continuous feedback loop, enhancing product and process quality (Nesensohn et al., 2015; Love et al., 2018). Thus, lean acts as both a framework and an enabler for improving construction quality outcomes over time.

Key Process Areas (KPAs) in lean reflect the foundational domains that must be developed to achieve sustained lean performance. These include continuous improvement, customer orientation, leadership involvement, team development, waste elimination, and knowledge sharing (Aziz & Hafez, 2013). Each KPA is associated with measurable outcomes, typically monitored through Key Performance Indicators (KPIs). In the context of quality management, relevant KPIs include defect frequency, rework rates, quality compliance ratios, customer satisfaction scores, and cost of quality. These metrics help organizations track performance trends, identify bottlenecks, and drive improvements systematically. However, the integration of KPAs and KPIs tailored to quality enhancement in lean remains under-researched, particularly in developing construction environments.

In the Sri Lankan construction industry, quality issues such as excessive rework, defects, and client dissatisfaction are persistent challenges. Despite growing awareness of lean principles, adoption remains limited and often isolated to individual projects or tools (Senaratne & Wijesiri, 2008). Cultural resistance to change, lack of training, and absence of a systematic approach to lean implementation hinder sustained impact. Moreover, quality management practices are often reactive and inspection-driven rather than prevention-focused. Introducing a lean perspective provides an opportunity to institutionalize continuous improvement, enhance process consistency, and build a proactive quality culture across the industry. Recent local research by Jayanetti et al. (2024) highlights a set of lean elements suited to Sri Lankan conditions, indicating the growing relevance of this approach for long-term quality enhancement.

RESEARCH GAP

Theoretical Gap

Although Lean Construction has been extensively studied across various international contexts, particularly in developed economies, its integration with quality management practices remains underexplored in developing countries. Prior research has demonstrated that lean implementation can significantly improve quality performance by minimizing waste, reducing variability, and fostering a culture of continuous improvement (Gartoumi et al., 2024; Aziz & Hafez, 2013; Love et al., 2018). However, much of this evidence is derived from projects in countries with mature construction industries, robust institutional frameworks, and strong regulatory systems (Nesensohn et al., 2015). As a result, there is a limited understanding of how lean, specifically contributes to quality enhancement in emerging markets such as Sri Lanka. Furthermore, the majority of existing lean models have been developed in Western contexts and are not tailored to the socio-economic, regulatory, and cultural nuances of South Asian construction industries. These models often lack adaptability to local conditions where resource constraints, skill shortages, and inconsistent project governance are common (Ranadewa et al., 2021). While some recent attempts have been made to define localized lean indicators (Jayanetti et al., 2024), they do not yet provide a comprehensive framework for linking lean construction with quality performance outcomes. This constitutes a critical literature gap, as it limits the theoretical understanding of how lean can be effectively integrated to improve quality management processes in these contexts.

Industry Gap

From an industry perspective, Sri Lanka's construction sector continues to struggle with recurring quality issues such as high defect rates, rework, client dissatisfaction, and poor documentation practices. These problems are often exacerbated by fragmented supply chains, inconsistent monitoring, and a lack of integrated quality management systems (Ranadewa et al., 2021). Although awareness of lean tools and techniques is gradually increasing, their practical application remains irregular and largely limited to isolated initiatives. There is no widely adopted mechanism for construction firms to assess their lean maturity levels in relation to quality performance metrics. This practical gap emphasize the absence of a validated, context-specific framework that construction organizations can use to systematically improve quality through lean practices.

METHODOLOGY

This study adopts a pragmatic research philosophy, which is well suited to investigations aiming to generate practical solutions grounded in real-world contexts. Pragmatism allows researchers to integrate both objective and subjective perspectives, thereby supporting the development of context-specific knowledge which is an essential requirement for addressing complex problems in the Sri Lankan construction industry (Saunders et al., 2019). The research follows an abductive approach, enabling iterative interaction between empirical data and theoretical insights. This approach is particularly appropriate for studies seeking to build new conceptual understanding while remaining responsive to the realities of practice (Dubois & Gadde, 2002). In line with the research aim, a mono-method qualitative choice was adopted to facilitate an in-depth exploration of expert perspectives and nuanced themes that are not easily quantifiable (Creswell & Plano Clark, 2017). A survey strategy was employed through the use of the Delphi technique, The Delphi technique was selected for its strength in capturing expert consensus in complex and under-researched domains, making it particularly suited for exploring context-specific process indicators within the Sri Lankan construction industry (Hasson et al., 2000; Okoli & Pawlowski, 2004). As a qualitative approach, Delphi technique enables structured and anonymous expert engagement, supports inbuilt validation, and allows iterative refinement of findings, aligning well with the pragmatic philosophy underpinning this study (Skulmoski et al., 2007). A cross-sectional time horizon was applied, as data were collected within a defined period to reflect current industry conditions. Data collection involved three rounds of semi-structured interviews with 25 purposively selected experts from academia and industry. These interviews, conducted either in person or via online platforms, ranged from 60 to 75 minutes in duration. In Delphi studies, various thresholds are commonly employed to determine consensus (Schifano and Niederberger 2025). Considering the depth of expertise within the selected panel and the scope of the research, a consensus threshold of 75% was deemed appropriate for this study to ensure the credibility and reliability of emerging findings across Delphi rounds (Linstone & Turoff, 2002). Data were analysed using thematic content analysis supported by NVivo software, which enabled systematic coding, theme development, and traceability of expert responses (Bazeley & Jackson, 2013). This methodological design ensured that the findings were both rigorously derived and contextually grounded, thereby enhancing their relevance to quality management practices in the Sri Lankan construction sector.

The selection of Delphi experts was carried out through a rigorous screening process to ensure that participants possessed substantial and relevant expertise in lean construction and construction quality management. The studies require the expertise of the panel in both areas to achieve accuracy and credibility of the data. The panel comprised a balanced mix of industry experts and academics who met the defined eligibility thresholds based on their experience, qualifications, and professional engagement. This ensured the inclusion of highly competent individuals with both practical insights and scholarly depth. A total of 25 experts participated in Round 1, with 24 continuing through Rounds 2 and 3, demonstrating a high level of engagement and commitment throughout the process. Initially, a panel of 30 experts was considered for the study. However, by the 23rd interview, data saturation had been reached, as no new themes or insights were emerging. To ensure robustness and confirm thematic stability, two additional expert interviews were conducted, bringing the total to 25 (Diamond et al., 2014). The strength of this panel enhanced the credibility and reliability of the consensus findings, ensuring that the outcomes reflect informed judgment rooted in both theory and practice.

Table 1 summarises the objectives of each Delphi round and corresponding phase. In Round 1–Phase I, experts identified process areas related to quality management in lean, while Phase II focused on identifying relevant performance indicators. Round 2–Phase I refined and contextualised the key process areas for Sri Lankan construction organisations, and

Phase II validated the corresponding performance indicators. In Round 3–Phase I, notable indicators were assessed for each key process area, followed by Phase II, which explored their practical application in enhancing quality management through lean implementation.

Table 19.Expert Profile and Delphi Rounds

Expert Code	Compulsory (Must satisfy at least one from each)				Additional Qualifications (Must satisfy at least 3)					Participation		
	A		B									
	5+ experience in LC job role	3+ academic experience in LC	10+ experience Construction quality management	10+ experience in academia	Graduated in built environment discipline	Professional affiliation to Lean related institution	Member of professional institution in built environment	Master's qualification in built-environment or lean	2+ indexed publications	Delphi R1 25	Delphi R2 24	Delphi R3 24
E1	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓
E2	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓
E3	✓		✓		✓	✓	✓	✓		✓	✓	✓
E4	✓		✓		✓		✓	✓		✓	✓	✓
E5	✓		✓		✓		✓	✓		✓	✓	✓
E6	✓		✓		✓		✓	✓		✓	✓	✓
E7	✓		✓	✓			✓	✓		✓	✓	✓
E8	✓		✓		✓	✓	✓			✓	✓	✓
E9	✓		✓		✓		✓			✓	✓	✓
E10	✓		✓	✓	✓		✓			✓	✓	✓
E11	✓		✓	✓	✓		✓			✓	✓	✓
E12	✓		✓	✓	✓		✓			✓	✓	✓
E13	✓		✓	✓	✓		✓			✓	✓	✓
E14	✓		✓	✓	✓		✓			✓	✓	✓
E15		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
E16		✓		✓	✓	✓	✓	✓		✓	✓	✓
E17		✓		✓	✓			✓	✓	✓	✓	✓
E18		✓		✓	✓			✓	✓	✓	✓	✓
E19		✓		✓	✓			✓	✓	✓	✓	✓
E20		✓		✓	✓			✓	✓	✓	✓	✓
E21		✓		✓	✓			✓	✓	✓	✓	✓
E22		✓		✓	✓		✓	✓		✓	✓	✓
E23		✓		✓	✓		✓	✓		✓	✓	✓
E24		✓		✓	✓		✓	✓		✓	✓	✓
E25		✓		✓	✓		✓	✓		✓		

Delphi Round	**Phase**	**Objective**
Round 1	Phase I	Identify process areas related to quality management in lean construction
	Phase II	Identify performance indicators related to quality management in lean construction
Round 2	Phase I	Investigate key process areas related to quality management in lean construction in the Sri Lankan construction organisations
	Phase II	Identify performance indicators related to quality management in lean construction in the Sri Lankan construction organisations
Round 3	Phase I	Assess performance indicators for each key process area related to quality management in lean construction in the Sri Lankan construction organisations
	Phase II	Investigate how to use the key process areas and performance indicators in lean construction to enhance quality management in the Sri Lankan construction organisations

FINDINGS

This section presents the findings of the Delphi rounds.

KEY PROCESS AREAS RELATED TO QUALITY MANAGEMENT IN LEAN IN THE SRI LANKAN CONSTRUCTION ORGANISATIONS (DELPHI ROUND 1 PHASE1, DELPHI ROUND 2 PHASE 1)

Initially, three model process areas were identified through a review of existing literature. In Delphi Round 1 Phase 1 (DR1P1), experts were invited to evaluate and determine which of these areas were relevant to quality management in the construction sector. Subsequently, in Delphi Round 2 Phase 1 (DR2P1), the experts contextualised these process areas to reflect the specific practices and conditions of the Sri Lankan construction industry. Table 2 presents the key findings of the study. The italicised text presents items identified from the literature and modified for the Sri Lankan context, while the bold text presents new suggestions by experts that received a consensus of more than 75%.

Table 2: Key findings of the research

Model process areas	75% or more	Model Indicators	75% or more	How to use model indicators	75% or more
Continuous improvement	✓	*Progress monitoring and reporting*	✓	Establish regular tracking systems to monitor quality performance trends	✓
	✓	Stretch targets	✓	Set challenging but achievable goals to drive continuous performance enhancement	✓
	✓	Employee empowerment	✓	Empower employees by involving them in decision-making and quality initiatives	✓
	✓	**Encouraging innovative ideas**	✓	Create structured platforms to capture and implement innovative ideas	✓
	✓	**Continuous improvement cycles**	✓	Implement structured continuous improvement cycles like PDCA or Kaizen	✓
	✓	**Learning by doing**	✓	Encourage reflective practice through experiential learning and feedback	✓
Benchmarking	✓	Benchmark to high industry standards	✓	Benchmark organisational performance against leading industry standards	✓
	✓	Industry analysis	✓	Conduct systematic industry analyses to inform quality benchmarks	✓
	✓	*Best practices incorporated to sub-processes*	✓	Integrate established best practices into operational subprocesses	✓
	✓	**Up to date benchmark criteria**	✓	Continuously update benchmarking criteria to reflect current standards	✓
	✓	**Performance Metrics**	✓	Use well-defined performance metrics to monitor and improve outcomes	✓
	✓	**Shared internal best practices**	✓	Share effective internal practices across teams and projects	✓
Standardisation	✓	Defined work processes	✓	Define and institutionalise standard workflows to ensure consistency	✓
	✓	Maintenance of quality standards	✓	Implement robust systems to uphold project-specific quality standards	✓
	✓	Process controlling and quality assurance	✓	Apply structured quality control and assurance procedures	✓
	✓	*Proper documentation*	✓	Maintain thorough and accessible project documentation for traceability	✓
	✓	**Standard Operating procedures for site operations**	✓	Develop and enforce SOPs for site-level operations	✓
	✓	**Matching building standards to performance metrics**	✓	Align construction standards with performance requirements and objectives	✓
Error detection and prevention	✓	Prompt defect response & Error prevention	✓	Establish rapid-response systems for defect identification and resolution	✓
	✓	Establishing teams for bottlenecks	✓	Create multidisciplinary teams to address recurring process bottlenecks	✓
	✓	**First-Time Right (FTR) Rate**	✓	Promote 'First-Time Right' practices to minimise rework and defects	✓
	✓	**Independent quality assurance entity**	✓	Engage independent quality assurance bodies for objective evaluations	✓

Three key process areas, namely continuous improvement, benchmarking, and standardisation, were identified through a comprehensive review of existing literature as foundational elements of lean construction that contribute to enhanced quality management. These process areas were presented to the expert panel for validation during Delphi Round 1, Phase I.

The experts endorsed all three areas, each achieving the required consensus threshold of 75 percent or higher, thereby confirming their relevance and applicability within the context of the Sri Lankan construction industry.

In addition to validating the literature-derived areas, the expert panel proposed an additional process area based on contextual insights and professional experience. This new area, identified as error detection and prevention, was not present in the initial literature but was considered critical for addressing practical quality issues in the local construction environment. It was also validated during Delphi Round 1, Phase I, and received more than 75 percent consensus, thereby confirming its significance. As presented in Table 2, this expert-driven process area is highlighted in bold to distinguish it from those established through the literature review.

Key performance indicators for each key process area related to quality management in lean construction in the Sri Lankan construction organisations (Delphi round 1 phase 1, Delphi round 1 phase II, Delphi round 2 phase I, Delphi round 3 phase I)

Experts were presented with 12 indicators derived from the literature for identifying relevant performance indicators. In Delphi Round 1 Phase 2 (DR1P2), all 12 indicators were validated by the expert panel, each achieving a consensus level of 75% or above, confirming their relevance to quality management in lean construction.

In Delphi Round 2 Phase 2 (DR2P2), experts proposed 10 additional performance indicators based on their professional insights and contextual knowledge of the Sri Lankan construction industry. These newly suggested indicators were also validated with the required consensus level, bringing the total number of validated indicators to 22. This outcome reflects the value of expert involvement in capturing nuanced, context-sensitive dimensions of quality management that are not always evident in global literature. A detailed summary of the validated indicators is provided in Table 2. In Table 2, indicators shown in plain text represent those accepted from literature without modification, italics indicate indicators identified from literature but refined by experts, and bold denotes indicators that were newly suggested by the experts.

Subsequently, in Delphi Round 3 Phase 1 (DR3P1), all validated indicators were systematically categorised under the four key process areas of quality management: continuous improvement, benchmarking, standardisation, and error detection and prevention. This categorisation established a clear structure linking each performance indicator to its respective process area, thereby supporting a comprehensive framework for evaluating lean integration for quality management within Sri Lankan construction organisations. This structured classification enhances practical applicability by enabling targeted assessment, monitoring, and improvement initiatives aligned with each process area, while also contributing to theoretical development by contextualising lean-based quality indicators within a developing country setting.

How to use the key process areas and performance indicators in lean construction to enhance the quality management in the Sri Lankan construction organisations (Round 3 phase I, Round 3 phase II)

In Delphi Round 3 Phase 2, experts were specifically tasked with investigating how the validated key process areas and performance indicators could be utilised to enhance quality management within Sri Lankan construction organisations as shown in Table 2. This phase moved beyond identification and validation, focusing instead on the practical integration of these elements into organisational processes and quality management systems.

In the area of benchmarking, experts underscored the dual importance of external alignment and internal knowledge dissemination. *As Expert E4 commented, "Benchmarking against industry standards helps align with global practices, but sharing internal best practices across sites can lead to faster diffusion of quality-enhancing methods."* Indicators such as *benchmark to high industry standards*, *updated benchmark criteria*, *performance metrics*, and *shared internal best practices* were viewed as strategic tools for elevating organisational quality. The integration of *industry analysis* and *sub-process benchmarking* was further seen as enabling data-driven alignment with evolving quality standards.

The standardisation process area was consistently recognised as fundamental to ensuring consistency and compliance. Experts advocated for clearly defined procedures, accessible documentation, and strict adherence to established protocols. *As Expert E1 observed, "A well-documented process is a quality assurance system in itself."* Indicators such as *defined work processes*, *standard operating procedures for site operations*, and *maintenance of quality standards* were viewed as essential for minimising process variability. The emphasis on *process control*, *quality assurance*, and *alignment with building performance metrics* further supports the establishment of a systematic and repeatable approach to quality management.

Finally, the inclusion of error detection and prevention as a distinct process area was acknowledged as a valuable contextual contribution, especially for addressing quality issues at source. Indicators such as *First-Time Right (FTR) rate*, *prompt defect response and error prevention*, and *independent quality assurance entities* were considered vital for embedding preventive quality practices. *Expert E3 stated, "We must move beyond post-completion inspections. Early error detection can reduce waste, time, and cost significantly."* The use of *teams for bottleneck resolution* was also proposed to enable more agile, cross-functional responses to emerging quality issues. Together, these indicators represent a shift from reactive quality control to a more anticipatory and system-wide preventive approach tailored to the Sri Lankan construction environment.

DISCUSSION

This study aimed to explore how lean construction can enhance quality management in Sri Lankan construction organisations by identifying key process areas and associated performance indicators. The Delphi method confirmed four core process areas as continuous improvement, benchmarking, standardisation, and error detection and prevention, mapped to 22 validated indicators.

The prominence of continuous improvement aligns with Kaizen and PDCA-based models (Liker, 2004; Womack & Jones, 2003), which stress iterative feedback and worker involvement. Indicators such as progress monitoring and employee empowerment reflect widely accepted lean practices (Ballard & Howell, 2003). Expert-suggested indicators like learning by doing and continuous improvement cycles reinforce the shift from top-down to collaborative learning processes, supporting findings by Salem et al. (2006) and Sarhan & Fox (2013). Benchmarking indicators confirmed, such as industry analysis and best practice, correspond with value stream mapping and performance gap identification (Sacks et al., 2010). Additions like shared internal benchmarks and real-time metrics mirror practices promoted by Anvari et al. (2011), indicating that both external and internal benchmarking are necessary for lean construction in fragmented construction environments. The role of standardisation is consistent with lean principles that require process stability to support flow (Modig & Åhlström, 2012). Indicators such as defined work processes and quality standards match the foundation of 5S and standard work (Formoso et al., 2002). The expert-validated inclusion of site-specific SOPs and performance-matched building standards highlights the need for regulatory and operational contextualisation, as also noted in Ranadewa et al. (2020). Notably, error detection and prevention emerged as a locally emphasised area. While not prominent in initial lean models, the validated indicators, including First-Time Right (FTR) rate and independent QA entities, reflect modern interpretations of jidoka and poka-yoke for quality at source (Ohno, 1988; Shingo, 1986). These findings align with Tezel et al. (2016), who argue that lean systems require built-in quality control mechanisms beyond inspection. Overall, the study findings confirm key process areas and indicators in lean construction provide tangible mechanisms and monitors to enhance quality management in construction. This supports ideas by Marodin et al. (2019) and Ochieng et al. (2020) for lean integration for successful quality management in construction projects.

RESEARCH CONTRIBUTIONS

Theoretical Contribution

This research advances the theoretical understanding of lean integration for quality management in construction by extending existing frameworks to the Sri Lankan context, where such integration has been limited. While global literature recognises lean maturity as a driver of performance improvement (Sacks et al., 2010; Marodin et al., 2019), its adaptation to quality-specific process areas within developing economies remains underexplored. This study fills that gap by identifying four key process areas, namely continuous improvement, benchmarking, standardisation, and error detection and prevention, and validating 22 associated performance indicators through expert consensus. The identification of these indicators provides a structured and contextually grounded extension to lean practices, which have traditionally emphasised tool adoption over measurable quality performance dimensions.

Practical Contribution

The study offers a practical framework that construction practitioners in Sri Lanka can use to assess and improve organisational quality management. The performance indicators provide measurable criteria for evaluating current practices, setting improvement targets, and benchmarking progress. This operational clarity enables both detailed process improvements at the project level and broader strategic alignment with organisational quality objectives. Furthermore, the framework helps construction firms address persistent challenges within the Sri Lankan industry, including low productivity, high levels of rework, and inconsistent quality control, by embedding lean principles into their quality assurance systems. Industry regulators and professional bodies may also utilise the indicators to develop lean-oriented guidelines and training content specifically adapted to the Sri Lankan construction context.

Methodological Contribution

This study demonstrates the structured application of the Delphi technique to develop a locally validated lean integrated quality management framework. Although Delphi is commonly used for consensus building, its phased use in this study across indicator identification, validation, contextualisation, and categorisation enabled an iterative yet systematic development process. This approach provides a replicable model for similar research in contexts where empirical data are limited, and expert input is essential.

Societal Contribution

This research promotes more efficient, reliable, and quality-focused construction practices in Sri Lanka. By embedding lean thinking into daily operations, the framework encourages a culture of continuous improvement and accountability. It supports long-term objectives related to capacity building and professional development, while also delivering benefits to clients, communities, and end users through more sustainable and socially responsive construction outcomes.

CONCLUSION

This study explored how lean construction practices can be strategically applied to enhance quality management within Sri Lankan construction organisations. Using a structured Delphi technique, four core process areas were identified and validated. These include continuous improvement, benchmarking, standardisation, and error detection and prevention. The process areas were supported by a set of twenty-two performance indicators, derived through a synthesis of established literature and expert judgement. This approach ensured both theoretical rigour and contextual relevance. The integration of these

components provides a coherent and practical framework for improving quality outcomes within lean-oriented construction environments.

The findings confirm that the validated process areas and indicators offer a reliable foundation for evaluating and enhancing quality management practices in the Sri Lankan construction industry. The final conclusion of the study is clearly established. The framework developed through this research can now be applied by industry practitioners and decision-makers to support systematic improvements in quality management. Future research may extend this work by testing the framework across a range of project types, organisational structures, and regional contexts, contributing further to the advancement of lean-based approaches to quality management.

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