ROLES OF LEAN LEARNERS FOR SUCCESSFUL LEAN IMPLEMENTATION IN THE CONSTRUCTION INDUSTRY: A FORCE-DIRECTED GRAPH

ABSTRACT

Purpose: The proliferation of lean principles in the construction industry is offset by the enduring uncertainty among industry stakeholders regarding their respective roles in lean implementation. This uncertainty is further compounded by the scarcity of empirical investigations in this area. Consequently, this study undertakes the task of bridging this knowledge gap by identifying the critical roles of lean learners and their indispensable contributions to achieving successful lean implementation.

Methodology: A qualitative exploratory approach informed by an interpretivism perspective was adopted. The case study strategy was employed to gather data from three contracting organisations that had implemented lean practices. Empirical data was collected through in-depth semi-structured interviews with fifteen industry experts and complemented by document reviews. To analyse the data, a code-based content analysis approach was employed using NVivo software, while Power BI software was utilised to develop a comprehensive force-directed graph visualisation.

Findings: The research findings substantiated nine lean learners and unveiled a set of seventy-three roles associated with them. The force-directed graph facilitated the identification of lean learners and their connections to the emerged roles. Notably, the graph highlighted the pivotal role played by project managers and internal lean trainers in ensuring the success of lean implementation, surpassing the contributions of other lean learners.

Originality: The implications of findings extend to industry professionals seeking to establish a robust lean learning framework to expedite lean implementation within the construction sector. This study not only provides a comprehensive definition of lean learners roles but also transcends specific construction types, making it a significant catalyst for global impact.

Keywords: Construction industry; force-directed graph; Lean construction; Lean learners; Lean implementation; Roles.

1. INTRODUCTION

In the contemporary and competitive landscape of the construction industry, firms are increasingly prioritising productivity as a focal element of project success (Al-Abbadi and Agyekum-Mensah,

2022; Dixit *et al.,* 2019). Multiple studies underscore the notable challenge posed by low productivity within the construction sector (Adebowale and Agumba, 2023; Al-Abbadi and Agyekum-Mensah, 2022; Manoharan *et al.,* 2023). Furthermore, productivity is intricately entwined with performance, encompassing both the economic and operational dimensions of the industry (Pekuri et al., 2011; Manoharan *et al.,* 2023). Consequently, scholars have emphasised the incorporation of lean principles in construction, recognising its potential to optimise construction performance and uplift productivity throughout the project life cycle (Aziz and Hafez, 2013; Awad *et al*., 2023; Besklubova and Zhang, 2019; Noorzai, 2023). Sbiti *et al.* (2021) defined lean principles in construction as a production management approach that focuses on delivering high-quality construction projects on time and within budget. The objective of lean construction is to complete the project while increasing value, minimising waste, and striving for perfection (Koskela, 2020; Al-Aomar, 2012b). The critical dimensions of lean construction encompass the formation of clear priorities in the delivery process, focused on enhancing customer efficiency at the project level, aligning product and process design, and implementing production management throughout the product's lifecycle, spanning from design to delivery (Rosli *et al.,* 2023). These components assume a pivotal role in rationalising waste management within construction projects, thereby positively influencing project performance. Several studies have found that implementing lean construction in construction projects reduces project duration (Ahmed et al., 2021; Babalola et al., 2019), whole life cycle cost reduction (Albalkhy and Sweis, 2021; Bajjou and Chafi, 2018), project rework (Babalola et al., 2019; Parameswaran and Ranadewa, 2021), increase in the quality of the project (Akinradewo *et al*., 2018; Shaqour, 2022); increase the productivity (Rosli *et al*., 2023; Moradi and Sormunen, 2023), enhanced production control and planning (Sarhan *et al.*, 2017; Shaqour, 2022); increase project performance (Albalkhy and Sweis, 2021; Adegbembo *et al*., 2016); health and safety (Albalkhy and Sweis, 2021; Sarhan *et al*., 2017), better value for the employer (Ahmed *et al*., 2021; Shaqour, 2022); and improvement in labour performance (Ahmed *et al*., 2021; Bajjou and Chafi, 2018). However, several barriers have been identified to hinder the successful implementation of lean construction.

These barriers include the long duration for implementation (Al Balkhy *et al*., 2021; Mano *et al*., 2021), additional cost (Ahmed and Sobuz, 2020; Albalkhy and Sweis, 2021), human attitudes (Ahmed *et al*., 2021; Bajjou and Chafi, 2018), inadequate commitment and support from top

management (Khaba and Bhar, 2017; Sarhan *et al*., 2018), insufficient dedication to work in teams (Mano *et al*., 2021; Neeraj et al., 2016) and lack of knowledge (Ahmed and Sobuz, 2020; Al Balkhy *et al*., 2021). Among those barriers, most research revealed that lack of knowledge of lean construction is the most significant barrier for successful lean implementation (Ahmed *et al*., 2021; Al Balkhy *et al*., 2021; Ranadewa *et al.*, 2021; Albalkhy and Sweis, 2021; Mano *et al*., 2021). On the other hand, stakeholders of the construction industry are uncertain about their roles in facilitating lean construction (Ahmed *et al*., 2021; Ahmed and Sobuz, 2020; Bashir *et al*., 2015; Omran and Abdulrahim, 2015; Sarhan *et al.*, 2018). Hence, it is evident that most lean implementation barriers are rooted around the stakeholders' uncertainty about their roles in implementing lean construction. Therefore, it is alarming the need of identifying the stakeholders for lean implementation. Parameswaran & Ranadewa (2023) defined them as the lean learners and highlighted the need of defining their roles in construction project.

To successfully adopt lean in the construction sector, it is crucial to provide research-based answers to issues such as: who are the lean learners in the construction industry and what do they need to do to partake in the implementation of lean construction. Consequently, it emphasises the significance of defining the role of lean learners in implementing lean in the construction industry. Nevertheless, research can be found in the past concerning the role of lean learners in the manufacturing industry (Bateman *et al*., 2003) and education industry (Hirota *et al.*, 1999; Hirota and Formoso, 1998; Mossman, 2015; Pellicer and Ponz-Tienda, 2014; Rybkowski *et al.*, 2018), as well as lean learners in the construction industry (Parameswaran and Ranadewa, 2023). Despite this, research on the role of lean learners in the construction industry has turned up a paucity of data, and there is no dedicated study defining lean learners roles in the construction industry. Therefore, a comprehensive empirical study defining the role of lean learners in the construction sector is required to bridge this research gap. This study aims to delineate the roles of lean learners in the construction industry, with two primary objectives: identifying these learners and defining their roles. This study will be the first of its kind in the construction industry that addresses the knowledge gap regarding lean learners' roles. To accomplish this, the study began with a review of the literature on lean construction, followed by the application of lean construction concepts and tools, benefits and barriers to lean implementation, and lean learners and their roles. The methodology followed to attain the research aim is discussed in the next section. Finally, a force-

directed graph is presented to identify the lean learners and their responsibilities in the construction sector.

2. Literature review

This section reviews the literature on lean construction, the benefits of lean construction, barriers of lean construction, lean learners and their roles in successful lean implementation.

2.1.Lean Construction

Al-aomar (2012a) affirmed that the construction sector is prone to a lack of productivity, excessive expenditures, wastage, and delays. In addition, projects are seldom within the schedule, acceptable quality and on the budget the client accepts. Therefore, lean can be defined as a method to reduce the waste of time, effort, and materials to create the maximum value out of a product and its production process as possible (Koskela, 1992; Koskela, 2020). Bajjou *et al*. (2017) stated that lean construction is a new management technique for organising construction projects with minimum resources. Furthermore, lean construction is a method that aims to improve the management of the construction process to meet the customer's expectations (Tezel *et al*., 2020). Further, a lean project management approach endeavours to utilise innovative management methods and practices, restructuring organisational frameworks to enhance efficiency through a flatter hierarchical setup (Dabestani *et al.*, 2017). Eldeep *et al*. (2022) described how lean construction aims to remove and decrease waste in the construction process. Many lean principles have been identified by various authors for the construction industry (Aisheh *et al.*, 2021; Koskela, 1992; Sacks *et al*., 2010). Further, lean-related tools have been developed and effectively implemented for both complex and simple construction projects *(*Abdelhamid *et al.*, 2008; Aslam *et al.*, 2020; Eldeep *et al.*, 2022; Shaqour, 2022).

Furthermore, a novel paradigm, termed 'Green Lean,' has emerged, integrating lean principles with an emphasis on sustainability. This 'Green Lean' approach signifies an optimal balance, concurrently ensuring organisational profitability and prioritising environmental conservation. It presents a readily adoptable method for firms, highlighting the synergy between economic success and environmental responsibility (Chugani *et al*., 2017; Garza-Reyes, 2015). Alike, the application of lean and agile principles in humanitarian supply chains holds the potential to enhance their effectiveness and efficiency by concomitantly eliminating wasteful practices (Upadhyay *et al.*,

2020). While relatively recent in the industry, concepts like lean production and agile production, when employed to refine production systems and enhance performance, offer substantial advantages, notably reducing the cost of quality and ultimately benefiting end users (Shahin and Rezaei, 2018).

Over the past two decades, the persistent integration of lean practices and Six Sigma has also served as an ongoing management enhancement strategy within firms (De Silva *et al*., 2023; Mundra *et al*., 2021). The symbiosis of Lean Six Sigma (LSS) and sustainability contributes positively to the economic, social, and environmental performance of firms (De Silva *et al*., 2023; Cherrafi *et al.,* 2017). Additionally, Aghaei *et al.* (2023) assert that continuous process improvement stands as a universal objective for firms aiming to establish and maintain a competitive edge in the global market. Muhammad *et al.* (2022) note that the implementation of lean and LSS methodologies yields favourable outcomes for firms, enhancing key performance metrics such as efficiency, profitability, and growth. Moreover, Chugani *et al*. (2017) propose that firms could embrace Lean, Six Sigma, and LSS practices, aligning not only with environmental regulations but also offering cost-saving measures while meeting quality management standards. Furthermore, Rosin *et al.* (2020) emphasises the necessity of adopting lean management practices through the utilisation of Industry 4.0 technologies. Consequently, the integration of the LSS methodology with blockchain technology is found to be advancing quality control and management (Ahmad *et al.,* 2023). Similarly, the lean concept has expanded its scope into various areas to optimize benefits through effective implementation.

2.2.Benefits of Lean Construction

Bajjou and Chafi (2018) stated that by incorporating lean into construction projects, many nations have reaped significant benefits. As indicated in Table 1, several researchers have emphasised the social, environmental, and economic benefits of lean implementation in construction projects.

Table 1. Benefits of Lean Construction

Factors	Benefits	References
Social	Increase health and safety	[1],[2],[3],[4],[7],[11],[12],[13],[15],[16], [17], [18],[22],[24]
	Improvement in labour performance	[1],[3],[6],[7],[11],[12],[13],[14],[15],[16],[17],[19],[24]
	Better value for the employer	[1],[2],[3],[5],[6],[7],[11],[12],[14],[15],[16],[17],[18],[19]
	Increase employee satisfaction	[3],[7],[11],[12],[17],[18],[19],[24]

Factors	Benefits	References
	Improve relationships with suppliers	[3],[6],[11],[17],[18]
	Improve stakeholder cooperation	[2],[3],[5],[12],[17],[18]
	Effective control and management	[3],[6],[13],[17],[18],[20], [23]
	Increase innovation at the site	[6],[12],[17]
Environmental	Sustainable development of the project	[1],[3],[7],[12],[17],[18]
	Decrease the environmental impacts	[1],[4],[7], [17]
	Decrease the waste	[2],[3],[5],[6],[7],[12],[15],[16], [17], [18],[19],[20], [21],[22],[23],[24]
Economic	Decrease the duration of the project	[1],[3],[4],[6],[9],[10],[11],[13],[14],[15],[16],[17],[18],[19], [20],[21], [24]
	Decrease the whole life cycle cost	[1],[2],[3],[6],[9],[10],[12],[13],[14],[15],[16],[17],[18],[19], [20],[21],[22],[23], [24]
	Increase in the quality of the project	[1],[2],[3],[4],[6],[10],[11],[12],[15],[16],[17],[18],[19],[21], [24]
	Adapting to continuous improvement	[2],[3],[5],[7],[9],[11],[12],[14],[17],[18], [21],[22]
	Efficient control in inventory	[3],[8],[11],[13],[15],[17],[18],[24]
	Good production control & planning	[5],[8],[11],[17],[18]
	Share market increment	[3],[17],[24]
	Minimum impact during sudden risks	[3],[14],[15],[17],[18]
	Increase the productivity	[2],[5],[6],[8],[11],[13],[14],[16],[17], [21],[23],[24]
	Decrease rework and variabilities	[3],[6],[9],[13],[14],[17],[18],[19]
	Increase project performance	[2],[6],[8],[13],[14],[16],[17], [21],[23],[24]
	Improvement in delivery methods	[2],[6],[8],[13],[14],[16],[17]
	Reliability and certainty of project	[3],[6],[9],[12],[14],[16],[17],[18]
	Increase the profit	[6],[12],[16],[17]
	Improve design, product, and process	[8],[16],[17]

[1] (Ahmed *et al*., 2021), [2] (Albalkhy and Sweis, 2021), [3] (Babalola *et al*., 2019), [4] (Bajjou and Chafi, 2018), [5] (Ogunbiyi *et al*., 2014), [6] (Locatelli *et al*., 2013)**,** [7] (Marhani *et al*., 2012), [8] (Aziz and Hafez, 2013), [9] (Ahiakwo *et al.*, 2013)**,** [10] (Al-aomar, 2012a), [11] (Sarhan *et al*., 2017), [12] (Ogunbiyi, 2014), [13] (Mohan and Iyer, 2005), [14] (Adegbembo *et al.*, 2016)**,** [15] (Akinradewo *et al.*, 2018), [16] (Mossman, 2009), [17] (Parameswaran and Ranadewa, 2021), [18] (Shaqour, 2022)**,** [19] (Simonsen et al., 2023), [20] (Noorzai, 2023), [21] **(**Moyo and Chigara, 2023), [22] (Gao et al., 2023), [23] (Rosli et al., 2023), [24] **(**Moradi and Sormunen, 2023).

According to Table 1, the most highlighted benefits (i.e., based on the number of references) are reduction of project duration, reduction of life cycle cost, increased project quality, higher satisfaction, better value for an employer, and improved health and safety. These benefits have tempted many researchers to look into the real-life implementation of lean in construction projects and monitor its role in improving value through minimising waste. Accordingly, Bajjou and Chafi (2019), through a series of real-life implementations, found that lean construction has resulted in a 14% increase in process efficiency, a 17% decrease in cycle time, and a 41% increase in process productivity. In addition, Issa (2013) established that overall project time can be decreased by 15.57% through lean implementation. Aziz and Hafez (2013) indicated that the construction

industry has a greater production-to-waste ratio than the manufacturing sector because the construction industry has 57% wastage and 43% production time, whereas the manufacturing industry has 12% wastage and 88% production time. This was further proven by the study of Bajjou *et al.* (2017). With its renowned potential for meeting customer expectations through value enhancement and decreasing all kinds of waste, the lean construction concept is regarded as an alternative strategy that may offer a revolutionary transformation to the construction sector (Bajjou *et al*., 2017). Hence, lean can be successfully implemented in construction by concentrating on improving the entire process, in which all stakeholders must be committed and collaborate to overcome the challenges that may be present in the construction sector. However, as is common for any innovation disruption in the much less enthusiastic construction industry, lean implementation also suffers from various barriers, which is the main discussion in the next section (Asri and Nawi, 2015; Bashir *et al.*, 2015).

2.3.Barriers for Lean Implementation in the Construction Industry

Barriers to lean construction implementation in the literature are listed in the following Table 2. Accordingly, the barriers are presented in two groups: internal and external barriers, based on whether they originate from within or outside the organisation's boundaries. Internal barriers have been further divided into five categories.

Table 2. Barriers for Lean Implementation in the Construction Industry

	Factors	**Barriers**	**References**
Internal barriers	**Cultural**	Lack of understanding and focus on requirements	[1],[2],[3],[4],[5],[8],[14],[15],[18]
		Long-time of implementation and result	[1],[2],[3],[4],[5],[7],[8],[10],[14],[16],[17],[19],[20],[22]
		Addition cost for Lean implementation	[1],[2],[3],[4],[5],[7],[8],[10],[11],[13],[14],[22]
		Limited tender prices	[4],[5],[21],[22]
		End-user preference	[4],[5],[7]
		High indirect costs	[3]
		Lack of incentives, motivation, reward, wages	[1],[2],[3],[4],[5],[7],[8],[11],[14]
		Poor long-term suppliers relationships	[1],[2],[3],[4],[5],[17],[21]
		Lack of standardisation, procedures and norms	[3],[4],[5],[10],[16],[17],[21]
		Utilise nonstandard components	[4],[5],[7]
		Unfriendly organisational culture	[4],[5],[7], [12],[13],[14],[15],[16],[22]
		Difficulty to abandon traditional practice	[3],[4],[5],[6],[7],[12],[14],[15],[19],[22]
	Managing human	Poor transparency and involvement among stakeholders	[1],[2],[3],[4],[5],[7],[9],[11],[12],[21],[22]
		Scarcity of constructible designs	[1],[2],[3],[4],[5],[7],[11],[12],[13],[14],[17],[18]
		Reluctance to share risks by project participants	[1],[2]
		Seeking guilty in the event of an error	[3]
		Lack of implementation of lean construction	[1],[2],[3],[4],[5],[7],[8],[13],[16]

	Factors	Barriers	References
		Human attitude, communication, and competition	[3],[4],[5],[6],[11],[14],[15],[17],[18],[19],[20],[21],[22]
		Unclear definition for individual responsibilities	[4],[5],[7],[11],[15],[18],[22]
	Project Management	Lack of long-term planning and philosophy	[1],[2],[3],[4],[5],[12],[13],[20],[22]
		Lack of quality control, and planning	[1],[2],[3],[8]
		Unsuitable hierarchies in organisational structure	[1],[2],[3],[13]
		Improper waste and resources management	[1],[2],[4],[5],[7],[8],[22]
		Unable to measure long-term project performance	[3],[4],[5],[7],[13],[14],[15],[22]
		Delay in materials delivery	[1],[2],[3],[11],[17]
		Uncertainty in the supply chain process	[4],[5],[7],[16]
		Manpower shortages	[4],[5]
		Unclear procedures	[3],[4],[5],[7]
		Utilise sub-contractors to project	[4],[5],[6],[8],[13],[21]
	Leadership	Inadequate commitment, and support from top management	[1],[2],[3],[4],[5],[6],[7],[8],[9],[10],[11],[13],[14],[15],[16],[17],[18],[19],[20],[21],[22]
		Resistance to change by management	[1],[2],[3],[12],[13],[16]
		Insufficient capacities to work in teams	[3],[4],[5],[7],[10],[11],[13],[14],[15],[17],[18],[19],[22]
		Difficult to achieve unity within teams	[3],[10],[11],[15],[17],[18],[19],[22]
		Insufficient leadership and management skills	[1],[2],[3],[9],[14],[18]
		Decision-making centralization	[1],[2],[3]
		Delay in decision making	[1],[2],[3],[4],[5],[7],[13],[17]
		The leadership resistance to change	[1],[2],[3],[6],[8],[10],[12],[13],[16],[21]
	Knowledge	Lak of knowledge to handle the change	[3]
		Lack of awareness, knowledge & understanding	[1],[2],[3],[4],[5],[6],[7],[8],[10],[11],[12],[13],[14],[15],[16],[17],[18],[19],[21]
		Poor administration to take corrective actions and initiate a learning cycle	[3],[19]
		Unsuccessful past experiences	[3]
		Insufficient prior experience	[3],[13]
		Fear and consider complex	[1],[2],[3],[8],[9],[10],[13],[20]
		Poor training	[1],[2],[4],[5],[7],[8],[9],[11],[12],[14],[16],[17],[19],[20]
External barriers	**External**	Government instability and bureaucracy	[1],[2],[3],[4],[5],[6],[7],[8],[11],[13],[16],[22]
		Increase in inflation rates	[4],[5],[7],[8],[11]
		Cyclic nature and fragmentation in construction	[1],[2],[4],[5],[6],[8],[11],[14],[16],[17]
		Inadequate financial resources	[3],[4],[5],[6],[7],[8],[11],[14]
		Stringent approvals and requirements	[1],[2],[8],[13]

[1] (Al Balkhy *et al.,* 2021), [2] (Albalkhy and Sweis, 2021), [3] (Mano *et al.*, 2021), [4] (Ahmed and Sobuz, 2020), [5] (Ahmed *et al*., 2021), [6] (Bajjou and Chafi, 2018), [7] (Sarhan *et al*., 2018), [8] (Khaba and Bhar, 2017), [9] (Hamzeh *et al*., 2016), [10] (Neeraj *et al*., 2016), [11] (Olatunji, 2008), [12] (Cano *et al*., 2015), [13] (Shang and Pheng, 2014), [14] (Sarhan and Fox, 2013), [15] (Omran and Abdulrahim, 2015), [16] (Ogunbiyi, 2014), [17] (Adegbembo *et al*., 2016), [18] (Alinaitwe, 2009), [19] (Abdullah *et al*., 2009), [20] (Kim and Park, 2006), [21] (Dulaimi and Tanamas, 2001), [22] (Bashir *et al*., 2015)

According to Table 2, most of the research highlighted that the primary barrier to lean practitioners implementing lean construction successfully was inadequate knowledge about lean construction. Additionally, Albalkhy and Sweis (2021) broadened the barriers that have been more frequently highlighted by other scholars, such as barriers related to knowledge, including a lack of proper lean understanding and awareness, as well as staff training. Moreover, the most significant barrier to lean construction has been highlighted as the lack of understanding of how to implement the

lean concept as a new system (Mano *et al*., 2021). Accordingly, it has been found that the prime cause behind most of the challenges encountered during lean adoption was a lack of understanding and knowledge of lean concepts (Haarr and Drevland, 2016; Hamzeh *et al*., 2016; Korb *et al*., 2016). Therefore, understanding the lean concept by construction industry professionals is critical to its successful implementation. Simultaneously, construction industry professionals are unclear about their roles when it comes to implementing lean construction, which has resulted in insufficient commitment and, hence, failure to achieve the prime goal of the lean concept. Therefore, there is a pressing need to overcome this barrier and successfully execute lean construction by defining the roles of lean learners and their roles in the construction industry.

2.4.Lean Learners and Their Roles

Within the scope of this study, lean learners have been viewed and defined as those engaged in lean construction implementation but lack knowledge of lean construction. Research has shown the involvement of several individuals in implementing lean for a construction project. Project leaders, quality control and quality assurance areas, production areas, administrative areas, technical offices, and prevention and safety area leaders were identified by Brioso (2015) as lean learners in construction projects. Bateman *et al.* (2003) have identified eight types of participants as the most important and essential stakeholders that require learning for a successful lean implementation: associate (operator), support functional manager, team leader, company expert, area manager, director, operations manager, and change agent. Labourers, technical officers, engineers/quantity surveyors, project managers, external lean experts, company lean trainers, directors, and support functional managers were identified as the eight types of lean learners for this study based on the studies of Bateman et al. (2003), Hirota et al. (1999), Hirota and Formoso (1998), and Mossman (2015). Subsequently, Parameswaran and Ranadewa (2023) recognised nine different groups of lean learners in the construction industry, including Labourers (Labourers/ Construction operators), Technical Officers, Construction Executives (Engineers/ Quantity Surveyors/ Designer), Project Managers (Project managers/ General managers), External Lean Consultants, Internal Lean Trainers, Directors, Support Functional Managers, and Chairman (CEO/CED/Chairman). Table 3 shows the lean learners and their roles.

Table 3. Role of Lean Learners

References	Role of lean learners	Learners							
		1	2	3	4	5	6	7	8
(Bateman *et al*., 2003)	Participate in performance improvement (PI) activities	x	x	x	x	x	x	x	x
	Contribute to Continuous improvement (CI) activities	x	x	x	x	x	x	x	x
	Maintain 5S at the site	x	x	x	x	x	x	x	x
	Interpret and maintain performance measures	x	x	x	x	x	x	x	x
	Lead CI activities		x	x	x	x	x		
	Lead close out of PI activities		x	x	x	x	x		
	Manage resources for activities		x	x	x	x	x		
	Ensure transfer of best practices between cells			x					
	Activities Set agenda for PI			x					
	Manage resources for CI activities in the area			x					
	Manage resources for lean activities				x	x	x		
	Ensure transfer of best practices between value streams				x	x	x		
	Set agenda for PI and CI activities in value streams				x	x	x		
	Lead mapping activities					x	x		
	Lead PI activities					x	x		
	Challenge the status quo					x	x		
	Ensure quality of PI and CI activities					x	x		
	Training of area personnel					x	x		
	Develop lean programme						x		
	Manage lean process						x		
	Manage resources and ensure commitment						x		
	Develop organizational strategies						x		
	Lead company board through lean process						x		
	Develop lean strategies							x	
	Lead some CI activities							x	
	The lead functional department through lean change								x
(Mossman, 2015)	Involved as both a coach and a coachee alongside other participants		x	x	x		x		
	Enhance the knowledge and skills through interacting with experts, practitioners	x	x	x	x	x	x	x	x
	Encourage to learn on their own - action research, action learning		x	x	x	x	x	x	x
	Recognise own learning requirements and adapt them over time	x	x	x	x	x	x	x	x
	Fulfill learning requirements as per the organisational guideline	x	x	x	x	x	x	x	x
	Evaluate and assess their learning progress.	x	x	x	x	x	x	x	x
	Provide evidence of the progress for an effective self- and peer evaluation process	x	x	x	x	x	x		
	Keep a learning record for their reflective process	x	x	x	x	x	x		
(Hirota *et al.*, 1999)	Motivation to learn			x	x	x	x	x	x
	Use their personal experience as a learning tool	x	x	x	x	x	x	x	x
	Self-directing	x	x	x	x	x	x	x	x
	Act and reflect on their experience	x	x	x	x	x	x	x	x
(Hirota and Formoso, 1998)	Change the culture and persuade the employee to continual development				x		x	x	x
	Take decisions under risky circumstances				x			x	x
	Engage in planning, coordination, and controlling				x		x	x	x
[1] Labourers (Labourers/ Construction operators), [2] Technical Officers, [3] Construction Executives (Engineers/ Quantity Surveyors/ Designer), [4] Project Managers (Project managers/ General managers), [5] External Lean Consultants, [6] Internal Lean Trainers, [7] Directors, [8] Support Functional Managers									

Bateman *et al.* (2003) emphasised that the expert hired by an organisation to execute lean construction is commonly known as an "external lean expert". The author further stated that the

internal team, known as the "company's lean expert," was created to carry out the organisation's lean learning process. All support functional managers in the organisational structure and all head office employees across all divisions are collectively referred to as support functional managers (Bateman *et al*., 2003). According to Table 3, each employee in the organisation should be a lean learner with different roles. However, engineers/quantity surveyors, project managers, external lean experts, and company lean trainers are the learners who have a higher number of roles compared to other learners in the construction organisation. Additionally, all lean learners undertake duties such as participating in PI activities, contributing to CI activities, maintaining 5S conditions, interpreting and maintaining performance measures, self-directing, recognising their learning requirements and adapting them over time, and using their personal experience as a learning tool. Further, all the lean learners evaluate and assess their learning progress, act and reflect on their experience, enhance their own personal corpus of knowledge and skills through interacting with other experts and practitioners, and fulfil their learning requirements within the learning materials that are accessible to them.

Moreover, considering the industry's pivot towards digitalisation, digital technology emerges as a key instrument for shaping and executing diverse roles. In the assessment of advancements and the assumption of responsibilities such as progress evaluation, planning, coordination, and control in construction projects, technology facilitates assessment, monitoring, and control through features encompassing automation, digitisation, integration, and interoperability. These capabilities, aligned with the tenets of the Industry 4.0, effectively enable data acquisition in the field, thereby supporting the execution and accomplishment of these roles (Duarte-Vidal *et al.,* 2021; Hardin and McCool, 2015; Martínez-Rojas *et al.,* 2016; Sepasgozar *et al*., 2022).

Similarly, as the industry embraces circularity, closed-loop systems, and a focus on green and sustainable practices, the imperative for efficient resource and waste management becomes evident. Consequently, the adoption of a circular or sustainability-oriented vision, coupled with a commitment to closed resource loops, assumes a crucial role in facilitating resource and waste management. Subsequently, this simplifies and aids in fulfilling the responsibilities associated with managing resources for various activities (Gerding *et al.,* 2021; Hossain *et al.,* 2020; Ogunmakinde *et al.,* 2022; Zhang *et al.,* 2022). Likewise, the incorporation of relevant concepts,

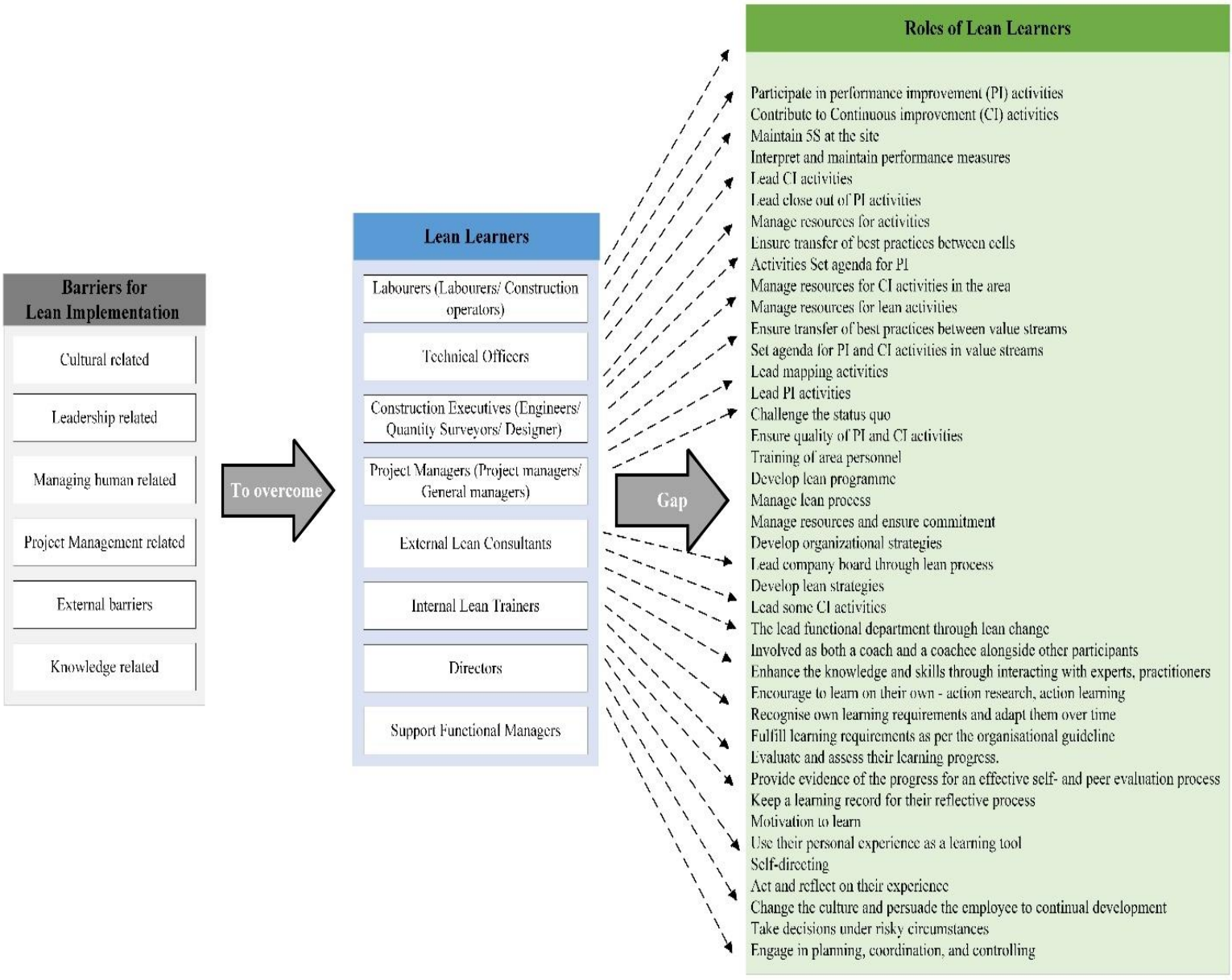
tools, methods, techniques, and technologies further enhances the ease of performing these roles, contributing to their successful fulfilment.

However, most of the research on lean learning in the construction industry (Zhang and Chen, 2016) and construction organisations (Lemahieu *et al.*, 2017) has not focused on the role of the lean learner. Thorough investigations into the roles of lean learners have already been conducted in the manufacturing industry (Bateman *et al*., 2003), as well as the education industry (Hirota *et al.*, 1999; Hirota and Formoso, 1998; Mossman, 2015; Pellicer and Ponz-Tienda, 2014; Rybkowski *et al.*, 2018). In addition, Parameswaran and Ranadewa (2023) identified lean learners in the construction industry. This emphasises the lack of empirical study on lean learners' roles in the construction industry. To address this knowledge gap, this study aims to define lean learners' roles in the construction industry.

2.5.Conceptual framework

The conceptual framework of the study portrays the roles of lean learners in the construction sector by synthesising insights from existing literature as present in the Figure 1.

Figure. 1. : Conceptual framework of lean learners and their roles



Lean construction, emphasising the delivery of high-quality projects within demanded timelines and budgets, has exhibited substantial advantages. Nonetheless, various barriers hinder its effective implementation, categorised cultural, managing human resources, project management, leadership, knowledge-related and external barriers. Evidently, stakeholder uncertainty regarding their roles in lean implementation constitutes a significant barrier. Thus, the clarity on the roles of lean learners assumes critical importance in overcoming these barriers. In pursuit of this objective, Figure 1 presents a conceptual framework delineating the roles of lean learners in the construction

industry. These roles encompass distinct groups, including Labourers (Labourers/Construction operators), Technical Officers, Construction Executives (Engineers/Quantity Surveyors/Designers), Project Managers (Project managers/General managers), External Lean Consultants, Internal Lean Trainers, Directors, and Support Functional Managers. Existing literature suggests a total of forty-one roles across these eight categories of lean learners. However, it is imperative to acknowledge that this conceptual framework primarily served as a guide for empirical investigation of this study laying the foundation for a more comprehensive framework addressing lean learners and their roles within the construction industry.

3. Methodology

The research philosophy encompasses the formation of knowledge and its fundamental nature, encapsulating critical presumptions about one's worldview (Saunders et al., 2009). In the realm of management research, four primary philosophies, namely positivism, realism, interpretivism, and pragmatism, shape the landscape. Pragmatism posits that the research question plays a pivotal role in determining the adoption of epistemology, ontology, and axiology. Positivism aligns with the empirical approach of natural science, focusing on observable social realities and striving for generalisations akin to law-like statements in natural sciences. Interpretivism emphasises the need for researchers to discern human differences as social actors, distinguishing research among people from that among non-human objects. Realism asserts that the reality lies in what our senses reveal, constituting the existence of objects independent of human cognition (Saunders *et al.,* 2009). A research paradigm provides a framework for examining social phenomena, facilitating specific understandings and explanatory attempts. Ontology delves into the nature of social phenomena as distinct entities, while epistemology concerns the criteria for acceptable knowledge within a field of study. Axiology focuses on value judgments (Saunders *et al.,* 2009). This research aimed to define lean learners and their roles in the construction industry. A literature review was conducted to investigate the theoretical background of the role of lean learners. Given the scarcity of studies, it becomes imperative to reveal the diverse perspectives of experts engaged in lean implementation within the construction sector. Recognising the importance of nurturing an open exchange of ideas, opinions, perceptions, and experiences within the investigated context, human interactions are deemed the primary catalysts of this research, aligning with the guidance of Saunders *et al.* (2009). Consequently, the overarching research approach adheres to the interpretivism stance. This study

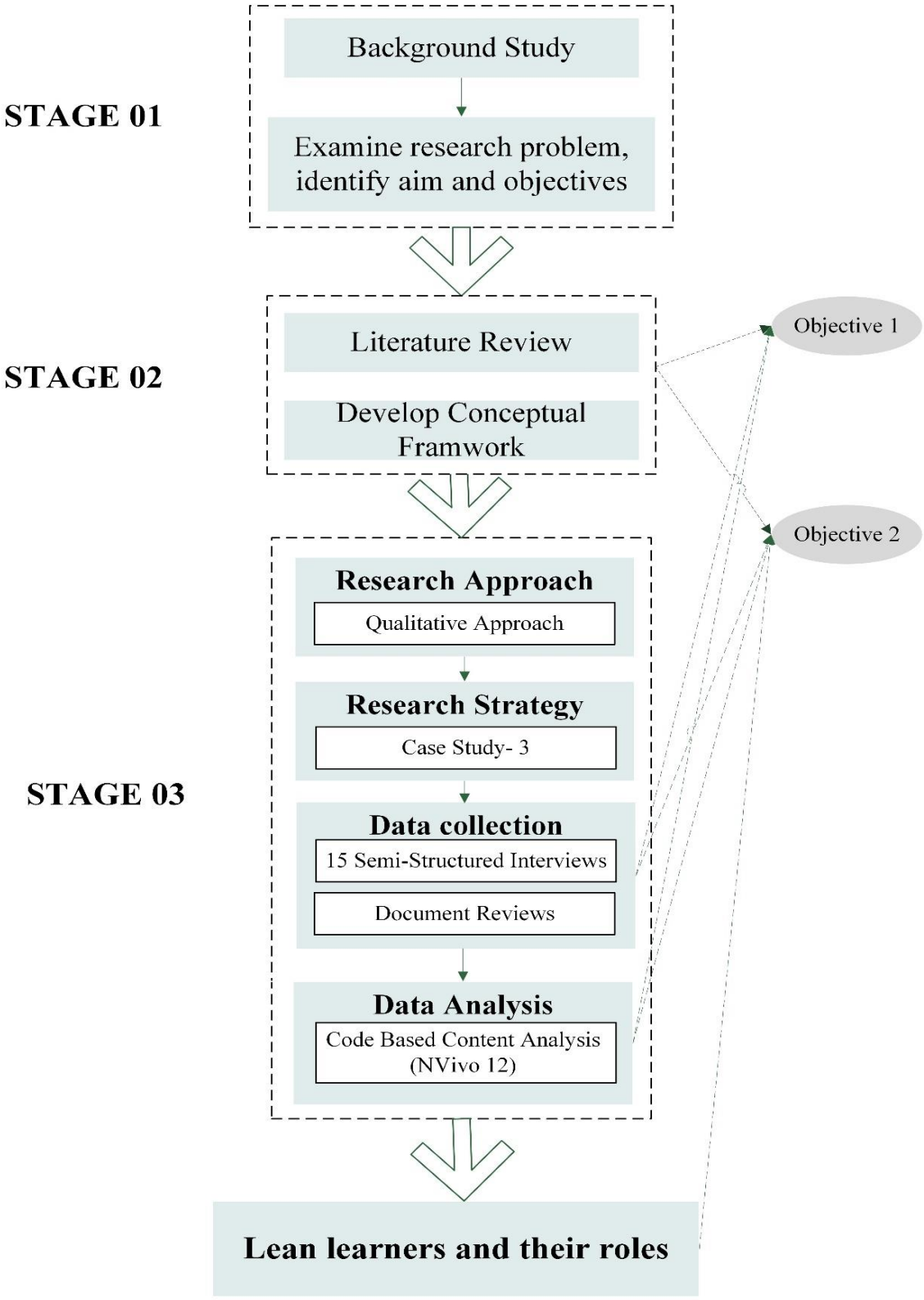
thus aligns with the ontological viewpoint positing that 'reality is shaped through social construction' and the epistemological stance asserting that 'knowledge is acquired by exploring individuals' perspectives (Saunders *et al.,* 2009). Furthermore, concerning axiology, the study adopts a position grounded in values, suggesting that the researcher's contribution will enrich the overall study.

Johnston (2014) expounded on the research approach as the foundational rationale directing the methodology employed in conducting research, underscoring its pivotal role in delineating the manner and purpose behind the research process. Creswell (2014) categorised three fundamental research approaches: qualitative, quantitative, and mixed methods. The distinction between qualitative and quantitative approaches centres on the use of words (qualitative) versus numerical data (quantitative), respectively. The mixed approach occupies an intermediate terrain, combining elements characteristic of both qualitative and quantitative methodologies (Terrell, 2012). A qualitative research approach centred on description addresses research inquiries commencing with "how," "what," or "why," as opposed to focusing on "how many" or "how much" (McCusker and Gunaydin, 2015). Merriam and Tisdell (2015) explored qualitative research as an inclusive term encompassing techniques that analyse phenomena by evaluating experiences, actions, and relationships without reliance on statistics, mathematics, or numerical data processing. However, addressing these inquiries necessitates detailed, contextually rich data descriptions, often referred to as "thick" descriptions (Borrego et al., 2009). Additionally, Bryman and Bell (2015) propose that this approach maintains a "humanistic focus," accentuating attentiveness to particulars and the context of the research setting. Hence, this study adopts a qualitative research approach due to the exploratory nature, aiming to acquire an in-depth understanding of the role of lean learners in the construction industry within its real-world context.

3.1.Research Process

The conventional research procedure encompasses several stages, comprising the formulation of research questions, data collection, data processing, addressing the research questions, and ultimately, presenting the findings (Goertz and Mahoney, 2012). Accordingly, Figure 2 provides a visual representation of the research process adopted for this study.

Figure. 2. : Research Process



3.1.1. Data Collection

Hackannson (2013) defined data collection methods that can be used for any empirical study. The most frequently utilised qualitative research methodologies include ethnography, interviews, field research, focus groups, case studies, and observations for quantitative research, field experiments, simulation, surveys, correlational studies, and multivariate analysis (Queirós *et al.*, 2017). The choice of a case study is deemed appropriate in situations necessitating a comprehensive understanding of the research context and processes (Saunders et al., 2009). Moreover, when a thorough analysis with diverse sources of evidence is imperative for addressing the research problem, the case study emerges as a strategic approach for developing an in-depth understanding of lean learners and their roles, utilising various sources of evidence. As a result, a case study research strategy was employed in this study. Three (3) contracting organisations were chosen as case studies. Cases were chosen using the purposive sampling method. This study concentrated on three cases rather than one to achieve data saturation and the possibility for cross-case study analysis. Furthermore, the research scope is delimited to large-scale contracting organisations, with the unit of analysis designated as lean-implemented large-scale contracting organisations.

Overview of three selected case studies

The main criteria for selecting the organisations were whether they had embraced lean principles and attempted to implement them in their day-to-day organisational activities. Due to the time and financial constraints of the research team, all the case studies were selected from the Sri Lankan context. Case one (C1) has the highest Construction Industry Development Authority (CIDA) grading in Buildings, Roads, Water Supply and drainage, and Bridges, with 24 ongoing projects (including ten international projects). Case two (C2) has the highest CIDA grading in the major disciplines of local construction, such as building construction, roads and bridges, and water supply and sanitation, with 18 active projects (including seven international projects). The selected third organisation, as case three (C3), has a CIDA-approved construction enterprise with the highest grade that has 20 ongoing projects. Even though the selected organisations are large rather than medium-scale or small-scale, they are active in multiple construction industry sectors.

Data collection strategies

Singh (2006) revealed that the phrase "data analysis" refers to the process of examining tabulated information to discover hidden meanings and facts. The research adopted semi-structured

interviews to glean insights from seasoned professionals well-versed in lean concepts and their organisational implementation under case studies. Each case comprised five interviews, featuring participants with expertise in the field, aimed at delving into their nuanced understanding of lean practices and implementation procedures within their respective firms. The semi-structured format of the interviews was tailored to elicit detailed information concerning the participants' expertise, with a focus on their specialised knowledge in the realm of lean concepts and procedures. These expert interviews primarily served the purpose of validating findings from existing literature, with an emphasis on identifying individuals recognised as "lean learners" and elucidating their roles to fulfil the study's first and second objectives. The profile of the interviewees is shown in Table 4.

Table 4. Profile of the interviewees

Case	Code	Designation	Industry experience	Awareness of Lean Construction	Type of project	Educational qualification
C1	R1	Planning Engineer	08 Years	Aware	Condominium apartment complex	BSc
	R2	Manager - Training & Development	12 Years	Well aware	Head office, training, and development	BBA
	R3	Deputy Project Manager	18 Years	Well aware	City development Project	BSc
	R4	Manager – Senior Construction Manager	22 Years	Aware	Super luxury apartment complex	MSc
	R5	DGM- Deputy General Manager	26 Years	Well aware	Condominium apartment complex	PhD
C2	R6	Quantity Surveyor	10 Years	Aware	Head Office	BSc
	R7	Assistant Manager Planning	10 Years	Aware	University complex	MSc
	R8	Chief Quantity Surveyor.	10 Years	Aware	Head office	BSc
	R9	Assistant Manager Quality Assurance.	12 Years	Well aware	Head office, Compliance department	BSc
	R10	General Manager	26 Years	Aware	Mixed development project	MSc
C3	R11	Senior Quantity surveyor	09 Years	Aware	Building project	BSc
	R12	Assistant Manager- for Estimation and Contracts	11 Years	Aware	Head office	BSc
	R13	Assistant General Manager	16 Years	Well aware	Building project	BSc and MBA
	R14	Project Manger	18 Years	Well aware	Apartment complex	MSc
	R15	Project Manger	22 Years	Well aware	Apartment complex	MSc

The interviews were limited to fifteen (15) respondents due to data saturation. According to Table 4, many of the experts have over ten years of experience in the construction industry, as well as knowledge about lean construction, ensuring the validity of the findings. In pursuit of the first

objective, which involved the identification of lean learners, the interviews were strategically deployed to discern individuals who embody lean principles within their organisational milieu. Subsequently, the focus shifted to the second objective, defining the roles undertaken by the identified lean learners. Complementing the semi-structured interviews, data collection was enriched through a comprehensive review of relevant documents. Hence, the data acquisition process involved a combination of semi-structured interviews and document reviews. An array of documents, encompassing the contract agreements, monthly reports, organisational charts, daily reports and schedules, training records, meeting minutes, audit checklists and records, manuals, and other relevant materials, underwent thorough scrutiny to extract the necessary data.

3.1.2. Data analysis

Content analysis is the act of analysing the contents of observational field notes or interviews to find the key themes that were identified from respondents' replies or the researcher's observation notes (Kumar, 2011). Consequently, there are approximately forty different analytical forms in qualitative research, with one frequently used being content analysis (Dey, 1993). Therefore, code-based content analysis through NVivo software (NVivo 12) was used to analyse the collected data. Following that, Power BI software was used to develop a force-directed graph to present the findings. In qualitative research, the coding process entails procedures crafted to thematically structure the collected qualitative data. These procedures contribute to the formation of a structured framework that aids in constructing meaningful interpretations from the gathered information (Williams and Moser, 2019). The coding process in this study adhered to the principles of open, axial, and selective coding, as proposed by Douglas (2003) and Williams and Moser (2019). Open coding represents the initial phase in the coding process, wherein the researcher is actively involved in identifying and delineating discrete concepts and themes with the objective of categorisation (Williams and Moser, 2019). During open coding, there is an unrestrained labelling of various lean learners and their roles, as identified by experts. Axial coding marks the subsequent phase, differing from open coding by not only recognising emerging themes but also refining, aligning, and categorizing these themes. Axial codes are then applied to establish relationships between the open codes, facilitating the development of core codes. The subsequent step, selective coding, involves the detailed selection of the central phenomenon, or core code, that emerges from

the axial coding phase (Flick, 2009; Williams and Moser, 2019). Therefore, this research adopted the open, axial and selective coding process during the content analysis process.

4. Research findings

The following section discusses lean learners and their roles identified from data collection. Then, a force-directed graph was developed for lean learners and their roles.

4.1.Lean Learners and Their Roles

The first question in the interview guideline was focused on lean construction. As a result, every respondent expressed their thoughts on lean construction in the way they understood it. The next question was to identify the lean learners in the organisation or project and their roles in the construction projects. Prior to that, the list of lean learners at the case-studied organisations was determined based on the document reviews. Thereafter, it was validated and clarified through interviews. Labourers (Labourers/ Construction operators), Technical Officers, Construction Executives (Engineers/ Quantity Surveyors/ Designer), Project Managers (Project managers/ General managers), External Lean Consultants, Internal Lean Trainers, Directors, Support Functional Managers, and Chairman (CEO/CED/Chairman) are among the nine (9) types of lean learners identified in the literature (Parameswaran and Ranadewa, 2023). As a result, all respondents agreed that these nine lean learners could engage in the organisation's lean learning programme. Besides that, all respondents stated that the CEO (Chief Executive Officer)/CED (Chief Executive Director)/chairman will also participate in the lean learning programme as they are the ones who direct the organisation, and that without their approval or concern, the lean learning programme will not be able to be implemented.

Furthermore, R5 and R14 suggested that instead of enrolling all labourers in the lean learning program, gang leaders among the labourers should be involved because only specific individuals will be actively working for them. Even though R5 indicated that site visits would be an excellent way for labourers to learn about the practical implementation of lean in construction, however, this is not possible because of the high number of labourers and the inability of labourers to effectively locate these types of items. Therefore, it makes it impossible to bring the labourers to the site visit. On the other hand, labourers can get knowledge from technicians and supervisors, and engineers and project managers are also responsible. R5 further said that *"subcontractors*

(domestic, nominated, or specialised) should also engage in the lean learning programme since the main contractor will benefit from whatever work they bring in. If the subcontractor is properly trained, the benefit will be utilised by the main contractor". Consequently, R4, R5, R10, and R14 emphasised the importance of construction operators participating in the lean learning programme since they may reduce NVAA (non-value-adding activity) (waste). Furthermore, all respondents agreed that, in addition to the project manager, the general manager should participate in the lean learning programme since the general manager plays a similar role to the project manager in this lean learning programme**.** R5 and R9 stated that the audit team will be included in the company's lean trainer team as they will check the progress of lean learning to see if it is going according to plan or not, see the plan and actual deviation, and come to project level for inspection to check the progress, like monitoring and controlling. Additionally, the support functional managers will be the title shared by all head office support functional managers, including those in all head office divisions.

According to the R9's opinion, "*designers should be included with engineers' and quality surveyors' categories since they must engage in the lean learning programme as part of the design team at the site level and also have a similar role to engineers' and quality surveyors' within the lean learning programme".* On the other hand, rather than gang leaders, it was difficult to incorporate labourers into this lean learning programme because the labourer count is quite large and there is a poor degree of understanding capacity. However, labourers were included since they were the only people who implemented actual work at the site. As a result, labourers were included in the lean learning programme. However, their learning criteria have been adjusted to make it easier for them to understand. Accordingly, the study confirmed nine (9) categories of lean learners who were Labourers (Labourers/ Construction operators), Technical Officers, Construction Executives (Engineers/ Quantity Surveyors/ Designer), Project Managers (Project managers/ General managers), External Lean Consultants, Internal Lean Trainers, Directors, Support Functional Managers, and Chairman (CEO/CED/Chairman).

Consequently, the third question in the third section of the interview guideline was developed to outline the roles of lean learners in the project or organisation to identify what roles lean learners play in the process of lean implementation. To define and specify the roles of lean learners, daily reports and schedules, training records, meeting minutes, audit checklists and records, manuals,

and other documentation are mainly used. However, the respondents who were interviewed also confirmed the indicated roles of each lean learner based on their experiences. Based on the data collected, Table 5 demonstrates the roles of lean learners.

Table 5. Lean learners and their roles

No	Role of lean learners	Lean Learners								
		1	2	3	4	5	6	7	8	9
1	Participate in PI activities	x	x	x	x	x	x	x	x	
2	Contribute to CI activities	x	x	x	x	x	x	x	x	
3	Maintain 5S at the site	x	x	x	x	x	x	x	x	
4	Interpret and maintain performance measures	x	x	x	x	x	x	x	x	
5	Lead CI activities		x	x	x	x	x			
6	Lead close out of PI activities		x	x	x	x	x			
7	Manage resources for activities		x	x	x	x	x			
8	Ensure transfer of best practices between cells			x						
9	Activities Set agenda for PI			x						
10	Manage resources for CI activities in the area			x						
11	Manage resources for lean activities				x	x	x			
12	Ensure transfer of best practices between value streams				x	x	x			
13	Set agenda for PI and CI activities in value streams				x	x	x			
14	Lead mapping activities					x	x			
15	Lead PI activities					x	x			
16	Challenge the status quo					x	x			
17	Ensure quality of PI and CI activities					x	x			
18	Training of area personnel					x	x			
19	Develop lean programme						x			
20	Manage lean process						x			
21	Manage resources and ensure commitment						x			
22	Develop organizational strategies						x			
23	Lead company board through lean process						x			
24	Develop lean strategies							x		
25	Lead some CI activities							x		
26	The lead functional department through lean change								x	
27	Involved as both a coach and a coachee alongside other participants		x	x	x		x			
28	Enhance the knowledge and skills through interacting with experts, practitioners	x	x	x	x	x	x	x	x	
29	Encourage to learn on their own - action research, action learning		x	x	x	x	x	x	x	
30	Recognise own learning requirements and adapt them over time	x	x	x	x	x	x	x	x	
31	Fulfill learning requirements as per the organisational guideline	x	x	x	x	x	x	x	x	
32	Evaluate and assess their learning progress.	x	x	x	x	x	x	x	x	
33	Provide evidence of the progress for an effective self- and peer evaluation process	x	x	x	x	x	x			
34	Keep a learning record for their reflective process	x	x	x	x	x	x			
35	Motivation to learn			x	x	x	x	x	x	
36	Use their personal experience as a learning tool	x	x	x	x	x	x	x	x	
37	Self-directing	x	x	x	x	x	x	x	x	
38	Act and reflect on their experience	x	x	x	x	x	x	x	x	
39	Change the culture and persuade the employee to continual development				x		x	x	x	
40	Take decisions under risky circumstances				x			x	x	
41	Engage in planning, coordination, and controlling				x		x	x	x	
42	Follow the procedure and instructions	x	x	x	x		x		x	
43	Participant for Learning with involvement	x	x	x	x		x		x	x

No	Role of lean learners	Lean Learners								
		1	2	3	4	5	6	7	8	9
44	Implement the lean as per learn	x	x	x	x				x	
45	Find the challenges faced by the learners when implementing lean			x	x	x	x	x	x	
46	Inform the challenges to upper-level staffs when implementing lean	x	x	x	x				x	
47	Get the suggestion and implement it	x	x	x						
48	Monitor the progress after lean implementation		x	x	x	x	x		x	
49	Advice and motivate to improve and get maximum output		x	x	x	x	x	x	x	x
50	Visit to a different site that implements the lean concept			x	x				x	
51	Provide the training to site learners as they can understand			x	x					
52	Maintain records to track performance and report to top management			x	x		x		x	
53	Inform proposed strategy to learners			x	x		x	x	x	
54	Determine any modifications that must be made to establish a lean culture.				x	x	x	x	x	
55	Implement the strategy				x			x	x	x
56	Take decision				x			x	x	x
57	Keep track of the lean implementation's progress and continuity.				x	x	x		x	
58	Coordinate with external lean consultants and internal lean trainer				x				x	
59	choose the most critical tool for the project				x	x	x			
60	choose the most critical tool for the organization					x	x		x	
61	Lead the team				x				x	
62	Prepare multiple hierarchical manuals for different levels of employees to use when implementing lean techniques and make them available.						x			
63	Provide proper lean learning					x	x			
64	Determine the audience.						x			
65	Divide the group into training segments						x			
66	Identify and hire a lean specialist to provide the lean learning programme						x			
67	Prepare a proper detailed plan for the entire lean learning programme.						x			
68	Obtaining managerial approval for the plan						x			
69	Provide the approval for lean learning							x		x
70	Evaluate the progress				x		x		x	
71	Provide rewards				x		x		x	
72	Identify and remove NVAA.				x	x	x	x	x	
73	Inspection of the site on a regular basis				x	x	x	x	x	

[1] Labourers, [2] Technical Officers, [3] Construction Executive, [4] Project Managers, [5] External Lean consultants, [6] Internal Lean Trainers, [7] Directors, [8] Support Functional Managers, [9] Chairman

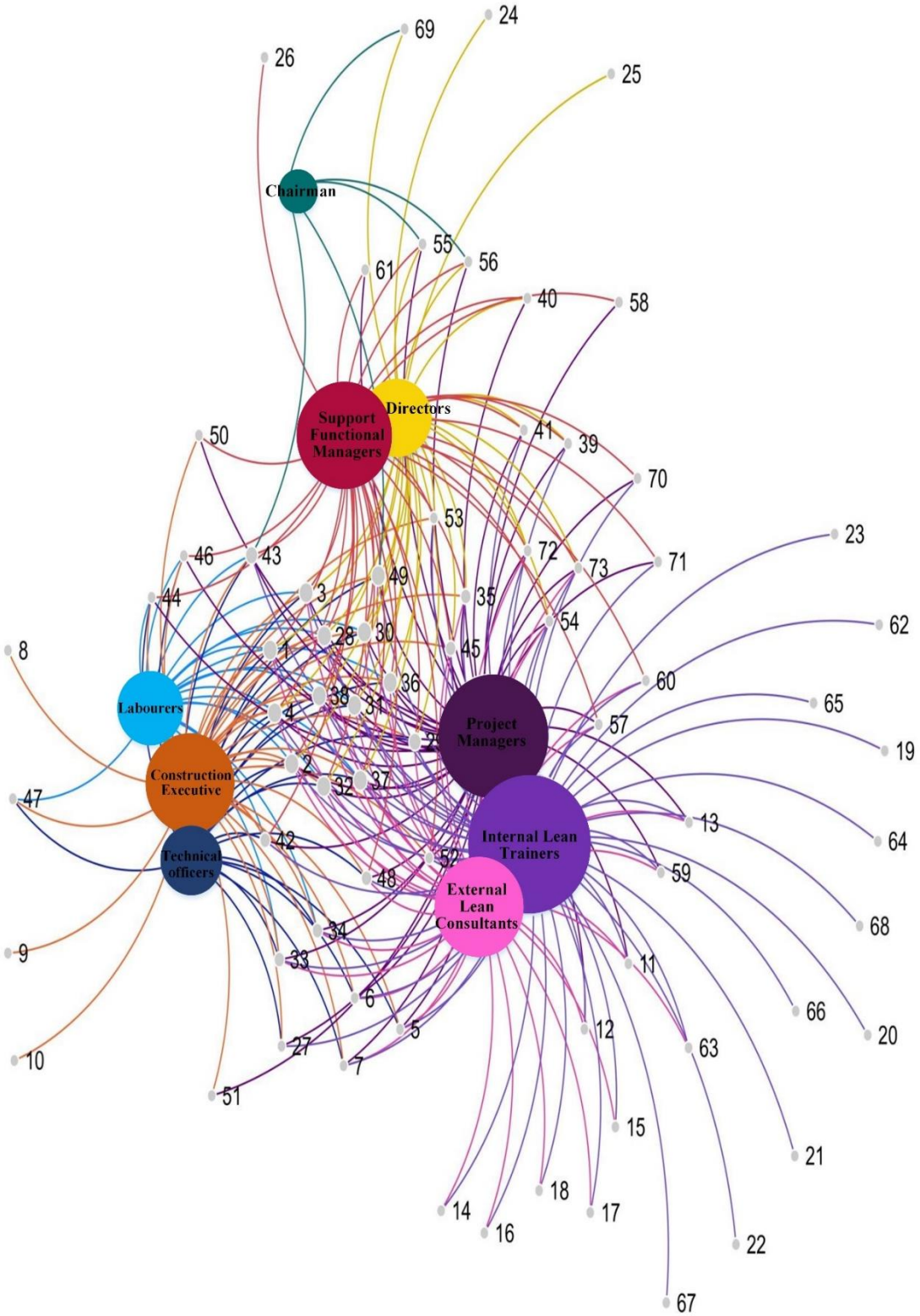
The roles of lean learners that have already been identified both in the literature as well as those that respondents have noticed have been highlighted in green in Table 5, such as 'organising lean learning programmes' and 'devising strategies to improve them'. Furthermore, the roles of lean learners that have already been established through literature are coloured in blue, whereas all other factors are the new empirical findings of the research.

4.2.Development of Force-Directed Graph for Lean Learners and Their Roles

Figure 3 maps the diverse types of lean learners and their roles in lean learning and implementation through a force-directed graph. This force-directed graph was created using Power BI software through feeding the empirical data derived from interviews and document reviews. The numbers

in this force-directed graph (Figure 3) indicate the roles of lean learners, as listed in Table 5, and those numbers are linked to nodes that symbolise lean learners. The size of a node represents the significance of a particular lean learner in the process of lean implementation in the construction industry.

Figure. 3. Lean learners and their roles



As a result of this investigation, a total of seventy-three roles of lean learners have been discovered, which are vested in nine lean learners. Furthermore, the size of the node represents the level of responsibility and significance of a specific lean learner. Accordingly, the project managers and the internal lean trainers emerged with noteworthy responsibilities in the organisation's lean learning procedure. There are forty-one roles that lean learners can play, according to the literature (Bateman et al., 2003; Hirota et al., 1999; Hirota and Formoso, 1998; Mossman, 2015). However, this was extended with another thirty-two roles at the end of the case study analysis.

5. Discussion of research finding

The findings on lean learners and their roles are consistent with Bateman *et al.* (2003), Hirota *et al.* (1999), Hirota and Formoso (1998), and Mossman's (2015) research findings. Further, Labourers (Labourers/ Construction operators), Technical Officers, Construction Executives (Engineers/ Quantity Surveyors/ Designer), Project Managers (Project managers/ General managers), External Lean Consultants, Internal Lean Trainers, Directors, Support Functional Managers, and Chairman (CEO/CED/Chairman) were recommended as lean learners in the lean learning process by (Parameswaran and Ranadewa, 2023). Olav et al. (2018) underlined that establishing a sustainable lean culture among employees necessitates, first and foremost, the commitment of all parties involved in the organisation. Besides, case study data indicates that when the lean learning procedure is implemented, all employees in the construction organisation are eventually becoming lean learners. As a result, the research confirmed nine (9) categories of lean learners, which were identified through literature, including labourers/construction operators, technical officers, engineers/quantity surveyors/designers, project managers/general managers, external lean experts, company lean trainers, directors, support functional managers, and CEO/CED/chairman. Thereafter, these individuals who were recognised as lean learners were classified into the following: labourers, technical officers, construction executives, project managers, external lean consultants, internal lean trainers, directors, support functional managers, and the chairman.

Several studies have found that lean concept is facing barriers to gain its envisioned benefits due to a lack of control and planning (Al Balkhy *et al.*, 2021; Albalkhy and Sweis, 2021; Khaba and Bhar, 2017; Mano *et al.*, 2021), inappropriate resource management (Ahmed *et al.*, 2021; Ahmed

and Sobuz, 2020; Al Balkhy *et al.*, 2021; Albalkhy and Sweis, 2021; Khaba and Bhar, 2017), project participants' reluctance to share risks (Al Balkhy *et al*., 2021; Albalkhy and Sweis, 2021), poor traning (Albalkhy and Sweis, 2021; Cano *et al*., 2015; Hamzeh *et al.*, 2016; Khaba and Bhar, 2017; Ogunbiyi, 2014), delays and avoid taking responsibility and decision making (Adegbembo *et al*., 2016; Ahmed *et al.*, 2021; Sarhan *et al.*, 2018; Shang and Pheng, 2014), lack of motivation(Ahmed and Sobuz, 2020; Al Balkhy *et al.*, 2021; Olatunji, 2008; Sarhan *et al.*, 2018) and an inability to monitor long-term project progress and performance (Ahmed and Sobuz, 2020; Bashir *et al.*, 2015; Mano *et al.*, 2021; Omran and Abdulrahim, 2015; Sarhan *et al.*, 2018). These barriers can be effectively mitigated through the identified roles of lean learners. The following section discusses the significance of each lean learner for a successful lean implementation as per the empirical findings.

5.1.Internal Lean Trainers

According to the literature (Table 3), construction executives, project managers, external lean consultants, and internal lean trainers are the learners in the lean learning procedure in the construction organisation who have a greater variety of roles compared to other learners. However, research findings (Figure 3) emphasised that the project managers and the internal lean trainers have substantial roles in the organisation's lean learning procedure since they are the ones in charge of it. Moreover, the internal lean trainers are the first category of lean learners who play a more important part in the lean learning process because the internal lean trainers are an internal team charged with overseeing the organisation's lean learning process. Accordingly, the majority of the barriers mentioned in the literature can be addressed by internal lean trainers who design a detailed plan, implement it, monitor it, and control it. As a result, the internal lean trainer’s roles began with preparing a detailed plan for the entire lean learning programme, obtaining managerial approval for the plan, evaluating progress, providing rewards, conducting regular site inspections, selecting the most critical tool for the organisation and project, keeping records to track performance, reporting to upper management and keeping an eye on the progress. In addition, the internal lean trainers continued to develop a strategy, lead the company board through the lean process and other roles as the person in charge of the entire organisation's lean learning procedure. Finally, the internal lean trainer's roles concluded with the participant for learning with involvement, participating in PI activities, contributing to CI activities, and other roles as learners.

Internal lean trainers' roles, as indicated by Bateman *et al.* (2003) and validated by the empirical investigation, include developing lean programmes and organisational and lean strategies. Therefore, it is crucial that internal lean trainers must be involved in the implementation of lean in the construction organisation. As a result, it is impractical to implement lean in the construction organisation without the support of internal lean trainers.

5.2.Project Managers

This lean learners category encompasses project managers. As highlighted by Meng and Boyd (2017), the significance of project managers is evident, given their substantial influence on crucial aspects such as time, cost, and quality, constituting primary objectives in construction project management. Likewise, this study underscores the pivotal role of project managers in lean learning procedures, emphasising their responsibility for implementing lean practices at the project or site level. Consequently, the second most significant team of lean learners, is comprised of project managers. This prominence arises from their responsibility for project or site-level lean implementation. The general manager further extends the impact by overseeing project or site-level and head office divisional-level lean implementation, thus solidifying their pivotal role in the overall lean learning process. Furthermore, a division manager's role is to encourage and monitor his staff's efforts to develop continuously (Olav *et al.*, 2018). Consequently, the project managers' roles expanded to include participants in learning with involvement, participation in PI activities, contributing to CI activities (Bateman et al., 2003), and other roles as learners. Furthermore, the project managers are responsible for motivating to learn, changing the company culture and persuading employees to commit to continuous learning, making decisions in high-risk situations, planning, coordinating, and controlling the activities, as well as other roles outlined by the Hirota et al., (1999) and Hirota and Formoso (1998). On the other hand, an empirical study found that project managers are accountable for providing training to site learners in a manner that they can comprehend, keeping records to measure performance and report to upper management, and selecting the most crucial tool for the organisation and project, determine any modifications that need to be made in order to build a lean culture, implement the strategy, lead the team conducting frequent site inspections, keep an eye on your progress, and other roles as the project or site level and head office divisional level lean implementation lead. Therefore, it is crucial that project managers must be involved in the implementation of lean in the construction organisation.

5.3.External Lean Consultants

The construction executives, external lean consultants, and support functional managers are the third significant category, with a higher number of roles in the organisation's lean learning process. External lean consultant engagement is essential to this lean implementation because it is the team that was outsourced by the organisation to execute lean efficiently. Pekuri *et al*. (2012) underscored the importance of allocating sufficient resources for cultural transformation within management, emphasising that supporting learning necessitates the implementation of training programs and the involvement of external lean consultants. According to Olav *et al.* (2018), external lean consultants attempt to incorporate and encourage employees personnel at all levels in the pursuit of continuous improvement. Even though external lean consultants' roles are similar to internal lean trainers' roles. However, in comparison to internal lean trainers, their responsibilities are limited because they are not responsible for developing lean programmes, managing lean processes, resources, and ensuring commitment, developing strategy, leading company boards through lean processes, deciding under risk circumstances, planning, coordination, and controlling, participating in learning with involvement, and other roles listed by Bateman *et al.* (2003) and Hirota and Formoso (1998). In addition, this argument has also been supported by the research findings, as it is not the responsibility of external lean consultants to formulate a detailed plan for the entire lean learning programme, keep records to monitor performance, and report to senior management and other roles. Determining the most important tool for the project or organisation, identifying NVAA, managing resources for lean activities, developing value streams to transfer the best practices, ensuring the quality of PI and CI activities, providing proper lean learning, monitoring the progress, motivating them, and other tasks cannot be accomplished without the support of external lean consultants. Therefore, their role is crucial in the implementation of lean.

5.4.Construction Executive

Engineers, quantity surveyors and designers are included in this category of lean learners. Construction executives have identical roles to project managers. However, Bateman *et al.* (2003) and Hirota and Formoso (1998) stated that compared to project managers, construction executive roles are restricted because they are not involved in managerial activities such as planning, coordinating, and controlling the lean implementation, ensuring transfer of best practices between

value streams, setting agenda for PI and CI activities in value streams and other roles. Similarly, research findings support this contention by keeping track of its progress and continuity, choosing the most critical tool for the project and organisation, decision-making, progress evaluation, leading the team, implementing the strategy and performing other roles that do not fall under the purview of construction executives. Furthermore, Hamza *et al*. (2022) asserted that ineffective labour supervision and insufficient management and planning adversely affect construction labour productivity and performance. Therefore, the role of the construction executive is pivotal. This involves visiting different sites where the lean concept has been implemented, providing training to site learners in a manner comprehensible to both labourers and other learners, maintaining records to monitor performance and reporting to top management, informing learners about the proposed strategy, identifying challenges faced by learners during lean implementation, informing upper-level staff of these challenges, ensuring the transfer of best practices between cells, and undertaking other relevant activities.

5.5.Support Functional Managers

Furthermore, support functional managers are professionals that encompass all support functional managers in the organisation's hierarchy or head office staff in all divisions. Support functional managers, like project managers, have comparable roles. Even though, in comparison to project managers, their roles are limited since their involvement in projects or at the site level is lower. As a result, they are not responsible for selecting the project's most critical tool, providing training to site learners in a way that they can comprehend, and other roles. However, the success of the lean implementation in the head office depends on the support functional managers' ability to select the most important tool for the organisation, lead the team to identify and remove NVAA at the head office level, inform learners about the proposed strategy, guide functional departments through lean change, monitor the progress and continuity of the lean implementation, participant for learning with involvement and complete other activities.

5.6. Labourers

This category of lean learners includes labourers and construction operators. Labour is acknowledged as the most critical and adaptable resource utilised in construction projects, with productivity directly linked to the efficiency and effectiveness of labour (Muqeem *et al.*, 2012). Similarly, labourers play a crucial role in the success of lean implementation since they are the

individuals on-site responsible for carrying out the actual work; until they fulfil their role effectively, lean implementation cannot be achieved. According to Bateman *et al.* (2003), Hirota *et al*. (1999) and Mossman (2015), labourers' roles are mostly focused on learning and evaluating their learning progress. Likewise, empirical research has proven that labourers are primarily involved in learning. In addition to the results from the literature, the study revealed that labourers must notify higher-level staff members of the difficulties in implementing lean, receive their suggestions, and put them into practice.

5.7.Directors

In line with Bateman *et al.* (2003), Hirota *et al*. (1999), Hirota and Formoso (1998) and Mossman (2015), this research finding confirms that the roles of directors are primarily focused on decision-making and strategic development as top-level managerial staffs, as well as engagement in learning as a learner. The main barriers to lean implementation, such as delays, avoidance of making decisions (Ahmed *et al.*, 2021; Sarhan *et al.*, 2018), inadequate commitment, and lack of support from top management (Al Balkhy *et al.*, 2021; Mano *et al.*, 2021) can be eliminated, according to the director's involvement in the process. As a result, the director role is essential for the successful implementation of lean.

5.8.Technical Officers

Technical officers perform a similar role to labourers. Additionally, technical officers supervise labourers to ensure that they implement lean effectively on the construction site; for these reasons, it is essential that technical officers participate in the implementation of lean at the site level. Moreover, technical officer training encompasses a series of activities designed to assist individuals in construction or related fields in acquiring the necessary knowledge, skills, attitudes, and motivations to perform specific tasks or jobs effectively (Femi, 2014). Further, Bateman *et al.* (2003) and Mossman (2015) pointed out the fact that in addition to learning, technical officers have a responsibility to lead CI activities, lead close out of PI activities and manage resources for activities. Femi (2014) emphasised that technical officers play a crucial role in the practical realisation of any construction project. These professionals are primarily involved in the technical aspects of construction, and at the management level, they serve as supervisors. Their role includes interpreting company policies into the practical realisation of organizational goals set by the

employer. This is supported by research findings, which also show that technical officers' responsibilities include tracking progress following the implementation of lean, advising and motivating labourers to improve, and ensuring that maximum output is achieved. Similarly, Femi (2014) suggested that technical officer training plays a vital role in helping organizations plan and meet their future workforce requirements. Therefore, it is crucial that technical officers are involved in the implementation of lean at the site level.

5.9.Chairman

Finally, this category of lean learners comprises the CEO, CED, and Chairman. Olav *et al.* (2018) emphasised the importance of top management focusing on condition and performance. Roberts (2002) asserts that chairmen and other non-executives play a crucial role in making a positive and effective contribution to the strategic direction and control of companies as integral members of the board team. Contrary to Bateman *et al.* (2003), Hirota *et al*. (1999), Hirota and Formoso (1998) and Mossman (2015), research revealed that the chairman is a lean learner with fewer roles than others at the top of the organisation's structure and has ultimate decision and strategy-development authority. As a result, the chairman has specific responsibilities in lean implementation, including providing approval for lean learning, participating in learning with involvement, advising and motivating employees to develop and achieve their full potential, implementing the strategy, and making decisions to improve or move to the next level of lean implementation.

This analysis emphasises that without the involvement of any identified lean learners and their roles, it is impossible to achieve successful lean implementation; as a result, it has been shown that the participation of all identified lean learners and their roles is necessary to accomplish successful lean implementation. According to several authors, the lack of clarity about individual accountability is a barrier to lean implementation in the construction industry (Ahmed *et al.*, 2021; Ahmed and Sobuz, 2020; Omran and Abdulrahim, 2015; Sarhan *et al.*, 2018). In addition, there were few studies on lean learners and their roles in the construction industry (Hirota *et al.*, 1999; Hirota and Formoso, 1998; Mossman, 2015). However, some studies focused on lean learners and their roles in lean learning procedures in the manufacturing industry (Bateman *et al.*, 2003). This force-directed graph was developed for lean learners and their roles in the Sri Lankan construction industry's lean learning procedures. Even though this developed force-directed graph for lean

learners and their roles in lean learning procedures is limited to the Sri Lankan construction industry, however, it can be widely applied to the entire construction industry because lean learners and their roles in lean learning procedures are common to all construction organisations. However, the lean learners' category will be changed in accordance with the construction organisation hierarchy. Additional or any adjustments can be made under the identified nine lean learners category because the group is divided based on the roles, so any changes to the lean learners' categories can be made based on that. It also serves as a platform for researchers to establish a lean learning framework for the construction industry.

6. Conclusions and Way Forward

The implementation of lean practices in the construction industry has proven to be advantageous. However, the challenges associated with lean implementation, particularly the lack of clarity among construction industry professionals regarding their roles in supporting this implementation, have posed significant obstacles. Consequently, there is a pressing need to ascertain the specific roles of lean learners in integrating lean methodologies within construction organisations. Thus, this research endeavours to identify and define the roles of lean learners in the construction industry through an extensive literature review and empirical research. The literature review has identified nine distinct types of lean learners, namely labourers, technical officers, construction executives, project managers, external lean consultants, internal lean trainers, directors, support functional managers, and chairmen. Moreover, the literature has proposed forty-one roles attributed to these lean learners, while the empirical findings have contributed an additional thirty-five activities. Ultimately, this study has successfully mapped the nine lean learners and their seventy-three roles using a force-directed diagram.

The findings further revealed that the project managers and the internal lean trainers were noted as the key players in the lean learning process. On the other hand, the Chairman is the least significant lean learner who has fewer roles than other learners. Accordingly, the study's findings show that it is impossible to successfully integrate lean in a construction organisation or project without the involvement of the project managers and the internal lean trainers. The results of the study revealed that in order to implement lean construction in the organisation or project, all stakeholders within the organisation must be involved and should be aware of their roles in this

process. The main contribution of this study is the force-directed graph that was developed to define lean learners and their roles in implementing lean learning practises in the construction organisation. Further, it can serve as a guide for lean practitioners and other professionals in the construction industry who want to implement lean successfully in their organisations.

This investigation holds significant practical implications for the construction industry by advocating the adoption of lean construction practices, specifically through the incorporation of lean learning methodologies elucidating the roles of lean learners. It sheds light on the advantages of implementing lean construction, emphasising its competitive edge when coupled with a clear understanding of lean learners' roles. A critical finding underscores the potential interference to successful lean integration caused by the lack of clarity among professionals regarding their responsibilities in sustaining lean implementation. Consequently, this study underscores the significance of comprehensive lean learning practices to maximise their value in the industry. The developed force-directed graph in this study will be beneficial for construction professionals, outlining the roles of lean learners in implementing lean in construction organizations. Through the utilisation of the force-directed graph, construction professionals could gain a clear understanding of their specific roles in the lean implementation and learning processes, enabling them to contribute more effectively to the successful integration of lean practices within their organisations. This research also enriches existing theoretical knowledge on the subject by delineating the roles of lean learners within lean learning practices implemented in construction firms. Given the scarcity of literature addressing the role of lean learners in the construction industry, the findings of this study can serve as a benchmark for future studies investigating similar aspects, especially regarding the scope and magnitude of construction projects.

6.1.Limitations of the study and future research directions

While the findings of this study contribute to knowledge and practice, it is crucial to acknowledge the context-bound nature of the results, stemming from the exclusivity in data collection from Sri Lanka. Therefore, future research directions could delve into lean learners and their roles in various country setups to enrich the understanding of lean implementation dynamics. As a qualitative study, criticised for its limitation in generalisability by prior research (Shorten and Smith, 2017), it is essential to recognise that the critique often stems from a statistical-probabilistic generalisability lens, more apt for quantitative studies. The limitations in generalisability inherent

in qualitative research could be addressed by employing suitable quantitative analysis techniques in future research, thus expanding the insights gained from this study within a proper context. Furthermore, future research directions could explore the practical implications of integrating the developed force-directed graph into the lean learning process across diverse construction types. Such an exploration holds the potential to significantly impact the global construction industry by fostering successful lean implementation on a worldwide scale.

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