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LEAN INTEGRATED CIRCULAR ECONOMY IN THE SRI LANKAN CONSTRUCTION INDUSTRY: A QUALITATIVE DELPHI STUDY

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ABSTRACT

The construction industry is known for its significant environmental impact and waste generation. To address this issue, the concept of Circular Economy (CE) has emerged, aiming to minimise waste and maximise resource utilisation. However, there are several barriers which impede the implementation of the CE concept in the construction industry. Therefore, this research aims to incorporate the lean concept to overcome the barriers of CE implementation in the construction industry. Therefore, this research develops a framework for a lean-enabled CE in the construction industry. The qualitative approach is used for this paper, and the Delphi technique was adopted. Purposive sampling was used to select the experts for the study, and data were analysed through manual content analysis. The findings revealed 10 benefits from CE and 12 benefits from Lean were identified, along with 8 benefits of CE and Lean integration. Furthermore, 19 barriers were identified towards this integration, and 12 strategies were identified to overcome these barriers. This study also provides a comprehensive mapping between CE and Lean implementation benefits, their integration benefits and barriers, and strategies. In addition, integrating lean and CE for the construction industry can lead to many significant benefits, such as cost savings, improved environmental performance, and enhanced stakeholder engagement.

Keywords: *Benefits; Circular Economy; Construction Industry; Lean Construction; Sri Lankan.*

1. INTRODUCTION

The construction industry is one of the industrial sectors that significantly contributes to many negative impacts on the environment, such as carbon emissions, resource depletion,

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waste generation, land degradation, and loss of biodiversity (Ryłko-Polak et al., 2022; Viknaruban et al., 2024). To overcome these negative impacts, at present, various sustainable practices have been introduced to the construction industry. Among them, CE (Circular Economy) holds a significant place, and it can be identified as a shift towards a closed loop instead of the ordinary linear method of construction holds an important place as it reduces the extraction of natural resources whilst managing the construction and demolition waste (EMF, 2015; Peck, 2023; Pomponi & Moncaster, 2017; Wang et al., 2019). Further, according to Valencia et al. (2023), the CE plan aims to extend the valuable existence of materials and components through repair, refurbishment, or remanufacturing, and then recycling once the end-of-life is unavoidably reached. However, the construction industry's effective application of CE is still in its early stages (Adams et al., 2017; Leising et al., 2018).

Many researchers highlighted the barriers to the CE, which can be summarised as cultural, financial, technological, regulatory, and environmental (Campbell-Johnston et al., 2019; Hart et al., 2019). Thus, these barriers caused budget and upfront costs (Adams et al., 2017; Guerra et al., 2021), schedule and project timeline (Hart et al., 2019), lack of awareness and change resistance (Benachio et al., 2020), and the current construction business model (Guerra & Leite, 2021) and a lack of regulations and implementation guidelines (Valencia et al., 2023) for the execution of certain circular strategies. To overcome these causes for the proper implementation of CE in the construction sector, lean is an appropriate approach to tackle this circumstance, as many surveys and empirical investigations have shown that the most adaptable lean methods can be applied to overcome barriers (Bajjou et al., 2017; Tezel & Aziz, 2017). On the other hand, Nadeem et al. (2019) emphasised that although lean construction and CE use distinct methods for their two primary shared aspects of "waste elimination" and "value creation," their combination appears natural to complement each other and considerably benefit the CE to be realistic, simple, and easy. According to Ciliberto et al. (2021), one of the matrices showed the existence of a strong, positive interaction between CE principles and lean strategies.

Accordingly, the CE aims to increase the management of building materials by treating them as valuable resources even after a building reaches the end of its life cycle, thereby reducing waste generation. Lean construction focuses on advancing building value by minimizing waste and increasing productivity. Thus, the synergy between these two concepts indicates that their integration could offer significant improvements to the construction industry (Benachio et al., 2021). Still, this combined approach has received limited attention in the construction industry, emphasizing the need for further investigation. Therefore, analysing and exploring the CE and lean combination in the construction industry will make a fresh approach.

The connections between lean and CE allow their integration, likely to deliver improvements to the construction industry (Benachio et al., 2021) because the integration of lean with the CE permits the design of a new "sustainability-oriented" business strategy, with the financial aim of the construction industry (Ciliberto et al., 2021). However, several studies have explicitly discussed lean construction (Parameswaran & Ranadewa, 2024; Ranadewa et al., 2021; Uhanovita et al., 2025) and CE (Bekchanov & Mirzabaev, 2018; Wijewansha et al., 2021) in the Sri Lankan construction industry, but there is a lack of research explicitly linking lean construction to the CE, and they are focused on lean principles and CE principles (Benachio et al., 2021; Nadeem et al., 2019).

Hence, this paper aims to develop a framework integrating Lean and CE towards achieving a sustainable construction industry. To achieve the aim of the study the study followed four objectives as; to investigate benefits of implementing CE and Lean in the Sri Lankan construction industry, to investigate the benefits of integrating lean into the CE in the construction industry, to analyse the barriers to integrate Lean into the CE in the construction industry, to propose strategies to overcome the barriers to integrate lean to the CE in the construction industry. This paper consists of a comprehensive literature review followed by the methodology adopted, findings, and the analysis of them, as well as the conclusion and recommendations of the study.

2. LITERATURE REVIEW

2.1 BENEFITS OF CE IMPLEMENTATION IN THE CONSTRUCTION INDUSTRY

The concept of CE has been grabbing traction in the construction industry because applying its principles can significantly reduce a building's negative environmental effects (Smol et al., 2015). However, its use in the construction sector is still in its early stages (Pomponi & Moncaster, 2017). According to the industry's current trends and practices, the CE may help ensure the sector's sustainability (Awan et al., 2021). Given that the CE may play a significant role in lowering the environmental impact of construction operations, the first step is to comprehend how the CE could benefit the construction sector (Ghisellini et al., 2018). Table 1 comprises the benefits of the CE in the construction industry.

Table 1: Benefits of the CE in the construction industry

No	Benefits	References
1	Reducing waste	[1], [2], [4], [5], [8], [10]
2	Time savings	[1], [2], [3], [5], [8], [10]
3	Cost savings	[1], [2], [4], [6], [8], [9]
4	Increasing the productivity of materials	[5], [7], [8], [1]
5	Maintaining or increasing the value of materials	[4], [5], [8], [9], [10], [11]
6	Increased resilience	[6], [8], [9]
7	Regulatory compliance	[8], [9], [11]

[1] - (Zuofa et al., 2023), [2] - (Barnabè & Nazir, 2022), [3] - (Campbell-Johnston et al., 2019), [4] - (Barón et al., 2020), [5]- (Charef, 2022), [6] - (Rahla et al., 2021), [7] - (Adams et al., 2017), [8] - (Merli et al., 2018), [9] - (Mangialardo & Micelli, 2018), [10] - (Quedou et al., 2021), [11] - (Charef et al., 2021)

Overall, Table 1 provides a concise and clear overview of the benefits of the CE approach, which can be helpful for individuals or organisations who are considering adopting this approach. However, it should be noted that the list of benefits is not exhaustive and that the actual benefits may vary depending on the specific context and implementation of the CE practices. Moreover, there is a variety of R principles to incorporate the CE into the construction industry. Finally, the CE approach in the construction industry can lead to significant environmental, economic, and social benefits (Zuofa et al., 2023). However, achieving a CE in the built environment will require collaboration among stakeholders and policy support from governments (Mhatre et al., 2023).

2.2 BENEFITS OF IMPLEMENTING LEAN IN THE CONSTRUCTION SECTOR

Construction projects frequently experience challenges, including cost overruns and schedule delays (Aziz & Hafez, 2013; Bajjou et al., 2017). Additionally, the construction industry experiences significant problems with low quality (Marhani et al., 2012), inadequate construction safety (Young et al., 2016), and negative environmental effects (Parameswaran et al., 2024). Moreover, lean construction has gained significant popularity in recent years as construction organisations seek to improve their operations and deliver projects more effectively (Parameswaran et al., 2025). In this context, it is important to understand the benefits of lean construction to appreciate why it has become a preferred approach in the construction industry. Some of the key benefits of lean construction include improved efficiency, cost savings, increased quality, better safety, and enhanced team morale (Bajjou & Chafi, 2018; Ghisellini et al., 2018). By adopting lean construction principles, construction organisations can achieve better project outcomes, reduce waste and costs, and increase their competitive advantage (Aslam et al., 2020). Many researchers highlighted benefits and improvements by adopting lean construction within construction projects, as shown in Table 2.

Table 2: Benefits of lean construction in the construction industry

No	Benefits	References
1	Lower costs and faster turnover of construction projects	[1], [2] [3] [4] [7] [9]
2	Improving the quality	[3] [4] [6] [8] [9] [10]
3	Better planning and scheduling	[3] [5] [6] [8]
4	Better risk and safety management	[1] [4] [5]
5	Improving the safety of workers	[2] [5] [10]
6	Improving the environmental performance	[4] [6] [7] [9] [10]
7	Reducing the total project duration	[1] [2] [3] [8] [9] [10]
8	Greater customer satisfaction	[2] [5] [8]
9	Increased team productivity	[6] [8] [9][10]
10	Better management of changing priorities	[1] [5] [6][7]
11	Real-time access to relevant information	[3] [7] [8][10]

[1] - (Salem et al., 2005), [2] - (Aziz & Abdel-Hakam, 2016), [3] -(Bajjou et al., 2017), [4] - (Sarhan et al., 2017), [5]- (Marhani et al., 2012), [6] - (Bajjou & Chafi, 2018), [7] - (Oakland & Marosszeky, 2017), [8]- (Hyatt, 2011), [9] - (Saieg et al., 2018), [10] - (Eriksson, 2010)

The provided Table 2 appears to be a list of benefits associated with a certain approach or method for construction projects. The references cited for each benefit suggest that the approach has been studied and tested in various contexts and has been found to yield positive results. According to Table 2, lower costs, improving the quality and reducing the total production are highly mentioned by authors. Overall, the information suggests that the approach in question has the potential to improve construction project outcomes across multiple dimensions significantly. This could be of great interest to stakeholders in the construction industry, as well as to policymakers and others concerned with promoting sustainable and efficient building practices (Ahmed et al., 2021). Moreover, lean techniques are adding more value by adopting lean construction into the construction sector.

2.3 INTEGRATION OF LEAN CONSTRUCTION INTO THE CE

When it comes to their two main components of "waste elimination" and "value creation," lean and the CE take distinct approaches (Nadeem et al., 2019). The CE employs a closed-loop system, which the lean approach does not, and is not as comprehensive as it is.

Lean's emphasis on process optimisation is restricted to a single supply chain. However, the supply chain is enlarged to a much larger viewpoint under the circular economy's perspective of systems effectiveness and thinking, where value identification and the stream are not restricted to one life cycle of the product or supply chain but instead continue to evolve (Benachio et al., 2021). The lean construction idea of mapping the value stream in the resource, establishing flow inside the closed loop system, and pursuing excellence via continuous enhancement can help realise the circular economy's emphasis on protecting and increasing natural capital. Similarly, closed-loop flow can be established by generating only what is needed, and resource yield optimisation can be accomplished while pursuing perfection through continual improvement (Nadeem et al., 2019). Lean's philosophy of mapping value streams within resources and producing flow within a closed-loop system, combined with the pursuit of perfection through continuous improvement, can be applied to achieve the circular economy's focus on preserving and increasing natural capital. The resource yield optimisation can be accomplished similarly by creating pull by just producing what is needed, and again by building closed loop flow while pursuing excellence through continuous improvement (Nadeem et al., 2019).

2.4 BENEFITS AND BARRIERS FOR THE INTEGRATION OF LEAN CONSTRUCTION INTO THE CE

Table 3 consists of a summary of the literature discussed on the benefits and barriers of CE and Lean integration.

Table 3: Benefits of the integration of CE and lean in the manufacturing industry

Benefits	Barriers	References
Reduction of waste and resource consumption	Reluctant to change	(Salibi et al., 2022; Hartini et al., 2021)
Cost savings	Lack of awareness and understanding	(Kurdve & Bellgran, 2021; Lim et al., 2022)
Enhanced product quality and customer satisfaction	Poor documentation and tracking of materials and processes across the supply chain	(Salibi et al., 2022; Lim et al., 2022)
Compliance with regulations and standards	Limited research and innovation	(Salibi et al., 2022; Kurdve & Bellgran, 2021)
Improved reputation and brand image		(Hartini et al., 2021)

Table 3 summarises the benefits of integrating CE and lean in the manufacturing industry based on several references. The integration of CE principles and lean manufacturing practices can provide numerous benefits to the manufacturing industry. These benefits include reduced waste and resource consumption, cost savings, improved product quality and customer satisfaction, compliance with regulations and standards, and enhanced

reputation and brand image. The studies cited in the table provide evidence for these benefits and suggest that companies can achieve these advantages through various approaches such as eco-design, product lifecycle management, closed-loop supply chains, and waste reduction programs (Salibi et al., 2022). Overall, the adoption of CE and lean principles can help companies improve their sustainability, competitiveness, and overall business performance. Although there are inadequate researchers who highlight the convergence between lean and CE in the construction sector, this convergence remains underexplored. So, with the help of these benefits, there is a possible chance for adopting a lean integrated CE into the construction industry.

3. RESEARCH METHODOLOGY

To achieve the aim of this study, an in-depth study was conducted to determine the aforesaid factors. Therefore, this study adopted a qualitative approach as it is best suited to obtain human expertise and opinions on a subject matter from different perspectives (Malterud, 2016). Further, the Delphi technique was used to collect the qualitative data to develop a set of experts' opinions (Hsu & Sandford, 2007). Generally, a Delphi study consists of two or three rounds of interviews, whereas this study is limited to two interview rounds (Aghimien et al. 2020; Ameyaw et al. 2016). Thus, a two-round Delphi technique was used to achieve the objectives of the study. Experts were selected using purposive sampling, as it is optimal for qualitative studies (O'Reilly & Parker, 2013). Purposive sampling is more closely aligned with the research aims and objectives, as it involves selecting individuals who possess substantial experience/knowledge related to the topic. The selection criteria used for the purposive sampling are shown in Table 4. Further, studies adhere to a predefined set of criteria when selecting experts, as the reliability of the results largely depends on the quality of expert recruitment, as shown in Table 4. Accordingly, all experts were selected through purposive sampling, ensuring their relevant expertise and familiarity with lean and CE within the construction industry were taken into account. Manual context analysis was used to analyse the collected data from two interview rounds, as it helps to analyse qualitative data more effectively (Denscombe, 2014).

Table 4: Expert selection criteria

	Delphi round objectives
Delphi Round 1	Phase I – Identify the benefits of implementing CE in the construction industry in Sri Lanka Phase II – Identify the benefits of implementing Lean in the construction industry in Sri Lanka
Delphi Round 2	Phase I – Investigate the benefits of integrating CE and Lean in the construction industry Phase II – Identify the barriers towards integrating CE and Lean in the Sri Lankan construction industry Phase III - Investigate the strategies to overcome the barriers towards CE and Lean integration in the Sri Lankan construction industry and map the benefits of CE and Lean implementation.

Expert selection criteria								
Expert code	**Discipline**	**Qualifications:**		**Industry experience more than 8 years in construction**	**Awareness of the concepts:**		**Delphi round 1**	**Delphi round 2**
		Academic - Having at least a BSc degree in the Built Environment	**Professional – Obtaining a charter in the relevant field**		**Lean construction (Min 5 years)**	**CE (Min 5 years)**		
E01	General manager	✓	-	✓	✓	✓	✓	✓
E02	Senior Quantity Surveyor	✓	✓	✓	✓	✓	✓	✓
E03	Senior Quantity Surveyor	✓	-	✓	✓	✓	✓	✓
E04	Senior Quantity Surveyor	✓	-	✓	✓	✓	✓	✓
E05	Civil Engineer	✓	✓	✓	✓	✓	✓	✓
E06	Civil Engineer	✓	✓	✓	✓	✓	✓	✓
E07	Civil Engineer	✓	✓	✓	✓	✓	✓	✓
E08	Quantity Surveyor	✓	✓	✓	✓	✓	✓	✓
E09	Quantity Surveyor	✓	✓	✓	✓	✓	✓	✓
E10	Quantity Surveyor	✓	✓	✓	✓	✓	✓	✓
E11	Project Manager	✓	-	✓	✓	✓	✓	✓
E12	Associate Director	✓	✓	✓	✓	✓	✓	✓
E13	Project Coordinator	✓	✓	✓	✓	✓	✓	✓
E14	Project Engineer	✓	-	✓	✓	✓	✓	✓
E15	Site Engineer	✓	-	✓	✓	✓	✓	✓
E16	Project Manager	✓	-	✓	✓	✓	✓	✓

4. RESEARCH FINDINGS AND ANALYSIS

4.1 BENEFITS OF IMPLEMENTING CE AND LEAN IN THE CONSTRUCTION INDUSTRY

The literature review revealed 7 benefits of implementing CE in the construction industry. During the Delphi Round I – Phase I (DRI-PI), experts were given these benefits and asked whether they apply to the Sri Lankan context and asked to identify further benefits within the Sri Lankan construction industry. The literature review revealed 11 benefits of implementing Lean in the construction industry. During the Delphi Round I – Phase II (DRI-PII), experts were given these benefits and asked whether they apply to the Sri Lankan context and asked to identify further benefits within the Sri Lankan construction industry in terms of Lean implementation. Newly identified benefits are presented in *italics* in Table 5, and any changes to the benefits identified from the literature review have been indicated by **bold letters**.

Table 5: Benefits of implementing CE and Lean

Benefits of implementing CE in the construction industry – DR I -PI	Benefits of implementing Lean in the construction industry – DRI -PII
C1- Construction waste management	L1 - Lower costs and faster turnover of construction projects
C2 - Time savings	L2 - Improving the quality
C3 - Cost savings	L3 - Better planning and scheduling
C4 - Increasing the productivity of materials	L4 - Better risk and safety management
C5 - Maintaining or increasing the value of materials	L5 - Improving the safety of workers
C6 - Increased resilience	L6 - Improving the environmental performance
C7 - Regulatory compliance	L7 - Reducing the total project duration
C8 - Resource efficiency and reduction of resource extraction	L8 - Greater customer satisfaction
C9 - Reduction of carbon emissions	L9 - Increased team productivity and improved collaboration
C10 - New business opportunities for different stakeholders	L10 -Better management of changing priorities
	L11- Real-time access to relevant information
	L12 - Increased Client Satisfaction

The experts highlighted three new benefits from implementing CE in the Sri Lankan construction industry, apart from the seven benefits identified from the literature review. Further, experts renamed "reducing waste" to "**Construction waste management"** as shown in Table 5. E10 stated that "*One of the major benefits of CE is resource efficiency and reducing the amount of natural resource extraction*". E12 and E15 experts also confirmed the same by stating different keywords such as "closed loop", "R-principles". Furthermore, E09 highlighted a significant environmental benefit through CE implementation, specifically the reduction of carbon emissions. Another major fact

highlighted by experts was new business opportunities for stakeholders, specifically for profit seeking organisations.

4.2 BENEFITS AND BARRIERS OF INTEGRATING LEAN INTO THE CE IN THE CONSTRUCTION INDUSTRY

The literature review revealed 5 benefits which can be obtained through Lean and CE integration, while only four literature facts were available for barriers to integrating Lean and CE in the construction industry. During the DRII-PII, 15 new barriers were identified towards Lean and CE integration, and 3 new benefits of this integration were identified during DRII-PI interviews. Newly identified facts are presented in *italics*.

Table 6: Barriers and benefits of integrating Lean and CE

Barriers to integrating Lean into the CE in the construction industry – DRII-PII	**Benefits of integrating Lean into CE in the Sri Lankan construction industry DRII-P1**
BLC1 - Reluctant to change	BeLC1- Reduction of waste and resource consumption
BLC2 - Lack of awareness and understanding	BeLC2- Enhanced Project Time and Cost Performance
BLC3 - Preference for immediate gains over long-term sustainability benefits	BeLC3- Enhanced product quality and customer satisfaction
BLC4- Poor collaboration between departments and stakeholders hampers holistic implementation	BeLC4- Compliance with regulations and standards
BLC5- Incompatibility of processes	BeLC5- Improved reputation and brand image
BLC6- Lack of standardised practices	*BeLC6- Design for deconstruction and reuse*
BLC7- Poor documentation and tracking of materials and processes across the supply chain	*BeLC7- Enhanced stakeholder collaboration and engagement*
BLC8 - High upfront costs	*BeLC8- Regulatory and market advantages*
BLC9- Uncertain return on investment (ROI)	
BLC10- Funding constraints	
BLC11- Existing policies may not support or even hinder CE and Lean initiatives	
BLC12- Inconsistent standards	
BLC13- Weak implementation or monitoring of environmental and efficiency standards	
BLC14- Lack of training and education	
BLC15- The Workforce may lack the expertise to implement integrated Lean-CE strategies	
BCL16- Limited research and innovation	
BLC17- Difficulty coordinating circular and lean practices across diverse stakeholders	

Barriers to integrating Lean into the CE in the construction industry – DRII-PII	**Benefits of integrating Lean into CE in the Sri Lankan construction industry DRII-P1**
BLC18- Low stakeholder engagement	
BLC19- Weak mechanisms for learning and continuous improvement	

4.3 STRATEGIES TO OVERCOME THE BARRIERS TO INTEGRATING LEAN INTO THE CE IN THE CONSTRUCTION INDUSTRY

During DRII-PIII, experts suggested twelve strategies to overcome the barriers to integrating Lean and CE into the construction industry. Moreover, the recommended strategies are as follows.

Leadership commitment and vision (S1), Education and training (S2), Develop Expertise (S3), Pilot projects (S4), Data and metrics (S5), Collaboration and partnerships (S6), Capacity-building workshops (S7), Promote transparent data-sharing platforms (S8), Develop a certification scheme for Lean-CE integration (S9), Encourage long-term supplier and contractor partnerships (S10), Engage employees early with collaborative planning and feedback loops (S11), Emphasise the waste reduction cost savings from Lean processes (S12). Figure 1 illustrates the mapping of benefits from implementing CE and Lean in the construction industry, highlighting the connection between their integrated implementation and the strategies and barriers involved.

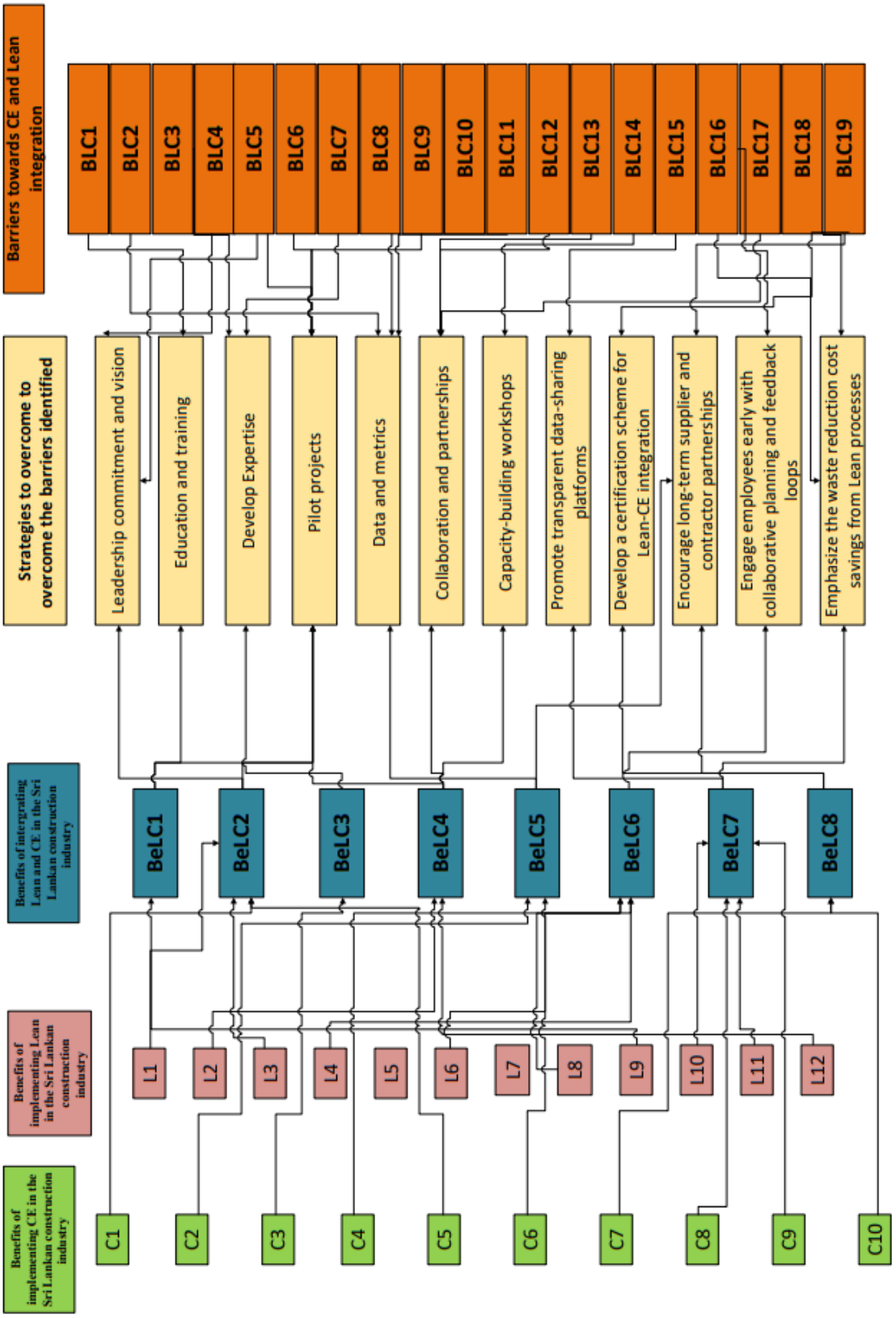

Figure 1: Final framework of the study

5. CONCLUSION AND RECOMMENDATIONS

In this research study, the CE for the construction industry was discussed. According to this study, the Sri Lankan Built environment can gain sufficient ideas. This study provides a list of the benefits of implementing CE and Lean in the construction sector and the connection between the benefits of integrating these two concepts. Further, this study analyses the barriers towards integrating CE and Lean and the strategies to overcome the barriers. To overcome those barriers, lean concepts and techniques were introduced in this research. Further, the study provided a framework that integrates Lean and CE to promote sustainability in the construction industry. In the Sri Lankan context, construction professionals lack knowledge regarding lean, lean techniques and CE as well. Through this research study, participants can enhance their understanding and skills related to lean and CE principles. The economic crisis has created project funding issues for the Sri Lankan construction industry; therefore, threats can be reduced by implementing a CE for the Sri Lankan construction industry. This study stands out among other studies as it is the only one to map various aspects, including the benefits and barriers of CE and Lean integration, along with strategies to overcome and enhance these integrations. Furthermore, the research contributes to the body of knowledge about the benefits and barriers of integrating Lean into the CE in the construction industry and strategies to overcome the barriers to integrating Lean and CE in the construction industry. As the scope of this research is conducted in the Sri Lankan construction industry, it can be developed for a specific type of construction, for example, road construction, building works, civil works and pile construction as well, because the types of wastages differ for one construction from another. Several barriers to implementing the CE were identified in this study. Future studies could focus on a specific barrier and explore methods to overcome it.

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