Senevirathne, S.A.A.B., Allis, C. and Guruge, K., 2026. Pivot strategies for lean construction implementation: A Sri Lankan perspective. In: Waidyasekara, K.G.A.S., Jayasena, H.S., Chandanie, H. and Tennakoon, G.A. (eds). *Proceedings of the 14th World Construction Symposium*, 10-11 July 2026, Sri Lanka. pp. 1328-1343. DOI: https://doi.org/10.31705/WCS.2026.97. Available from: https://ciobwcs.com/papers/

PIVOT STRATEGIES FOR LEAN CONSTRUCTION IMPLEMENTATION: A SRI LANKAN PERSPECTIVE

S.A.A.B. Senevirathne[1], Chamari Allis[2] and A.P.G.K.Veenadhi[3]

ABSTRACT

Multiple benefits arise from implementing lean principles, as illustrated in the existing literature. Many studies show that significant challenges are preventing lean implementation in the construction sector from being successful. Thus, one of the most important factors in successfully implementing the lean concept in the construction organization is overcoming difficulties. Consequently, the aim of the study is to examine the application of lean construction principles in Sri Lankan building projects and to identify the most suitable techniques that can improve project efficiency. Moreover, this paper also is looking into the advantages of overcoming barriers to successfully apply the lean approach in Sri Lanka. This study investigates how well Lean Construction methods work when used in construction projects in Sri Lanka. For an extensive understanding of how these strategies affected project performance, both quantitative and qualitative analysis methodologies were used. Accordingly, expert interviews and questionnaire surveys were conducted. Through correlation and regression analysis, the quantitative data was subjected to a comprehensive statistical review using SPSS. As a result several Lean tools, such as 5S, Visualization, Just-In-Time (JIT), Total Quality Management (TQM), and Value Based Management (VBM), were found to be appropriate to the Sri Lankan construction industry by the study. Visualization emerged as the most beneficial method of all, greatly improving project quality, time efficiency, and cost control. Nonetheless, the results additionally underscored that notable impediments to the extensive implementation of Lean techniques in Sri Lanka are ignorance and unfamiliarity with them. This emphasizes the need for more instruction and training to spread the advantages and real-world uses of lean construction methods throughout the area.

Keywords: *Lean construction; Visualization; Quality Management; Sri Lanka; Sustainability.*

1. INTRODUCTION

The construction industry plays a vital role in the economic development all around the globe, which is also has a significant influence on infrastructure development, employment generation, and industrial growth (Zhou et al., 2019). Even though, construction industry also faces major challenges such as, delays, cost overruns, material

[1] Quantity Surveyor, Senevirathne Contractors, Sri Lanka, adeesha.senevi@gmail.com
[2] Senior Teaching Fellow, Liverpool John Moores University, United Kingdom, chamaribuddhi@gmail.com
[3] Research Assistant, Department of Building Economics, University of Moratuwa, Sri Lanka, kaviniveenadhi1997@gmail.com

waste and inefficient coordination among stakeholders (Nowotarski et al., 2016). Apparently, maintaining a balance between time, cost and quality pillars is a significant challenge in many projects. In order to address this challenge, improving efficiency and minimizing waste within construction processes has become a major concern (Hao et al., 2011).

Consequently, lean construction has identified as an effective approach to address the above said matter through improving efficiency and minimizing waste (Singh, 2025). Lean construction is a project management philosophy that focuses on maximizing value while minimizing waste in construction processes. By emphasizing continuous improvement, efficient workflow, and better collaboration among project stakeholders, lean construction aims to enhance project performance and productivity (Coccolini & Bragadin, 2025). Central to this study is the concept of "pivot strategies" a term used here to describe a deliberate, context-sensitive repositioning of lean implementation approaches. Rather than directly transplanting globally practised lean tools into the Sri Lankan construction environment, pivot strategies reflect an adapted, locally viable approach that acknowledges the unique socio-organisational, cultural, and industry-maturity constraints of the sector. Although lean construction is a widely adopted practice in many developed countries, the level of implementation within the Sri Lankan context remains relatively limited (Kariyawasam & Siriwardana, 2021). Past researchers have also identified that barriers such as; limited awareness, lack of training, resistance to organizational change, and inadequate industry knowledge can reason for this issue. Therefore, it is important to examine the applicability of lean practices in Sri Lankan construction industry (Senevirathne & Wimalasena, 2025). Accordingly, this study aims to examine the application of lean construction principles in Sri Lankan building projects and to identify the most suitable techniques that can improve project efficiency. This aim is achieving through three objectives; firstly, to identify applicable lean construction techniques within the Sri Lankan construction industry, secondly, to analyse the benefits and barriers associated with the implementation of lean principles in the Sri Lankan building construction sector and finally to assess the impact of suitable lean techniques on the efficiency of Sri Lankan building projects. To achieve these objectives, this study adopts a mixed-method research approach, and the findings of this research are expected to provide insights into the current level of lean construction adoption in Sri Lanka and highlight the key factors influencing its implementation.

2. LITERATURE REVIEW

2.1 OVERVIEW OF LEAN CONSTRUCTION

Lean construction is a project management philosophy derived from lean production principles. The goal of lean construction is to maximize value while minimizing waste in construction operations (Coccolini & Bragadin, 2025). Lean construction places more emphasis on continuous improvement, effective workflow, and improved stakeholder collaboration than traditional construction management techniques, which are largely focused on cost and schedule (Maraqa et al., 2023).

Lean production concept, which were first developed within the Toyota Production System, were adapted and brought to the construction industry. Since its establishment in 1993, the International Group for Lean Construction (IGLC) has been instrumental in advancing lean research and implementation in the architecture, engineering, and

construction (AEC) sector (Chen et al., 2023). According to lean construction, construction should be viewed as a production system with processes that are optimized to enhance flow, get rid of non-value-adding tasks, and boost project efficiency (Bertagnolli, 2022).

As mentioned before, inefficiencies like delays, rework, material waste, and inadequate stakeholder collaboration are frequent problems in construction projects (Moradi & Sormunen, 2023). By increasing cooperation, decreasing waste throughout project phases, and improving process transparency, lean construction solutions seek to address these problems. Lean construction thereby helps to increase client happiness, project performance, and productivity (Kariyawasam & Siriwardana, 2021).

2.2 LEAN CONSTRUCTION PRINCIPLES

Lean construction is based on a number of fundamental concepts that emphasize maximizing customer value while reducing waste in project operation (Rosli et al., 2023). Construction projects are planned, managed, and carried out according to these principles.

Accordingly, the fundamental principles can be identified as below in table 1.

Table 1: Fundamental principles of lean construction

Key Principle	Explanation
Value identification	Establishing the project's worth in accordance with the requirements and expectations of the client.
Value stream mapping	Identifying every task necessary to complete the project and removing those that don't provide value.
Flow optimization	Making sure that all project operations are carried out continuously and smoothly.
Pull-based manufacturing	Producing work based on actual demand rather than forecasts.
Continuous improvement	Enhancing procedures over time to increase productivity and quality

By putting these principles into practice, construction companies may minimize delays, enhance stakeholder cooperation, and maximize resource use (Maraqa et al., 2023).

2.3 LEAN TECHNIQUES USED IN CONSTRUCTION PROJECTS

With the requirement of approaching improved work efficiency and reduced construction waste along with enhanced communication with the project stakeholders, various lean techniques have been adopted in the construction industry (Aslam et al., 2022).

One widely used technique is 5S, which focuses on maintaining an organized and efficient workplace. The flow of operations that create value for the client is the main emphasis of lean construction. There are five levels of housekeeping in the 5S process, which is also called the Visual Work Place and is used to get rid of unnecessary resources. Sort, Set in Order (Section), Shine, Standardize (Seiketsu), and Sustain (Shitsuke) are the five major stages in this concept (Chen et al., 2024). The five stages; Sort, Set in Order, Shine, Standardize, and Sustain help improve site organization, increase productivity, and reduce unnecessary movement and material waste on construction sites. On Construction sites, the 5S housekeeping technique is frequently employed in relation with lean

construction. Enhanced productivity, quality, set-up times, space creation, lower lead times, higher machine uptime, enhanced morale, teamwork, and continual development are all advantages of applying through 5S. On a construction site, the material layout is frequently employed to implement the 5S methodology (Salem et al., 2006).

Another important technique is Just-in-Time (JIT), which aims to deliver materials and resources exactly when they are required in the construction process. This approach helps minimize inventory costs, reduce storage requirements, and improve workflow efficiency (Garcés & Peña, 2023).

Moreover, visual management is also commonly used in lean construction (Ibrahim et al., 2025). The main objectives of visual management are to encourage the extensive exchange of information in the workplace and to lessen barriers to the information's dissemination (Garcés et al., 2025). It involves using visual tools such as information boards, charts, and progress indicators to enhance communication and transparency among project stakeholders. These tools help teams quickly identify problems and make timely decisions (Hasan et al., 2024).

In addition, Total Quality Management (TQM) supports lean construction by promoting continuous quality improvement through collaboration, training, and stakeholder involvement. To increase performance, TQM is a global endeavour involving all organizations (Nowotarski et al., 2016). It affects every part of an organization and elevates quality to a strategic aim. TQM is attained by staff members at all levels working together to continually improve performance to raise customer satisfaction (Marhani et al., 2013). TQM aims to promote customer happiness, cost-effectiveness, and defect-free work by emphasizing process improvement, customer and supplier interaction, cooperation, and training and education. TQM offers the environment and culture necessary for technological advancement and innovation (Moradi & Sormunen, 2023).

Furthermore, building project briefs usually include a definition of values, along with needs, goals, and expectations. Achieving these standards specified by the building customer and users is the primary objective. Market value and utility value are the two types of values. The impact on human behaviour is the central idea of VBM (Hartanti et al., 2022). The actions required to construct are linked to human behaviour in the construction industry. These consist of managerial work and workmanship. In essence, VBM can be understood as a synthesis of values-based management. Since building is not a new field, the main focus of this research is management by values. As a result, it is acknowledged that value management in today's building is far from ideal (Singh, 2025). The building process primarily involves employees working on construction sites, who are primarily concerned with process values such as good cooperation, agreement, discipline, communication, etc. in addition to their pay. Because they will be residing or working in the built structure, the end users are primarily concerned with the product values, such as brick type, roof light, flexibility, economy, architecture, etc (Ibrahim et al., 2025).

Among the lean tools applied in the construction sector, the Last Planner System (LPS) stands out as the most widely researched and operationally implemented scheduling methodology globally (Ballard, 2000; Jayanetti et al., 2024). Originally developed by Glenn Ballard and Greg Howell in the 1990s, the LPS was conceived as a collaborative production planning and control approach designed to address the chronic unreliability of construction schedules (Ballard, 2000). Its theoretical foundation is rooted in lean

production principles, specifically the concepts of pull scheduling, workflow reliability, and continuous improvement.

The LPS operates through a hierarchical planning structure comprising three interrelated components:

1. The Master Schedule, which defines the overall project milestones and sequencing;
2. The Look-Ahead Schedule, a three-to-six-week rolling plan that identifies and removes workflow constraints in advance; and
3. The Weekly Work Plan (WWP), which formalises commitments made by the "last planners"

Those directly responsible for executing work on site (Ballard, 2000; Parameswaran et al., 2024). The performance of the LPS is measured using the Percent Plan Complete (PPC) metric, which tracks the proportion of planned tasks completed as committed, thereby providing a quantitative indicator of workflow reliability.

Empirical evidence from international studies confirms the effectiveness of the LPS in improving schedule predictability, reducing waste, and enhancing team collaboration on construction projects (Moradi & Sormunen, 2023; Garces et al., 2025). Within the Sri Lankan context, Jayanetti et al. (2024) and Parameswaran et al. (2024) have identified the LPS as a promising lean tool, noting its alignment with the collaborative and relationship-driven nature of construction project teams in the region. However, broader adoption of the LPS in Sri Lanka remains limited due to the same barriers prevalent across other lean techniques, particularly low awareness, lack of structured training programmes, and resistance to changing established planning routines (Kariyawasam & Siriwardana, 2021; Senevirathne & Wimalasena, 2025).

In the context of the present study, the LPS represents a significant lean scheduling technique that complements the tools analysed in the quantitative phase such as 5S, JIT, Visualization, TQM, and VBM. Its omission from the original study was a recognised limitation; future research should specifically investigate the applicability and effectiveness of the LPS as a pivot strategy for lean implementation in the Sri Lankan construction sector.

2.4 LEAN CONSTRUCTION IN THE SRI LANKAN CONSTRUCTION INDUSTRY

As per the past researchers, Sri Lankan construction industry has been playing a crucial role in the perspective of economic growth, by fostering the development of infrastructure, the creation of jobs, and the expansion of industry, etc (Parameswaran et al., 2024). Regardless of that fact, low productivity, project delays, material waste, and ineffective stakeholder collaboration are some of the industry's problems identifies in past literature (Hettiaarachchige et al., 2022). Evidently, lean construction practices can support positively on overcoming the above said issues simply by, improved project planning, improved communication, and waste reduction throughout the construction process (Perera et al., 2024). By emphasizing on value creation and effective workflow lean construction can enhance project delivery performance, lower costs, and boost customer satisfaction (Senevirathne & Wimalasena, 2025).

As mentioned in the beginning of the study, Sri Lanka is in its earliest phase of adopting lean construction practices. While some organizations have started implementing lean techniques, widespread adoption remains limited due to several barriers such as lack of awareness, insufficient training, resistance to change, and inadequate organizational support (Parameswaran et al., 2024).

2.5 BENEFITS OF USING THE LEAN CONCEPT IN SRI LANKAN PROJECT

Although the construction industries worldwide encountered numerous challenges whilst implementing the Lean Concept, a few industries have recognized the possibility of including enhancements through lean implementation.(Senevirathne & Wimalasena, 2025) Various methods and benefits have been known by using the researchers. The maximum vital benefit of using the Lean Concept in corporations is the reduction of waste (Fernando et al., 2024). By putting off waste inside the creation, Lean Concept encourages the following: Minimise double handling and movement of system and employees, Balance team, coordinate flows, Take off fabric constraints, Minimise variance in input, Minimise changeovers and hard setups and Reduce interpersonal dynamics (Kalubovila et al., 2023).

Three primary benefits of lean practices as economic (price, quality, and time), social (courting and satisfaction), and environmental in terms of production tasks. Under monetary advantages reduction in time and fee, improvement of satisfaction, higher stock control and hazard minimization were some of the benefits identified (Senevirathne & Wimalasena, 2025). Social worker satisfaction, worker health and safety, and better cooperation among stakeholders were some of the blessings. Under environmental advantages, reduction of waste and achieving green construction have been recognized. There are challenges to overcome in the construction industry's lean implementation (Jayanetti et al., 2024). The global construction sector is seeing difficulties in implementing lean due to many obstacles, regardless of the specific economic standing of the nation. A significant amount of research papers in many developed, developing, and underdeveloped nations worldwide (Hettiaarachchige et al., 2022).

2.6 BARRIERS TO USING LEAN CONCEPT IN SRI LANKA

Given that the Sri Lankan construction industry has brought attention to the need for improving the technical know-how and lean knowledge of implementing lean construction, introducing enough training programs on lean practices, and upholding a proper organizational culture as strategies to overcome the difficulties in implementing lean construction in SMEs (Jayanetti et al., 2024). Studies have also highlighted several tactics for overcoming the difficulties associated with implementing lean, including integrating policies to support cultural shifts, decentralizing top management, and guaranteeing training and growth inside the organizations (Moradi & Sormunen, 2023). The results of the literature review above indicate that there is a lack of research on methods for resolving human-related lean implementation difficulties in Sri Lanka's large-scale contractors.

According to (Kariyawasam & Siriwardana, 2021), under their research findings, they identified key barriers to creating a sustainable lean culture in Sri Lanka.

Table 1: Key barriers to creating a lean culture in SL

Number	Key Barrier
1	Difficulty in convincing the need for change.
2	The dearth of learning experts.
3	Cultural and human attitudes of employees.
4	Construction fragmentations.
5	A long time is required for lean transformation.
6	Employer issues.
7	The difficulty of changing employee attitudes towards a production system view of construction.
8	Lack of team spirit.
9	Improper department proceedings.
10	Poor involvement of employees during change.
11	Unexpected and sudden disturbances created to existing processes.
12	Inability to review lean as a continuous process.
13	Difficulty of maintaining a consistent workflow.
14	Reluctance to follow orders from superiors.
15	Consultant and supplier-related issues.
16	Low attention is given to the acquisition of soft skills by employers.
17	Blame culture.
18	Multiple definitions are given to lean.
19	More barriers and specific barriers which are suggested by respondents discussed in the upcoming sections.

3. RESEARCH METHODOLOGY

The research is firmly grounded in a mixed research methodology by adopting both qualitative and quantitative techniques, seeking to identify the primary Lean Technique for the Sri Lankan construction industry. The choice of a mixed method approach was made to address the study's research question, offering an explanatory analysis of the key Lean Techniques and the primary barriers to implementing these techniques in the Sri Lankan construction industry. To accomplish the research objectives, a comprehensive literature review and semi-structured interviews were utilized as data collection techniques. Nine interviews were conducted with construction experts possessing at least a Bachelor of Science qualification along with relevant professional credentials and over five years of experience. The data obtained from the interviews were categorized into six distinct groups, which encompass awareness of the lean concept and Lean Techniques, prior utilization of Lean Techniques in their respective firms, the most comprehensible Lean Technique, the most easily applicable Lean Technique, the most effective Lean Technique post-implementation, and the key barriers to applying these techniques within the Sri Lankan Construction industry. The collected data were analyzed using both manual calculations and the SPSS (Statistical Package for the Social Sciences) data analysis tool.

3.1 DATA COLLECTION METHODS

A designated questionnaire was circulated among the expert professionals in the Sri Lankan construction sector. A questionnaire was designed and shared via email and social media amongst construction industry professionals actively employed in the industry. The questionnaire was not distributed openly to the general public. It was circulated through targeted professional networks and directed to pre-identified individuals meeting the inclusion criteria: construction industry professionals actively employed in the sector with relevant professional qualifications. Email was the primary distribution channel to contact these pre-screened individuals; social media (LinkedIn) served only as a supplementary means to reach known professional contacts within the same network. Only respondents with verifiable professional credentials and industry experience were included in the final analysis. The respondents were requested to rank the extraordinary viewpoints in keeping with a "Likert Scale". The questionnaire changed into disbursed amongst 30 wide variety of specialists (decided on via stratified random sampling technique) from diverse disciplines along with Project Managers, Construction Managers, Engineers, Quantity Surveyors, and Architects due to the fact primarily based on differences in thought processes, backgrounds, and work experiences, people's replies to the questions may differ. Stratified random sampling was selected because the target population consists of distinctly defined sub-groups based on professional role. Ensuring proportional representation across these subgroups was critical to capturing diverse professional perspectives that would not have been reliably achieved through simple random sampling. Each stratum was defined by professional designation, and respondents were proportionally drawn from each group. To fulfil the aim of this study semi-structured interviews were conducted with the professionals who were selected using purposive sampling.

3.2 CONCEPTUAL FRAMEWORK

The overall research methodology of this study is based on below conceptual framework below.

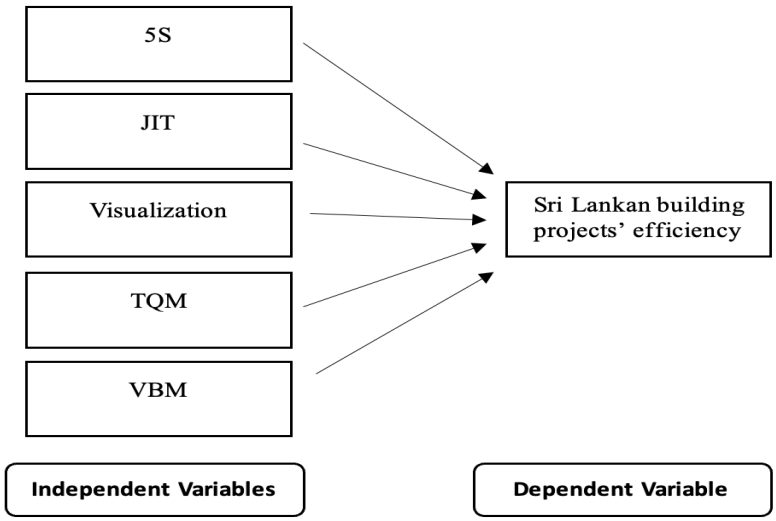

Figure 1: Conceptual framework

Independent Variables are identified to describe the lean techniques and the dependent variable describes how lean techniques affect Sri Lankan building projects. The hypotheses were developed as follows,

Table 2: Hypotheses of the study

Identification	Hypotheses
HA_1	There is a relationship between 5S and Sri Lankan building projects' efficiency.
HB_1	There is a relationship between JIT and Sri Lankan building projects' efficiency.
HC_1	There is a relationship between visualization and Sri Lankan building projects' efficiency.
HD_1	There is a relationship between TQM and Sri Lankan building projects; efficiency.
HE_1	There is a relationship between VBM and Sri Lankan building projects; efficiency.

3.3 DATA ANALYSIS METHODS

Qualitative data provide background information and direction for the literature review. Following that, statistical techniques such as regression analysis and correlation were utilized to observe quantitatively the links between Lean Construction techniques and challenge performance criteria. When controlling for other relevant variables, regression analysis enables us to evaluate the predictive power of precise Lean techniques on cost reduction, time performance, and quality improvement. Correlation analysis also helps to determine the strength and direction of the associations between variables. The implementation of this blended-strategies approach will guarantee a comprehensive and robust comprehension of the efficacy of Lean Construction techniques inside the Sri Lankan construction sector.

4. RESULTS

4.1 DEMOGRAPHICAL DATA

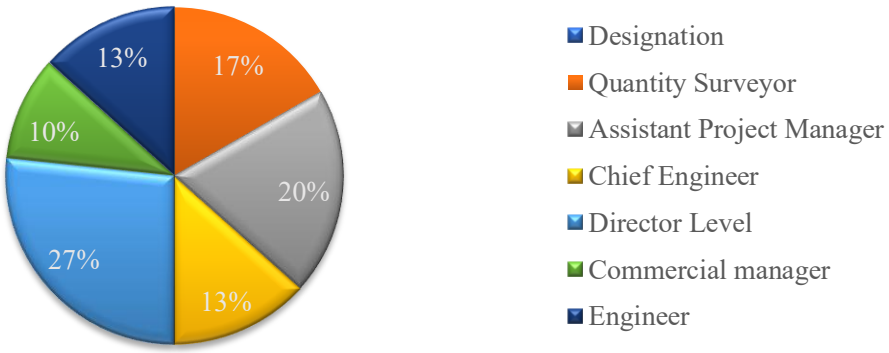

Figure 2: Respondents' profile

The above figure certified that the professionals of the construction industry who have an idea regarding the lean concept helped to achieve the objectives of this study via a questionnaire survey. The majority of the respondents were Director - level Professionals in the construction industry. It is 27% and the lowest respondents were commercial managers, it is 10%.

4.2 CORRELATION ANALYSIS

The data gained from the questionnaire survey were analysed through SPSS software to examine the above-mentioned hypothesis between independent and dependent variables. Because the "Pearson Correlation Coefficient" indicates linear correlations between two variables, it was utilized in this study using the SPSS software. variables having a -1 to +1 range. A positive correlation between two variables indicates that when the value of one grows, so does the value of the other. When there is a negative correlation between two variables, it means that when one variable increases, the other variable's value decreases. The significance value (P) will determine whether or not the correlation coefficient is met. If P is less than 0.05, there is a relationship between the DV and the specific IV; if P is greater than 0.05, there is no association.

Table 3: Correlations analysis of the independent & dependent variables

Correlations

		AIV	AJIT	AVZ	ATQM	AVBM	ADV
AIV	Pearson Correlation	1	.933**	.370*	.439*	0.357	.433*
	Sig. (2-tailed)		0.000	0.044	0.015	0.052	0.017
	N	30	30	30	30	30	30
AJIT	Pearson Correlation	.933**	1	0.331	.466**	0.333	.402*
	Sig. (2-tailed)	0.000		0.074	0.009	0.072	0.027
	N	30	30	30	30	30	30
AVZ	Pearson Correlation	.370*	0.331	1	.702**	.966**	.886**
	Sig. (2-tailed)	0.044	0.074		0.000	0.000	0.000
	N	30	30	30	30	30	30
ATQM	Pearson Correlation	.439*	.466**	.702**	1	.730**	.721**
	Sig. (2-tailed)	0.015	0.009	0.000		0.000	0.000
	N	30	30	30	30	30	30
AVBM	Pearson Correlation	0.357	0.333	.966**	.730**	1	.879**
	Sig. (2-tailed)	0.052	0.072	0.000	0.000		0.000
	N	30	30	30	30	30	30
ADV	Pearson Correlation	.433*	.402*	.886**	.721**	.879**	1
	Sig. (2-tailed)	0.017	0.027	0.000	0.000	0.000	
	N	30	30	30	30	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Where; N = Number of Respondents, AIV = Average of 5S, AJIT= Average of JIT, AVZ = Average of Visualization, AVBM = Average of Value-based Management (VBM), ADV= Average of Dependent Variable.

According to the above table all variables' Pearson correlations range from -1 to +1 and $P < 0.05$, it may be concluded that every independent variable and dependent variable are related.

4.3 REGRESSION ANALYSIS

The purpose of this study was to identify the independent variable that had the maximum impact on the dependent variable. The same set of information was obtained by using SPSS software, and regression analysis was conducted on the questionnaire used for the correlation analysis.

Table 4: Regression analysis of the independent & dependent variables

Coefficients[a]						
Model		Unstandardized Coefficients		standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.214	0.829		-1.465	0.156
	AIV	0.213	0.513	0.105	0.415	0.681
	AJIT	-0.030	0.585	-0.013	-0.052	0.959
	AVZ	0.631	0.409	0.530	1.541	0.136
	ATQM	0.217	0.213	0.140	1.016	0.320
	AVBM	0.293	0.448	0.232	0.654	0.519
a. Dependent Variable: ADV						

The regression's unstandardized β value or coefficients show how much of the building project's efficiency (DV) is reflected by tools for lean construction (IV). According to the above table, there is a 29.3% variance in between Vale based management system lean technique and the Sri Lankan building projects' efficiency. With the increase of properly implemented 5S lean tool building projects efficiency increases by 21.3%. With the proper visualization lean technique, the building projects' efficiency can be increased by 63.1% and the properly implemented JIT technique can delay the projects' efficiency by 3%.

conducting education efforts for lean construction, testing the tools on a brief project with specialists, and increasing, working together and pushing the company's upper management to apply lean construction tools across the board are two short-term solutions to problems with lean construction tool implementation. Long-term recommendations for the effective application of lean construction tools in Sri Lanka include creating a government institute for lean construction, encouraging the construction sector to adopt new technologies, creating an appropriate framework for implementation, carrying out a case study to determine the advantages of lean construction, and offering appropriate lean construction education and training.

5. DISCUSSION

The correlation analysis confirmed statistically significant positive relationships between all five lean techniques and building project efficiency ($p < 0.05$), with VBM approaching significance ($r = 0.879$, $p = 0.052$). This aligns with international evidence consistently linking lean tool adoption to improved project performance (Garces & Peña, 2023; Moradi & Sormunen, 2023; Ibrahim et al., 2025). The strong correlation for Visualization ($r = 0.886$, $p < 0.001$) corroborates Kariyawasam and Siriwardana (2021), while the high Visualization–VBM correlation ($r = 0.966$) suggests these techniques tend to be adopted in tandem, reflecting the complementary nature of visual transparency and value-driven decision-making.

The regression analysis identified Visualization as the most influential predictor of project efficiency ($\beta = 0.530$), followed by VBM ($\beta = 0.232$), TQM ($\beta = 0.140$), and 5S ($\beta = 0.105$). Despite a significant bivariate correlation ($r = 0.402$, $p = 0.027$), JIT yielded a negative, non-significant regression coefficient ($\beta = -0.013$, $p = 0.959$), suggesting its effect is largely mediated by other techniques, particularly 5S ($r = 0.933$). The primacy of Visualization is further reinforced by the expert interview findings, where visual management tools were consistently rated as the most comprehensible and readily applicable lean practices. This convergence of quantitative and qualitative evidence aligns with Garces et al. (2025) and Coccolini and Bragadin (2025), who identify visual management as an accessible entry point for lean adoption in organisations with limited lean exposure. The predominance of awareness and knowledge deficits as implementation barriers is consistent with the international literature (Moradi & Sormunen, 2023; Nowotarski et al., 2016) and Sri Lankan-specific findings (Kariyawasam & Siriwardana, 2021; Senevirathne & Wimalasena, 2025). The present study advances beyond barrier identification by proposing context-sensitive pivot strategies, addressing a gap noted by Jayanetti et al. (2024) and Perera et al. (2024). Visualization and 5S are recommended as first-phase priorities; TQM and VBM as second-phase strategies following foundational lean literacy development. The cautious treatment of JIT reflects the well-documented supply chain fragmentation in Sri Lanka, underscoring that lean tools must be sequenced and locally adapted rather than transplanted wholesale from higher-maturity environments.

6. CONCLUSIONS

This research explored the adaptability and effectiveness of lean construction methods in the Sri Lankan construction industry, focusing specifically on identifying appropriate lean tools and assessing their influence on project efficiency. This study carried out in mixed method approach utilizing both expert interviews and questionnaire surveys.

The results of the research reveal that various lean construction techniques, such as 5S, JIT, Visualization, Total TQM, and VBM, are relevant to the construction sector in Sri Lanka. The correlation analysis demonstrated that all selected lean techniques show a positive relationship with building project efficiency, suggesting that the adoption of lean practices can contribute to improving project performance in terms of time management, cost control, and quality improvement.

Moreover, among the identified techniques, Visualization has figured out as the most influential lean practice in Sri Lankan construction industry. Collected data through both the methods, expert interviews and the questionnaire surveys indicate that visualization

techniques have significant contribution to improve communication, coordination and transparency among the project stakeholders. By enabling clear information sharing and faster decision-making, visualization tools help reduce misunderstandings, delays, and inefficiencies during project execution. Furthermore, study reveals that, during the procedures of improving workplace organization, workflow efficiency, and stakeholder alignment with project objectives; 5S and VBM also has positively influence the project efficiency. Additionally, study also reveals that though the JIT is a widely used and adopted lean technique globally in Sri Lankan context it has a relatively limited influence on project efficiency. The reason for the limitation has identified as due to the complexity of construction supply chains and the uncertainties associated with project environments.

Apart from the potential benefits, study also identified several barriers which impacts on widespread adoption within the Sri Lankan construction industry. The main barriers are a lack of understanding and familiarity with lean concepts, a lack of training opportunities, organisational change resistance, disjointed project structures, and inadequate stakeholder participation.

Therefore, a number of strategic initiatives are suggested to improve the adoption of lean construction principles in Sri Lanka. Improving industry knowledge and acceptance of lean processes requires raising awareness and offering professional training on lean methodologies. Additionally, construction companies should encourage supportive organisational cultures that enable ongoing improvement and encourage cooperation among project participants. The adoption of lean practices in the industry may be further stimulated by the establishment of institutional support mechanisms, such as industry guidelines or government-backed lean construction programs.

In conclusion, providing actual data on the efficacy of lean construction methods in the Sri Lankan setting, this study adds to the body of knowledge already in existence. The findings of this study carry several practical implications for construction industry stakeholders in Sri Lanka. For construction firms and project managers, the most immediate recommendation is the prioritisation of Visualization tools as the primary entry-point lean strategy. Visual management practices, including site layout boards, task tracking displays, daily stand-up boards, and colour-coded progress indicators, can be introduced with minimal capital investment and without requiring deep organisational restructuring. Their demonstrated impact on project quality, time efficiency, and cost control makes them the most compelling first pivot for organisations beginning their lean journey.

For industry bodies and professional associations, the findings highlight the critical need for structured lean construction awareness and training programmes. The expert interviews consistently identified ignorance and unfamiliarity as the foremost barriers to lean adoption; therefore, targeted capacity-building initiatives, including workshops, certified short courses, and pilot project demonstrations, are essential to building the lean literacy necessary for broader industry-wide adoption.

For government and policy stakeholders, the study recommends the establishment of a dedicated lean construction institute or centre of excellence, modelled on similar bodies in Singapore and the United Kingdom, to provide a national focal point for lean research, training, and implementation support. Policy incentives, such as procurement requirements favouring contractors who demonstrate lean construction competency, could further accelerate adoption across the industry.

This study opens several avenues for future research. First, longitudinal investigations tracking lean adoption and its impact on project efficiency over multiple years would provide stronger causal evidence than the cross-sectional design employed here. Second, future studies should seek to incorporate the Last Planner System (LPS) as an explicit research variable, given its global prominence and the current gap in Sri Lankan-specific empirical evidence on its applicability. Third, qualitative case study investigations of organisations that have successfully implemented lean practices in Sri Lanka would generate rich, contextual insights into the enabling conditions and implementation pathways that quantitative surveys cannot fully capture. Fourth, comparative studies examining lean adoption across different construction sub-sectors, including infrastructure, industrial, and housing projects, would extend the generalisability of the present findings. Finally, research investigating the integration of lean construction with emerging digital technologies, including Building Information Modelling (BIM) and prefabrication practices, represents a particularly promising direction given the growing interest in construction digitalisation within Sri Lanka.

Notwithstanding the contributions outlined above, this study is subject to several methodological limitations that should be considered when interpreting the findings. First, the quantitative phase of the study was based on a sample of 30 construction industry professionals. While this sample size is appropriate for an exploratory mixed-methods study and is consistent with comparable studies in the lean construction literature within developing country contexts (Senevirathne & Wimalasena, 2025; Kariyawasam & Siriwardana, 2021), it nonetheless limits the statistical robustness of the regression model and restricts the generalisability of the quantitative findings beyond the Sri Lankan context. Larger, nationally representative samples would be required to yield more definitive conclusions regarding the relative predictive power of each lean technique. Second, the study was conducted exclusively within Sri Lanka and may not fully capture the diversity of conditions across different project types, organisational sizes, and regional sub-contexts within the country. Third, the cross-sectional nature of the data collection means that the directionality of relationships between lean techniques and project efficiency cannot be conclusively established; longitudinal designs would be better suited to examine causal mechanisms. Future research should seek to address these limitations through expanded sampling, longitudinal designs, and geographically diverse case study investigations.

7. REFERENCES

Aslam, M., Gao, Z., & Smith, G. (2022). Framework for selection of lean construction tools based on lean objectives and functionalities. *International Journal of Construction Management*, *22*(8), 1559–1570. https://doi.org/10.1080/15623599.2020.1729933

Ballard, H. G. (2000). The last planner system of production control (unpublished dissertation). University of Birmingham. http://www.leanconstruction.org/media/docs/Ballard2000-Dissertation.pdf

Bertagnolli, F. (2022). *Lean management: Introduction and in-depth study of Japanese management philosophy.* Springer Nature. https://link.springer.com/book/10.1007/978-3-658-36087-0

Chen, X., Kurdve, M., Johansson, B., & Despeisse, M. (2023). Enabling the twin transitions: Digital technologies support environmental sustainability through lean principles. *Sustainable Production and Consumption, 38,* 13–27. https://doi.org/10.1016/j.spc.2023.03.020

Chen, Y., Qiu, D., & Chen, X. (2024). Integrating lean construction with sustainable construction: Drivers, dilemmas and countermeasures. *Sustainability, 16*(21), 9387. https://doi.org/10.3390/su16219387

Coccolini, D., & Bragadin, M. A. (2025). History and overview of lean construction fundamentals. In R. Albatici, M. Dalprà, M.P. Gatti, G. Maracchini & S. Torresin (Eds.), *International Conference of Ar.*

Tec.(Scientific Society of Architectural Engineering (766, pp. 197-207). Springer, https://doi.org/10.1007/978-3-032-06993-1_12

Fernando, M. H. V., Costa, D. D., Malsha Nadeetharu, B. K., & Kulatunga, U. (2024). Application of lean principles for building refurbishment projects in Sri Lanka. Built Environment Project and Asset Management, 14(2), 244–259. https://doi.org/10.1108/BEPAM-02-2023-0047

Garcés, G., Forcael, E., Osorio, C., Castañeda, K., & Sánchez, O. (2025). Systematic review of Lean Construction: Aan approach to sustainability and efficiency in construction management. *Journal of Infrastructure Preservation and Resilience, 6*(1), 1–28. https://doi.org/10.1186/s43065-025-00119-1

Garcés, G., & Peña, C. (2023). A review on lean construction for construction project management. *Revista Ingeniería De Construcción, 38*(1), 43-60. https://doi.org/10.7764/RIC.00051.21

Hao, J. L., Tam, V. W. Y., Yuan, H. P., & Wang, J. Y. (2011). Construction waste challenges in Hong Kong and Pearl river delta region. *International Journal of Construction Management, 11*(1), 37–47. https://doi.org/10.1080/15623599.2011.10773160

Hartanti, L. P. S., Gunawan, I., Mulyana, I. J., & Herwinarso, H. (2022). Identification of waste based on lean principles as the way towards sustainability of a higher education institution: A case study from Indonesia. *Sustainability, 14*(7), 4348. https://doi.org/10.3390/su14074348

Hasan, S., Işık, Z., & Demirdöğen, G. (2024). Evaluating the contribution of lean construction to achieving sustainable development goals. *Sustainability, 16*(8), 3502. https://doi.org/10.3390/su16083502

Hettiaarachchige, N., Rathnasinghe, A., Ranadewa, K., & Thurairajah, N. (2022). Lean integrated project delivery for construction procurement: the case of Sri Lanka. *Buildings, 12*(5), 524. https://doi.org/10.3390/buildings12050524

Ibrahim, A., Zayed, T., & Lafhaj, Z. (2025). Trends and gaps in lean construction practices for construction of megaprojects: A critical review. *Alexandria Engineering Journal, 118*, 174–193. https://doi.org/10.1016/j.aej.2025.01.046

Jayanetti, J., Perera, B., & Waidyasekara, K. (2024). AS Key parameters of lean construction maturity: A Delphi study. In Y. G. Sandanayake, K. G. A. S. Waidyasekara, K. A. T. O. Ranadewa, and H. Chandanie (eds). *Proceedings the 12th World Construction Symposium* (pp. 712-726), CIOB. https://doi.org/10.31705/WCS.2024.56.

Kalubovila, K., Kawmudi, W., & Lakmal, A. (2023). The impact of lean construction tools on reduction of contractor related causes of delay in Sri Lankan construction industry. *KDU Journal of Multidisciplinary Studies, 5*(2), 84-92, https://doi.org/10.4038/kjms.v5i2.79

Kariyawasam, D., & Siriwardana, C. (2021). Feasibility study on, enablers and barriers for the implementation of lean construction and the applicability of visual management practices through forms of digital communication in the Sri Lankan industry. *2021 Moratuwa Engineering Research Conference (MERCon),* (pp. 1-6). IEEE, https://doi.org 10.1109/MERCon52712.2021.9525758.

Maraqa, M. J., Sacks, R., & Spatari, S. (2023). Strategies for reducing construction waste using lean principles. *Resources, Conservation & Recycling Advances, 19,* 200180. https://doi.org/10.1016/j.rcradv.2023.200180

Marhani, M. A., Jaapar, A., Bari, N. A. A., & Zawawi, M. (2013). Sustainability through lean construction approach: A literature review. *Procedia-Social and Behavioral Sciences, 101*, 90–99. https://doi.org/10.1016/j.sbspro.2013.07.182

Moradi, S., & Sormunen, P. (2023). Implementing lean construction: A literature study of barriers, enablers, and implications. *Buildings, 13*(2), 556. https://doi.org/10.1016/j.sbspro.2013.07.182

Nowotarski, P., Pasławski, J., & Matyja, J. (2016). Improving construction processes using lean management methodologies: Cost case study. *Procedia Engineering, 161*, 1037–1042. https://doi.org/10.1016/j.proeng.2016.08.845

Parameswaran, A., Ranadewa, K., Rajini, P., & Jayanetti, J. (2024). State-of-the-art lean learning practices in construction: A case study in Sri Lanka. In Y.G. Sandanayake, K.G.A.S. Waidyasekara, K.A.T.O. Ranadewa, & H. Chandanie (Eds.), *Proceedings the 12th World Construction Symposium* (pp. 947-960) CIOB. https://doi.org/10.31705/WCS.2024.75

Perera, L., Kajewski, S., & Coffey, V. (2024). A review of developed lean construction frameworks in the Sri Lankan context. *Proceedings - 8th international research symposium of University of Vocational Technology 2024* (pp. 751-758). https://eprints.qut.edu.au/262395/

Rosli, M. F., Muhammad Tamyez, P. F., & Zahari, A. R. (2023). The effects of suitability and acceptability of lean principles in the flow of waste management on construction project performance. *International Journal of Construction Management*, *23*(1), 114–125. https://doi.org/10.1080/15623599.2020.1853006

Salem, O., Solomon, J., Genaidy, A., & Minkarah, I. (2006). Lean construction: From theory to implementation. *Journal of Management in Engineering*, *22*(4), 168–175. https://doi.org/10.1061/(ASCE)0742-597X(2006)22:4(168)

Senevirathne, H., & Wimalasena, B. (2025). Implementation of lean principles in building construction industry, Sri Lanka. *Advances in Technology*, *5*(1), 27-31. https://www.researchgate.net/publication/392575365_Implementation_of_Lean_Principles_in_Building_Construction_Industry_Sri_Lanka

Singh, J. (2025). Lean construction principles and practices. In D. Bajaj (Ed.), *Handbook of Construction Project Management* (1st ed, pp. 941–968). Springer. https://doi.org/10.1007/978-981-96-7631-6_30

Zhou, Z., Wu, J., & Zhang, W. (2019). Construction resource allocation for industrial solid waste treatment centers in cities of Anhui province, China. *Management of Environmental Quality: An International Journal, 30*(5), 1190–1202. https://doi.org/10.1108/MEQ-01-2019-0001