Parameswaran, A., Ranadewa, K.A.T.O., Rajini, P.A.D. and Jayanetti, J.K.D.D.T., 2024. State-of-the-art lean learning practices in construction: A case study in Sri Lanka. In: Sandanayake, Y.G., Waidyasekara, K.G.A.S., Ranadewa, K.A.T.O. and Chandanie, H. (eds). *Proceedings of the 12th World Construction Symposium*, 9-10 August 2024, Sri Lanka. pp. 947-960. DOI: https://doi.org/10.31705/WCS.2024.75. Available from: https://ciobwcs.com/papers/

# STATE-OF-THE-ART LEAN LEARNING PRACTICES IN CONSTRUCTION: A CASE STUDY IN SRI LANKA

**Agana Parameswaran[1], K.A.T.O. Ranadewa[2], P.A.D. Rajini[3] and J.K.D.D.T. Jayanetti[4]**

## *ABSTRACT*

*Integrating lean learning practices in construction is paramount for elevating project quality, thus bolstering industry competitiveness and sustainability. However, there exists a notable dearth of research addressing lean learning practices specifically within the Sri Lankan construction industry. Therefore, this study aims to investigate the state-of-the-art lean learning practices in the Sri Lankan construction industry. An interpretivism stance is adopted, and a qualitative research approach is used. A case study strategy was adopted, focusing on three large Sri Lankan contracting organisations selected through purposive sampling. Data was collected through semi-structured interviews with fifteen experienced individuals, and document reviews. The collected data was then analysed using code-based content analysis using NVivo 12. Different lean tools, including Last Planner System (LPS), Value Stream Mapping (VSM), and 5S, are presently being utilised in an ad-hoc manner within contracting organisations. Comprehensive lean learning practices, including regular training sessions, workshops, and hands-on exercises, were emphasised to translate theoretical lean concepts into practical knowledge. By identifying the ad-hoc nature of their implementation, the study shed light on the importance of structured lean learning initiatives tailored to different organisational levels. It is recommended to implement clear communication channels, ongoing training, and a culture of continuous improvement for sustaining lean transformation in the Sri Lankan construction industry. By focusing on lean learning practices, the topic acknowledges the continuous improvement aspect of lean construction, emphasising the need for ongoing education and skill development within construction teams. This study has the potential to contribute valuable insights to both academia and industry practitioners seeking to enhance efficiency, quality, and sustainability in construction projects.*

***Keywords:*** *Construction Industry; Lean Construction; Lean Learning; Lean Tool; Sri Lanka.*

## 1. INTRODUCTION

[1] PhD Scholar, School of Engineering, Design and Built Environment, Western Sydney University, Australia, aganaparameswaran@gmail.com
[2] Senior Lecturer, Department of Building Economics, University of Moratuwa, Sri Lanka, tharushar@uom.lk
[3] Lecturer, Department of Facilities Management, University of Moratuwa, Sri Lanka, damithar@uom.lk
[4] Lecturer, Department of Quantity Surveying, General Sir John Kotelawala Defence University, Sri Lanka, qsthamasha@gmail.com

Lean construction is the outcome of a new type of production management being applied to the construction industry. As Aziz and Hafez (2013) outlined, key elements of lean construction include establishing clear delivery process objectives to enhance client performance at the project level, implementing production control throughout the product lifecycle from design to delivery, and integrating concurrent product and process design. On the other hand, Albalkhy and Sweis (2021) defined lean construction as a philosophy that focuses on improving collaboration among all project-relevant stakeholders to increase value for the client. Accordingly, Asri and Nawi (2015) explored that through lean construction, lean thinking was also introduced into the construction industry. Further, the implementation and adaption of the fundamental principles, and concepts of the Toyota Production System (TPS), which had been already established in the 1950s to create a new approach for managing construction projects, is referred to as lean construction (Al-aomar, 2012; Albalkhy & Sweis, 2021; Sacks et al., 2010). Moreover, Oey and Lim (2021) underlined since its introduction in the early 1990s, lean construction has drawn many firms to incorporate it into their construction business processes. Koskela (1992; 2020) presents construction as a manufacturing process, describing the construction process as a flow of information and material, transformation, and value creation. Furthermore, Koskela who created the Transformation Flow View philosophy of production on the construction was a pioneer of lean construction (Ogunbiyi et al., 2014). Consequently, Mostafa et al. (2016) findings confirmed new production philosophies may be adopted and transferred to handle construction project processes. While numerous tools and principles from the TPS are applicable in construction, there are specific principles and techniques within lean construction that are underutilised (Sacks et al., 2010).

Tezel and Nielsen (2013) listed government studies, institutes, construction management researchers, certain occupational organisations, and practitioners who have all promoted and studied the lean construction idea since the beginning of the 1990s. Subsequently, the International Group for Lean Construction and the United States Lean Construction Institute are the two most significant organisations dedicated to the promotion of lean concepts in the construction sector (Salem et al., 2005; Tezel & Nielsen, 2013). Moreover, lean construction has been implemented with considerable benefits in countries construction industries all over the world including Sri Lanka (Ranadewa et al., 2021). Several researchers have highlighted that lean construction is an approach, which can be used to maximise value, minimise waste, reduce costs, balance the resources, and deliver projects on time in Sri Lanka (Uhanovita et al., 2023).

Nevertheless, to gain the advantages of lean practices in the construction sector, researchers emphasise the importance of embracing lean learning concepts for the successful implementation of construction projects (Parameswaran et al., 2024; Parameswaran & Ranadewa, 2023). Before integrating lean learning into construction organisations to effectively adopt lean principles in this sector, it is essential to address key research questions such as identifying the lean tools utilised in construction and understanding the lean learning practices specifically within the Sri Lankan construction industry. Numerous studies have explored the application of lean principles and practices, the implementation of lean tools, the benefits of lean, challenges in implementing lean, lean culture, and related topics within the construction industry in Sri Lanka (Ranadewa et al., 2021; Uhanovita et al., 2023). However, there is a lack of research on lean learning practices in Sri Lankan construction (Parameswaran et al., 2024; Parameswaran &

Ranadewa, 2023) Therefore, this study aims to investigate the state-of-the-art lean learning practices in the Sri Lankan construction industry. This paper commences with a literature review on lean learning practices in construction, followed by a discussion of the methodology employed. The research outcomes are then presented, focusing on the lean tools implemented in the construction industry and detailing the specific lean learning practices observed in Sri Lanka's construction sector.

# 2. LITERATURE REVIEW

## 2.1 LEAN LEARNING PRACTICES IN THE CONSTRUCTION INDUSTRY

The transition to lean construction also necessitates increased support and awareness of lean construction knowledge. Since lean construction is still considered a relatively new concept, it is often absent from the curricula of most educational programs. Encouraging labour participation in the adoption of lean construction entails supporting their education and training, as well as integrating them into the mindset transformation process. (Albalkhy & Sweis, 2021). Further, Pasquire and Court (2013) stresses that knowledge management is a critical component of lean construction's success. Even though understanding every element of the project is impractical, all stakeholders must have a holistic picture of the entire (Mano et al., 2021). Mano et al. (2021) recognised this is achieved mainly by communication among the different parties involved, and that necessitates extra effort on the part of everyone engaged to comprehend the changes that will influence their job as a result of the implementation of lean management. The firm used the strength of "experience-based learning" to facilitate the integration of lean practices and the related culture shift. This approach enabled site managers and workers to personally experience the benefits, utilising "learning-by-doing" to effectively implement the concept of lean construction principles (Bygballe, 2014; Ranadewa et al., 2021). Five steps of learning processes were identified in Figure .


*Figure 1: Five steps of learning processes*
*Source: (Freitas & Heineck, 2012)*

In the construction industry, the SECI (socialisation, externalisation, combination, internalisation) model provides a connection between lean construction approaches and knowledge management (Zhang & Chen, 2016). In addition, Brioso (2015) established through lectures, discussion sessions, and workshops, the training course offered knowledge of the lean construction method and principles. Further, simulation (Neeraj et al., 2016), the game with computer simulation (Biotto et al., 2021), and digital solutions (Cisterna et al., 2021) provide the learning environment as it is simpler to comprehend the operation of an actual system under real-time settings. Furthermore, before commencing the deployment, establish a robust knowledge base among company leaders since, as managers gain experience with lean construction, being aware of successful instances as well as the challenges that may occur during deployment, they will be able to commit and support the project and also well prepared to carry out the change (Mano et al., 2021). However, owing to the influence of COVID-19, traditional educational models needed to be adapted to meet societal needs through lean simulations powered by digitalisation (Cisterna et al., 2021). Even though, Deshpande and Huang (2011) revealed

there are numerous reasons why games with computer simulation should not be used: a lack of understanding of simulation technologies' capabilities, acquiring the required resources is challenging, and the incapacity of the instructor to employ the latest technologies. Moreover, a lean construction coach, consultant, trainer, or teacher, the facilitator must have the following qualifications shown in Figure .

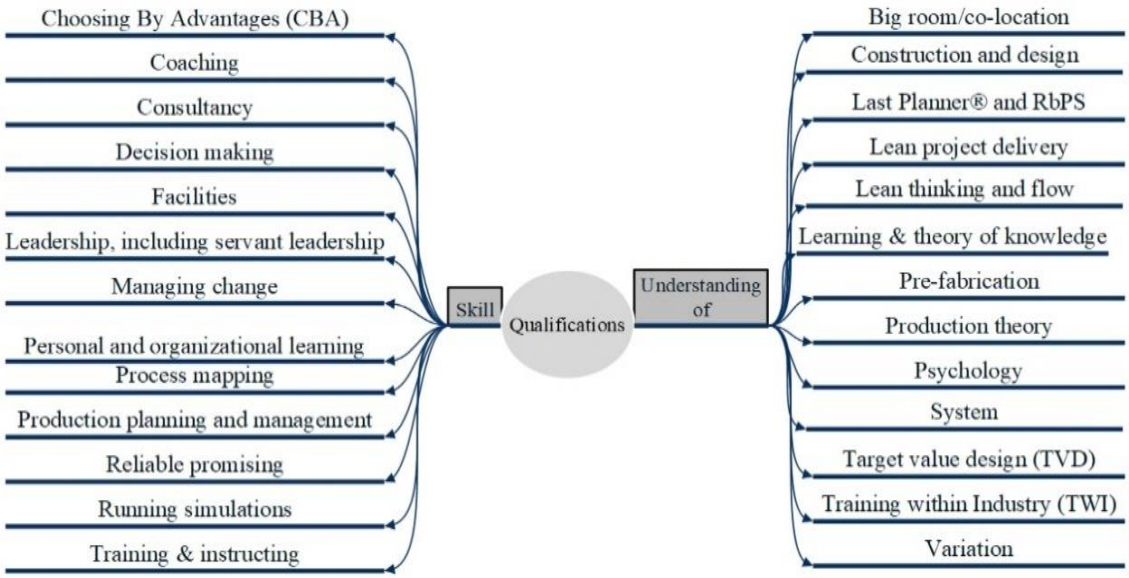


*Figure 2: Qualifications of a lean construction coach*
*Source: Adapted from Mossman (2015)*

A lean transformation for success in design, construction, or facilities management requires a coach with the appropriate skills and knowledge, as shown in Figure . Mossman (2015) highlighted those owners, clients, designers, constructors, and consultancy, along with educational institutions like universities and colleges, seeking to engage lean leaders, coaches, facilitators, instructors, trainers, or consultants are inclined to select individuals who demonstrate evidence of practical application across a diverse spectrum of skills, knowledge, and experiences. Furthermore, they value candidates who exhibit an ongoing commitment to learning and professional development.

## 3. RESEARCH METHODOLOGY

This research aimed to investigate and analyse the implementation of lean learning practices within the Sri Lankan construction industry. A thorough literature review was conducted to establish a theoretical background. To gain diverse perspectives from experts regarding lean learning practices in the Sri Lankan context, the study emphasised and valued the exchange of ideas, opinions, perceptions, and experiences within the research environment, recognising human interaction as pivotal to the study (Altheide & Johnson, 2011). Therefore, the research aligns with an interpretivism stance. A case study offers researchers a comprehensive understanding of a specific phenomenon or sequence of events by integrating various sources of evidence (Noor, 2008). It provides a complete picture and can effectively capture the dynamic nature of organisational life, particularly in rapidly evolving environments. Moreover, Noor (2008) stated that it enables the exploration of emergent properties and the fluctuating patterns of organisational activities. Therefore, the research strategy employed in this study was a 'case study strategy' focused on analysing lean learning practices within the Sri Lankan construction

industry. Through the examination of multiple cases, generalisations can be drawn, enhancing the potential for findings to be replicated (Verschuren, 2003). Specifically, case studies were carried out in three large-scale Sri Lankan contracting organisations (CA.1, CA.2, & CA.3), each involving five interviews (R1 to R15), document reviews and observations. Consequently, each case involved conducting five interviews with various experts from different organisational levels, all experts in lean principles and lean learning methodologies within the organisation. All three cases were Sri Lanka's leading construction companies that had the highest grade according to Construction Industry Development Authority (CIDA) registration. Further, these three cases were chosen for this investigation through purposive sampling. Although these organisations are large-scale, they operate across various sectors within the construction industry. Further, semi-structured interviews were conducted with three cases, each consisting of five interviewees selected through purposive sampling. Purposive sampling is known for its effectiveness in identifying suitable respondents and selecting subject matter experts for research (Tongco, 2007). Purposive sampling is widely employed in qualitative research to select and identify information-rich cases. It allows researchers to efficiently utilise limited resources and enhance the depth of understanding within the study (Campbell et al., 2020). The selection criteria for the sample were based on years of experience and expertise in lean construction principles. The profile of the case study contracting organisations is summarised in following Table 1.

*Table 1: The profile of the case study contracting organisations.*

| | **Case one – CA.1** | **Case two – CA.2** | **Case three – CA.3** |
|---|---|---|---|
| Certifications | ISO 9001:2015, ISO 14001:2015, & ISO 45001:2018. | ISO 9001, 18001, & 14001 | ISO 9001:2015, ISO 14001:2015, & BS OHSAS 18001: 2007. |
| Respondents | R1 to R5 | R6 to R10 | R11 to R15 |
| Description | There is a department called Training & Development in this organisation that is dedicated to providing chances for continual learning, career advancement, and personal improvement for all employees. Furthermore, supervisory skills development, management training programs, and continuous professional development (CPD) programs are also part of our training and development activities. | The board of directors' chairman was at the top of the organisation's hierarchy. Following that, the CEO (Chief Executive Officer) reports to the chairmen. Thereafter, six directors are in charge of several functional units such as Designs and Estimates, Roads and Bridges, Plant & Equipment or International Division, Project Division, administration division HR (Human Resources) and administration, IT (Information Technology), and compliance, and finance division. | This organisation is led by the Chairman, who is the organisation's senior management. Following that, the Managing Director. Thereafter, the Leasing, Mechanical, Quantity Surveying, Tendering division, as well Designs division and Ready-mix Batching Plant division of the organisation, have two Executive Directors in charge. Nevertheless, the organisation contained various departments led by the Deputy General Manager (DGM), including Finance, Projects, Specialised Services, Asset Management, HR and Administration, and others. |

The interviews were limited to fifteen respondents due to data saturation, ensuring insights from experienced individuals with over ten years of industry experience and knowledge of lean construction. The interviews were conducted at different levels of the organisation, including project and head office levels, to understand lean learning practices comprehensively. If there was a designated individual responsible for lean learning within the organisation, they were also interviewed. The data collected from these interviews underwent code-based content analysis using NVivo 12. NVivo 12 facilitated the organisation, exploration, and acceleration of the data analysis process, particularly beneficial for handling unstructured data (Dalkin et al., 2021).

# 4. RESEARCH FINDINGS

## 4.1 LEAN TOOLS IMPLEMENTED IN THE CASE STUDY ORGANISATIONS

The first question in the interview guideline part two was regarding lean construction opinions. As a result, every respondent expressed their thoughts on lean construction in the way they understood it. The key term chosen by the respondents when defining lean construction was "decrease non-value-adding activities". Further, the phrase "manage the project efficiently" was used by a few more respondents. According to the respondents' opinions, lean construction may be defined as "the elimination of non-value-adding activities and maximisation of value-adding activities throughout the project to accomplish the target and manage the project effectively". Furthermore, in section two, the question was framed to discover the lean techniques used in this organisation. Figure presents all recognised existing lean tools in the organisations.

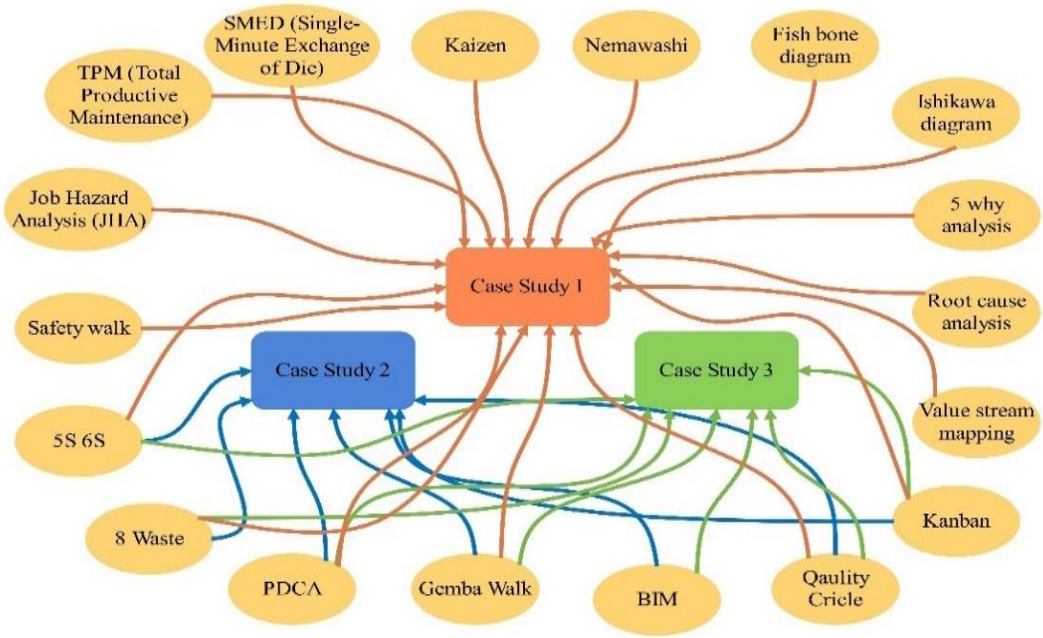


*Figure 3: Lean tools implemented in the case study organisations.*

All the respondents indicated that there have been many lean practices in the organisation, which are practised in an ad-hoc manner. Subsequently, R2, R9, and R15 also stated that "the quality management system contains several lean approaches such as 5S, Plan–Do–Check–Act (PDCA), and quality circle as a result of the organisation's adaptation of the

ISO standard". Since R2 has worked in the manufacturing industry, he has emphasised most of the lean tools with practical examples.

## 4.2 LEAN LEARNING PRACTICES IN THE SRI LANKAN CONSTRUCTION INDUSTRY

Reviewing the lean learning practices in the Sri Lankan construction industry is one of the research objectives. However, the major question in section two was to determine the organisation's lean learning procedures, since several lean learning processes have been discovered in the construction industry, according to literature findings. Therefore, lean learning practices in the Sri Lankan construction industry have been recognised, through empirical investigation.

To enhance lean implementation in the organisation, all the respondents anonymously agreed that adequate lean learning is essential. Furthermore, R4 noted, "*The Lean Learning Program is significant since individuals are not that knowledgeable in theory. However, when it comes to lean construction, everyone should be aware of it, including the labourers. For example, when it comes to not wasting cement, even labourers are aware of this. As a result, those kinds of extremely systematic theoretical jargon must be translated into practical language acceptable for construction workers. Let's assume engineers or the project management can handle half of the task, while the other half is handled by construction workers. Therefore, if they do not even know what they are attempting to achieve. Whatever effort you put forth will be worthless. That is a circumstance in which proper learning should be provided*". Furthermore, all respondents mentioned sufficient knowledge and awareness are required; otherwise, waste would grow. As a result, there should always be a proper learning procedure in place.

According to CA.1.R1, they highlighted that there have been a lot of lean practices in the organisation, however not under the label of lean. Furthermore, the Training & Development department, as the main custodian, and the Activity Centre, as the project leader, are both jointly responsible and actively work together to accomplish the lean practices throughout the organisation. Additionally, R2, R3, R4, and R5 stated that the project manager is responsible for lean learning at the project or site level.

Moreover, R4 emphasised that *"When considering lean learning procedure, generally continuing training sessions like monthly or type of regular training session, that is how inside our organisation applying that kind of theory, thus lean is there, nevertheless they are coming up and demonstrating them with the practical word".* Despite this, the training department conducts an annual training session with the consent of top management. Therefore, in December, the training department will finalise all training needs by negotiating with the site, and then they will meet with the steering committee with senior management. Thereafter, publish what type of training is needed for the coming year include lean in this as well. Following that, multiple segments exist, with project managers being the first, followed by project engineers, quantity surveyors, and finally supervisors and foremen. Furthermore, certain individuals verbally encourage workers to execute or implement procedures. This suggests that labourers' competence is accountable to the project manager and the entire team, as they are required to learn, necessitating education for the workers. Therefore, for example, shop floor workers will be trained by the Supervisor, gang leader, or technical officers who are mostly on the site mostly through verbally and occasionally prepare a small instruction manual that they may retain in their hands. Finally, while not exactly a lean tool, they were taught to use it

with similar terminologies, such as minimising waste, project management, and others. Consequently, when it comes to the organisation level, training is managed in a variety of departments, as well as different sectors such as construction, road, water, and others. Accordingly, the organisation has a variety of departments, and they are always striving to get the maximum benefit from it.

Similarly, R5 remarked that this training would take place individually for different levels of individuals since their understanding level, knowledge, and expectations fluctuate depending on their level. Therefore, supervisors and top management personnel provide knowledge to labourers in regular practice. Further, the training took place alone in a training room. Thus, the practical or continuing procedure that the project manager and team will undertake. In addition to that, usually undertake in-house training through the training department. Training takes the form of a presentation, and all of these experts may be from a university or another institution. Further, they are giving their lectures by several well-known professionals.

However, R3 indicated that *"before commencing activities, they should have a specific or site meeting with a quality engineer and a technical engineer to explain to the workers what we expect as an outcome and how to achieve it using lean procedures. Likewise, within the site, come together every day and share our knowledge on any difficulty facing and how to improve the product. Workers are briefed daily in the morning meeting. Every day, after the briefing, only sending the people to work, during this time not directly advising about the lean, informing about the concept of whatever you want to do, whatever don't want to do, what is the problem facing, how to solve that one, everything to improve the process or improve the product or output".* Additionally, R2 stated that rather than training sessions, project managers at the site level and the training department at the corporate level have incorporated CPD or any other sessions linked to lean concepts, published by professional institutions. Moreover, they send their selective employees and obtain individual knowledge updates on lean and its procedures. Thereafter, they will share their expertise in meetings, discussions, spot meetings, and presentations.

CA.2.R6 emphasised that there have been a lot of lean practices in the organisation, not under the term lean. In addition, R9 identified the Divisional Head or Project Manager as the primary custodian of lean learning. Even though a lean implementation for an organisation requires training needs should be addressed at the project or division level. There are numerous tools in lean, and the designated lean training-related division will start the training program at the head office and the project level. The Compliance section will handle any recognised lean training that is connected to quality, safety, or the environment, such as 5S, PDCA, Gemba Walk, quality circle, and others. The training will be conducted by either the head Office Compliance Division, which has a different manager for each discipline, or the Project Quality Assurance Engineer, or the Project Safety Officer, depending on the severity of the training required. Further, it necessitates a high level of attention or gravity, which will be handled by the Chief of the Compliance Division, who will be engaged in this training. On the other hand, Minor site improvements, or "regular" improvements, imply that there are requirements. For example, site worker productivity and efficiency will be improved by lean training provided by project staff, such as a quality assurance engineer, a site health and safety environment officer, a site planning engineer, or a project manager. Furthermore, conducted physical training at the head office, and project-level staff were forced to come

to the head office. It is not the complete team. The project management, namely the project manager, chooses who will attend this training and who will gain knowledge from it. Thereafter, returned to the project, conducting another project-wide awareness training. Moreover, depending on the scenario, they may be required to attend training for their specific project.

Further, there is a meeting room or conference room for every project. At the project site, a PowerPoint presentation or awareness or training will be given, it is situational. For example, some things cannot be done in the conference room and others cannot be done on the site. Moreover, labourers are sometimes asked to come to the conference room or project meeting room, and in certain cases, they are given physical training in the project at specific sites where they work. Subsequently, site workers receive training in groups. As an example, to deliver quality-related lean training to a block work worker, have to notify them that this is the desired quality, this is the requirement, this is how the process will be carried out, and these are the standards that we must follow. Thereafter, go to the conference room with the targeted group and have a conversation or an awareness session. Likewise, to provide a common training or awareness presentation, have a meeting every Tuesday morning or a toolbox meeting before starting work. This meeting may include training provided by the project manager, individuals from the head division, or experts from the outside, depending on the circumstances. Similarly, R7 stated, "*The project noticed that they needed to improve their BIM skills as the client requested it. They had outsourced Trained officers instructing them in handling BIM at the head office; in this example, the head office Design team conducted the training for three months. Once a week to draft persons and engineers at the site level, and to design teams at the head office level".*

Even though R10 recognised the need for training on some lean tools, and there is a well-trained officer within the division who can handle the lean tool very well, therefore the division head can arrange training for other officers with the help of that specifically trained officer, and if that person also needs to improve his knowledge, the division head can request that the training be done by an outside party. Alternatively, the Divisional Manager or Project Manager knows of a specific party, an external party, who is qualified to do this training. For that, notify HR and administration that require this training, and this external entity is capable of providing it. As well as ready to get this training from these individuals, with HR and administration making the appropriate preparations to send this training to that specific project or division. In addition to training, R8 underlined that the lean concept has been incorporated into the organisation through CPD. The sessions were organised by a project manager or divisional head as an internal committee, with participants ranging from top management to site engineers from each project. However, the number of participants is determined by the program type. After gaining knowledge, the project manager or engineer or any other staff who attended and gained knowledge should share their knowledge and information with their subordinates through small pocket meetings.

Further, R9 specified that lean training needs related to the project are recognised by the HR division, notify and request that the appropriate department or project conduct this type of awareness. Similarly, emphasise that it would be preferable if some training could be arranged for this project to develop this component of the process. On the other hand, the HR department may receive external training at any time, and they will be notified of

relevant projects, such as receiving information from this external party regarding this training program and asked to suggest eligible officers for this training to arrange training.

CA.2.R13 explained that *"Lean practices there, however, do not act this as a concept of lean, diverse ways that are in accordance with lean concept or practice*". R11 further recognised the HR department or the Project Manager as the organisation's principal custodian of lean learning. R12 reportedly revealed that employees have been sent to CPD and any other external courses linked to the lean concept through the HR department. After receiving the invitation for these programs, the HR department informs the appropriate department or project that this program is required. Further, selected workers were invited to participate in this program and were chosen by the divisional head under division and the project manager at the project level.

Additionally, R15 indicated that though the organisation implements a quality management system, continual improvement is possible for lean principles. This quality management system adheres to ISO standards and incorporates lean techniques such as 5S, PDCA, and others. As a result, training programmes and improvement for the lean concept are available throughout the organisation, which is linked to the quality management system. Nevertheless, the HR department is in charge of this training, with the help of the quality assurance department. The project engineer and quality engineer will work with them to give suitable training at the project level. The quality assurance department will provide this training regularly to the organisation's employees. Additionally, in certain cases, the HR division will contract with an outside party to give training to the organisation's employees. Consequently, this training will take place at the head office or a relevant project location. Furthermore, the head office and project-level senior management staff attended the training program. Following that, the project manager or quality engineer will provide the training on-site at a site meeting for the rest of the staff. Thereafter, it will be trained to labourers by the supervisor or project staff at a morning meeting or on the worksite. The quality assurance department and quality engineer on-site assess whether this concept is being implemented properly or not.

On the other hand, R14 emphasised that rather than quality-related lean tools, staff would acquire other common tools as contrasted with following the usual method. It does not implement it as a separate concept as it is part of the work. Moreover, it practices routine work. It means that practice it in general work, rather than doing it separately as a separate concept. It simply means that it is in normal project management tasks. Further, there are a few concepts that have been incorporated into the typical working procedure. Apart from the fact that this has not been established as a separate procedure, the project manager has no specific responsibilities in this area. The project manager is used to working, and his routine includes certain lean elements. According to their experience, the project manager and top-level people are knowledgeable of it; they will implement it and share their expertise with others through regular site practices; low-level individuals will implement it. There is no special training; rather, it is a common procedure that is based on the project manager's expertise and knowledge.

# 5. DISCUSSION

Rosli et al. (2023) stated that lean construction involves establishing clear priorities during the delivery process, with a focus on improving customer efficiency at the project level. This includes aligning product and process design and implementing production

management across the product's lifecycle, from design to delivery. Further, Koskela (2020) highlighted that the goal of lean construction is to complete projects by enhancing value, minimising waste, and striving for perfection. Similarly, a study revealed that lean construction is defined as the process of eliminating non-value-adding activities and maximising value-adding activities throughout the project. Tezel et al. (2018) have highlighted the most often used lean tools in the construction industry, including Last Planner System (LPS), Value Stream Mapping (VSM), visual Management, Poka-Yoke, 5S, Just in Time (JIT), Kanban, supply chain integration, Jidoka, PDCA, and others. However, all respondents noted the presence of numerous lean practices within the organisation, yet they are implemented in an ad-hoc manner. Furthermore, the study revealed that as a result of the organisation's adoption of the ISO standard, its quality management system incorporates several lean approaches, including 5S, PDCA, and quality circles. The findings point out the significance of proper training and awareness across all levels of the organisation, from top management to labourers. Likewise, Albalkhy and Sweis (2021) underlined that encouraging labour participation in the adoption of lean construction entails supporting their education and training, as well as integrating them into the mindset transformation process. In addition to that, the study underscored the importance of structured training sessions organised by internal departments or external experts and further highlighted a more informal sharing of knowledge through routine site practices and interactions. Also, Bygballe (2014) and Ranadewa et al. (2021) point out that the firm used the strength of "experience-based learning" to help with the adoption of lean and the related culture shift, allowing site managers and workers to experience the benefits personally, and "learning-by-doing" is used to transform and translate the concept of lean construction. The study highlighted the necessity for ongoing improvement and the integration of lean practices to boost efficiency and minimise waste. Accordingly, the finding reveals that successful lean implementation depends on educating a culture of continuous improvement and ensuring that employees receive the essential training, support and resources to enhance their skills and knowledge in lean practices. Most of the existing lean learning practices research has focused on educational institutions rather than their application within construction projects or organisations (Rybkowski et al., 2018). As a result, there is a notable gap in investigating lean learning practices specifically within the Sri Lankan construction industry. Therefore, this study fills this gap by being the first to investigate lean learning practices in Sri Lankan construction.

## 6. CONCLUSIONS

This research aimed to investigate the state-of-the-art lean learning practices in the Sri Lankan construction industry. This is the first research to uncover lean learning practices in the Sri Lankan construction industry. Accordingly, the study revealed that lean construction is perceived as a strategic approach aimed at enhancing project efficiency by minimising non-value-adding activities and optimising value-adding activities throughout the project lifecycle. Further, the implementation of lean tools within the investigated organisations is notable, with respondents recognising various lean methodologies such as LPS, VSM, visual management, Poka-Yoke, 5S, JIT, Kanban systems, and others. Despite not always being labelled explicitly as "lean," these tools are employed to improve quality, productivity, and overall project performance. Furthermore, the study underscores the critical role of lean learning practices in fostering successful lean adoption within Sri Lankan construction firms. Respondents emphasised

the importance of comprehensive training programs tailored to different organisational levels, from top management to site workers. Training initiatives encompass a variety of formats, including regular sessions, workshops, presentations, and hands-on exercises, designed to translate theoretical lean concepts into practical knowledge applicable to daily construction tasks. The organisational structure for lean learning is also remarkable, with departments responsible for overseeing lean initiatives, ensuring continuous improvement, and aligning practices with quality management systems, for example, ISO standards. This structured approach reflects a commitment to embedding lean principles into organisational culture and operations. While lean practices are being implemented, there is scope to enhance awareness and engagement across all levels of the organisation. Clear communication, ongoing training, and a culture of continuous improvement are essential to sustain lean transformation and drive clear benefits in terms of efficiency, waste reduction, and project outcomes.

This study addresses the growing importance of lean practices in the construction industry, particularly in the context of Sri Lanka, where the construction sector is experiencing rapid development and faces unique challenges. By focusing on lean learning practices, the topic acknowledges the continuous improvement aspect of lean methodologies, emphasising the need for ongoing education and skill development within construction teams. Additionally, the inclusion of a case study in Sri Lanka provides a specific and contextualised examination of how lean principles are being implemented and their impact on construction projects in the country. Overall, this study has the potential to contribute valuable insights to both academia and industry practitioners seeking to enhance efficiency, quality, and sustainability in construction projects. Further, the study provides the knowledge base by providing insights into the current state-of-the-art lean practices and learning initiatives in the Sri Lankan construction industry. Moreover, the study revealed the range of lean tools employed by organisations, their practical application and their impact on project performance. This study provides valuable insights for policymakers, particularly CIDA and relevant ministries, to enhance lean practices through structured training programs and lean awareness initiatives in the construction industry. Moreover, further research directions could delve into exploring the impact of technology and digitalisation on enhancing lean learning and implementation practices within the construction organisation. Additionally, data collection was restricted to three construction organisations that have adopted lean construction practices.

# 7. REFERENCES

Al-aomar, R. (2012). Analysis of lean construction practices at Abu Dhabi construction industry. *Lean Construction Journal*, 105–121. Retrieved from https://leanconstruction.org/wp-content/uploads/2022/08/LCJ_12_006.pdf

Albalkhy, W., & Sweis, R. (2021). Barriers to adopting lean construction in the construction industry: A literature review. *International Journal of Lean Six Sigma*, *12*(2), 210–236. https://doi.org/10.1108/IJLSS-12-2018-0144

Asri, M. A. N., & Nawi, M. N. M. (2015). Actualizing lean construction: Barriers toward the implementation. *Advances in Environmental Biology*, *9*(5), 172–174. https://doi.org/10.1108/IJLSS-12-2018-0144

Aziz, R. F., & Hafez, S. M. (2013). Applying lean thinking in construction and performance improvement. *Alexandria Engineering Journal, 52*(4), 679–695. https://doi.org/10.1016/j.aej.2013.04.008

Biotto, C. N., Herrera, R. F., Salazar, L. A., Pérez, C. T., Luna, R. M., Rodrigheri, P. M., & Serra, S. M. B. (2021). Virtual parade game for lean teaching and learning in students from Brazil and Chile. Proc.

*29th Annual Conference of the International Group for Lean Construction (*pp. 340–349). doi.org/10.24928/2021/0203

Brioso, X. (2015). Teaching lean construction: Pontifical catholic university of Peru training course in lean project & construction management. *Procedia Engineering*, 123, 85–93. Retrieved from https://doi.org/10.1016/j.proeng.2015.10.062

Bygballe, L. E. (2014). Implementing lean construction: a practice perspective. *Proceedings 22nd Annual Conference of the International Group for Lean Construction* (pp. 3–14). https://iglc.net/papers/Details/1022

Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., Bywaters, D. and Walker, K. (2020), "Purposive sampling: complex or simple? Research case examples", *Journal of Research in Nursing*, *25*(8), 652-661. doi: 10.1177/1744987120927206.

Cisterna, D., Hergl, M., Oprach, S., & Haghsheno, S. (2021). Digitalization of lean learning simulations: teaching lean principles and last planner® system. In L. F. Alarcon & V.González (Eds.), *Proc. 29th Annual Conference of the International Group for Lean Construction* (pp. 279–288). doi.org/10.24928/2021/0136

Dalkin, S., Forster, N., Hodgson, P., Lhussier, M., & Carr, S. M. (2021). Using computer assisted qualitative data analysis software (CAQDAS; NVivo) to assist in the complex process of realist theory generation, refinement and testing. I*nternational Journal of Social Research Methodology*, *24*(1), 123-134. https://doi.org/10.1080/13645579.2020.1803528

Deshpande, A. A., & Huang, S. H. (2011). Simulation games in engineering education: A state-of-the-art review. C*omputer Applications in Engineering Education, 19*(3), 399–410. https://doi.org/10.1002/cae.20323

Freitas, A. A. F. De, & Heineck, L. F. M. (2012). Technological capability: Evidence from building companies in a lean learning environment. *20th Annual Conference of the International Group for Lean Construction.* Retrieved from https://www.iglc.net/Papers/Details/771

Koskela, L. (1992). *Application of the new production philosophy to construction*. Retrieved from https://www.researchgate.net/profile/Lauri-Koskela-2/publication/243781224_Application_of_the_New_Production_Philosophy_to_Construction/links/5bcd97a792851cae21b8dd9a/Application-of-the-New-Production-Philosophy-to-Construction.pdf

Koskela, L. (2020). *"Theory of lean construction", in lean construction: Core concepts and new frontiers* (1st edition). Routledge. Retrieved from https://www.taylorfrancis.com/chapters/edit/10.1201/9780429203732-1/theory-lean-construction-lauri-koskela

Mano, A. P., Costa, S. E. G. da, & Lima, E. P. de. (2021). Criticality assessment of the barriers to lean construction. *International Journal of Productivity and Performance Management*, *70*(1), 65–86. https://doi.org/10.1108/IJPPM-11-2018-0413

Mhetre, K., Konnur, B. A., & Landage, A. B. (2016). Risk Management in Construction Industry. *International Journal of Engineering Research*, 5(1), 153–155. doi: 10.17950/ijer/v5i1/035

Mossman, A. (2015). Bringing lean construction to life: Developing leaders, consultants, coaches, facilitators, trainers & instructors. *Proceedings of 23rd Annual Conference of the International Group for Lean Construction* (pp. 413–423). Retrieved from https://www.iglc.net/papers/details/1176

Mostafa, S., Chileshe, N., & Abdelhamid, T. (2016). Lean and agile integration within offsite construction using discrete event simulation: A systematic literature review. *Construction Innovation*, *16*(4), 483–525. https://doi.org/10.1108/CI-09-2014-0043

Noor, K. B. M. (2008). Case study: A strategic research methodology. *American journal of applied sciences*, *5*(11), 1602-1604.

Neeraj, A., Rybkowski, Z. K., Fernández-Solís, J. L., Hill, R. C., Tsao, C., Seed, B., & Heinemeier, D. (2016). Framework linking lean simulations to their applications on construction projects. *IGLC 2016 - 24th Annual Conference of the International Group for Lean Construction* (pp. 3–12). Retrieved from https://iglc.net/Papers/Details/1295

Oey, E., & Lim, J. (2021). Challenges and action plans in construction sector owing to COVID-19 pandemic – a case in Indonesia real estates. *International Journal of Lean Six Sigma*, *12*(4), 835-858. https://doi.org/10.1108/IJLSS-09-2020-0149

Ogunbiyi, O., Goulding, J. S., & Oladapo, A. (2014). An empirical study of the impact of lean construction techniques on sustainable construction in the UK. *Construction Innovation, 14*(1), 88–107. https://doi.org/10.1108/CI-08-2012-0045

Parameswaran, A., & Ranadewa, K. A. T. O. (2023). Learning-to-learn sand cone model integrated lean learning framework for construction industry. *Smart and Sustainable Built Environment,* 13*(4)* , 852-886. https://doi.org/10.1108/SASBE-10-2022-0234.

Parameswaran, A., Ranadewa, K. A. T. O., & Rathnasinghe, A. P. (2024). Roles of lean learners for successful lean implementation in the construction industry: a force-directed graph. *International Journal of Productivity and Performance Management*. Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/IJPPM-07-2023-0346

Pasquire, C., & Court, P. (2013). An exploration of knowledge and understanding - The eighth flow. *21st Annual Conference of the International Group for Lean Construction 2013* (pp. 944–953). Retrieved from https://iglc.net/Papers/Details/938

Ranadewa, K. A. T. O., Y.G. Sandanayake, Y. G. S., & Siriwardena, M. (2021). Enabling lean through human capacity building: An investigation of small and medium contractors. *Built Environment Project and Asset Managemen*t, 11(4), 594-610. https://doi.org/https://doi.org/10.1108/BEPAM-03-2020-0045

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

Rybkowski, Z.K., Forbes, L.H. and Tsao, C. (2018), "The evolution of lean construction education (part 1 of 2): at US-based universities", in Gonzalez, V.A. (Ed.), *26th Annual Conference of the International. Group for Lean Construction,* Chennai, India, (pp. 1013-1023). doi: 10.24928/2018/0447

Sacks, R., Koskela, L., Dave, B. A., & Owen, R. (2010). The Interaction of Lean and Building Information Modeling in Construction. *Journal of Construction Engineering and Management, 136*(9), 1–29. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000203

Salem, O., Solomon, J., Genaidy, A., & Luegring, M. (2005). Site implementation and assessment of lean construction techniques Work Performance Indicator Measurement for the Improvement of Productivity, Quality and Safety in the Workplace View project. *Lean Construction Journal,* 2(2), 1–21. www.leanconstructionjournal.org

Tezel, A., Koskela, L., & Aziz, Z. (2018). Lean thinking in the highways construction sector: motivation, implementation and barriers. *Production Planning & Control, 29*(3), 247–269. https://doi.org/10.1080/09537287.2017.1412522

Tezel, A., & Nielsen, Y. (2013). Lean Construction Conformance among Construction Contractors in Turkey. *Journal of Management in Engineering, 29*(3), 236–250. https://doi.org/10.1061/(asce)me.1943-5479.0000145

Tongco, M.D.C. (2007), "Purposive sampling as a tool for informant selection". *Ethnobotany Research and Applications*, 5, pp. 147-158, http://hdl.handle.net/10125/227

Uhanovita A.C., N., K.A.T.O., R. and Parameswaran, A. (2023), "Poka-Yoke to minimise variations: a framework for building projects", *Construction Innovation,* Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/CI-12-2022-0343

Verschuren, P. (2003). Case study as a research strategy: Some ambiguities and opportunities. *International journal of social research methodology*, *6*(2), 121-139. https://doi.org/10.1108/IJLSS-12-2018-0144

Zhang, L., & Chen, X. (2016). Role of Lean Tools in Supporting Knowledge Creation and Performance in Lean *Construction. Procedia Engineering, 145,* 1267–1274. https://doi.org/10.1016/j.proeng.2016.04.163