THE CIRCU-LEAN REVOLUTION: A REVIEW OF THE SYNERGIES BETWEEN LEAN AND THE CIRCULAR ECONOMY

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ABSTRACT (200)

Due to the impacts of industrialisation on the planet's environmental systems, industrial practice has had to evolve. Sustainable development goals have been set by the United Nations to limit industrial impacts on the environment. At the core of the development goals are the efficient use of materials and the reduction of waste. Two common production philosophies are becoming prevalent within the literature as a solution to consumption and waste within the construction industry, Lean and the Circular Economy (CE). Both provide aspects of green supply chain management that are required to meet the goals set by governments. There are clear synergies between the two philosophies though there are few investigations into their likeness within the literature. This paper aims to further investigate the synergies between Lean and the CE within the construction industry to develop the extant body of knowledge. The findings of the research identified that the majority of interactions between the concepts were positive although not entirely explored in construction. The core similarities surround waste reduction whereas the key differences are Lean's human management and the CE's closed-loop value retention. Therefore, it is suggested that a complimentary mixed Circu-Lean philosophy will be the future of production and construction.

KEYWORDS (5)

Lean Philosophy, Circular Economy, Circu-Lean, Construction, Built Environment

INTRODUCTION

Since the early innovations of man, the analysis of the economic system and its activities have brought forth knowledge for the advancement of the production process. Revelations in economic and production theory have revolutionised countries and humanity's way of life. Allowing production activities to produce higher quantities, higher quality, and in a shorter timeframe (Liker, 2004; Ghisellini *et al.*, 2016). By increasing these aspects of production, economies, and organisations have created competition for the best system structure (Shah and Ward, 2003; Liker, 2004). The creation of Mass and Lean production proposed differing philosophies which focus on aspects of the supply chain in order for improved outcomes such

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as quantity or value (Liker, 2004). Since the late twentieth century, the rhetoric has refocused on the impacts of the economy on organic life and the biological systems that support it (Huovila and Koskela, 1998; McDowall *et al.*, 2017; Ogunmakinde *et al.*, 2022). This is due to the analysis and understanding of the environmental impacts produced by economic activities. The results of which identified an unsustainable future for humanity without industrial change. Sustainable development goals set to limit the impact of humanity's expansion have been created by the United Nations (UN, 2022). The targets set by the United Nations commonly aim to reduce the number of resources consumed and the wastes concurrently produced in the development and maintenance of economies (UN, 2022). In this effort, the improved management of resources within the construction industry is proposed through waste-focused production philosophies and Supply-Chain Management (SCM) (Carvajal-Arango *et al.*, 2019; Hossain *et al.*, 2020; Ogunmakinde *et al.*, 2022).

Green Supply Chain Management (GSCM) is becoming more popular within academic literature (Kalemkerian *et al.*, 2022). In the development of a green philosophy of production to reduce waste, the benefits of Lean production in reducing waste and environmental impacts were identified (Huovila and Koskela, 1998; Marhani *et al.*, 2013; Carvajal-Arango *et al.*, 2019). The Lean philosophy's promotion of value through the reduction of waste in all its forms has provided a basis for green production. However, a more recent philosophy has grasped similar attention for the reduction of waste within the economic supply chain, the Circular Economy (CE) (Adams *et al.*, 2017; Geisendorf and Pietrulla, 2018; Chen *et al.*, 2021). The CE production philosophy creates a closed-looped flow of materials within the supply chain (MacArthur, 2013). The value of the original material input is the core focus of the philosophy and is therefore maintained throughout the supply chain (MacArthur, 2013). Thus, the CE reduces waste through the informed design and conservation of resources (Benachio *et al.*, 2020). Both the Lean and CE philosophies of production reduce waste within the supply chain to meet the demands of a modern sustainable industry. However, the synergies between the concepts are scarcely investigated in the literature with publications only appearing from 2021 (Benachio *et al.*, 2021; Schmitt *et al.*, 2021; Silva *et al.*, 2022). Furthermore, publications specifically looking at the synergy between the two concepts within the construction industry is limited to one pertinent journal publication by Benachio *et al.* (2021). This gap in knowledge requires addressing though as of yet the extant knowledge is yet to be coalesced. This paper aims to investigate extant literature surrounding the synergies between Lean and the CE within both manufacturing and the construction industry to coalesce and contrast current knowledge to guide future investigations into the synergies within construction.

RESEARCH METHODOLOGY

The research conducted was in the form of a systematic literature review, in which data was collected using Scopus, Web of Science, and Google Scholar by using keywords to search for the titles, abstracts, and keywords of extant literature. The following keyword strings were used; **String 1 (CE):** ("Circular Econom*" OR "Circular Practice" OR "circular manage*") AND ("construction industry" OR "construction" OR "built environment") ; **String 2 (Lean): (**"Lean Philosophy" OR "Lean Production" OR "Lean Principle") AND ("construction industry" OR "construction" OR "built environment"); **String 3 (Synergies) (**"Circular Econom*" OR "Circular Practice" OR "circular manage*") AND ("Lean Philosophy" OR "Lean Production" OR "Lean Principle"); **String 4 (Synergies in Construction): (**"Circular Econom*" OR "Circular Practice" OR "circular manage*") AND ("Lean Philosophy" OR "Lean Production" OR "Lean Principle") AND ("construction industry" OR "construction" OR "built environment"). Twenty papers were identified for String 3 and five papers were identified for String 4 within the literature, String 1 and 2 have large bodies of extant literature from which only core literature had to be selected for context.

The sampled papers were manually reviewed and excluded if they were not a journal article or were deemed irrelevant to the research or of a low quality. The final sum of papers for String 3 and 4 included eight journal articles on the synergies between the two topics, four of which were construction related. An interpretivist philosophy and deductive reasoning guided this study to review and compare the synergies within the literature (Saunders *et al.*, 2009). The selected literature from String 4 was analysed through content analysis to identify the core principles of the two concepts and their synergies (Saunders *et al.*, 2009; Patton, 2014). A qualitative research synthesis analysis was conducted to compare and contrast the results of the literature on the synergies using a matrix of the identified synergies within literature (Patton, 2014). The identified Lean principles have been numerically coded, and the CE practices have been assigned alphabetical codes for cross examination. The synergies within the literature were analysed individually and then overlayed to view the density of relationships. The synergies identified are shown within Table 6 to highlight commonalities, differences, and gaps within both topic areas as identified within the extant literature. Finally, the results of the matrix will be observed and discussed to understand the nature of said results and areas for future research to guide researchers and practitioners.

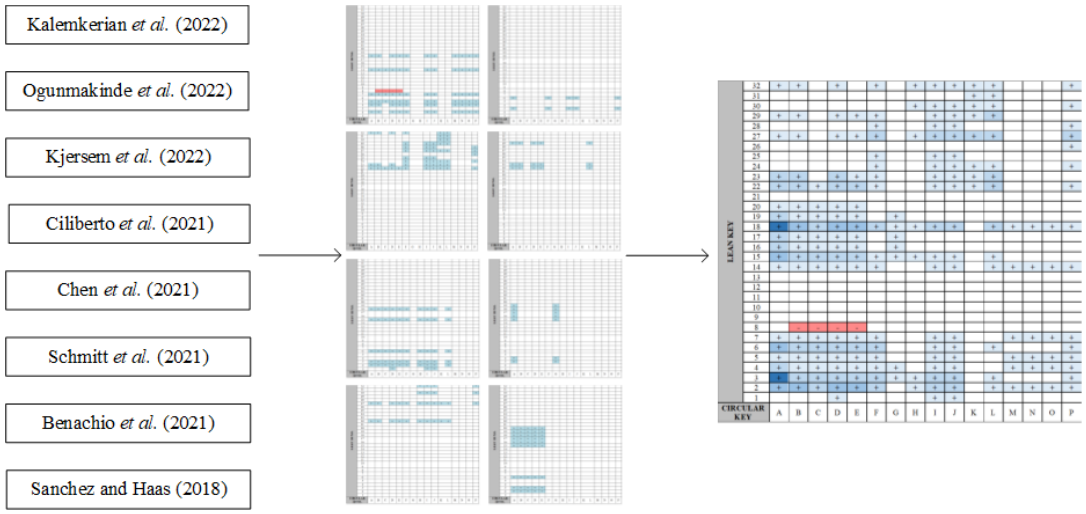

Figure 1: Development of qualitative research synthesis analysis matrix

THE LEAN PHILOSOPHY OF PRODUCTION

The TPS system established 14 management principles to improve the workplace and seven wastes (Table 1) which created the Lean philosophy of production (Liker, 2004). The Lean philosophy of production aims to promote value within the production process and reduce waste that hinders those efforts (Shah and Ward, 2003; Liker, 2004). The pull system utilised by Lean allows for the reduction of several wastes such as overproduction, waiting time, and inventory expenditure by drawing demand from the consumer (Liker, 2004). Lean principles create a consumer-led production with the "pull" system, whilst refining the process to ensure the quality of the product, and the effective management of the workers and their knowledge, well-being, and skills (Shah and Ward, 2003; Liker, 2004). Lean principles are made to be used together to form focussed multi-method strategies such as Just-In-Time (JIT), Total Quality Management (TQM), Human Resource Management (HRM), and Total Productive Maintenance (TPM) (Shah and Ward, 2003; Liker, 2004). The incorporation of the Lean philosophy within the production and construction industries has shown an improvement in the performance of the system in terms of cost, time, quality, and in turn the environmental impact of the process (Hines *et al.*, 2004; Liker, 2004; Marhani *et al.*, 2013; Carvajal-Arango *et al.*,

2019). Due to the positive impacts of Lean within production, it has become a popular philosophy within manufacturing and construction. Ultimately, it has become intertwined with modern methods of production management.

Table 1: Lean Principles from Liker (2004)

ID	MANAGEMENT PRINCIPLE
1	Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals.
2	Create continuous process flow to bring problems to the surface.
3	Use "pull" systems to avoid overproduction.
4	Level out the workload (Work like the tortoise, not the hare.)
5	Build a culture of stopping to fix problems, to get quality right the first time.
6	Standardized tasks are the foundation for continuous improvement and employee empowerment.
7	Use visual control so no problems are hidden.
8	Use only reliable, thoroughly tested technology that serves your people and processes.
9	Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others.
10	Develop exceptional people and teams who follow your company's philosophy.
11	Respect your extended network of partners and suppliers by challenging them and helping them improve.
12	Go and see for yourself to thoroughly understand the situation
13	Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly
14	Become a learning organization through relentless reflection (hansei) and continuous improvement
15	Over Production - Producing more than the customer demands
16	Inventory - Related to Overproduction, inventory beyond that needed
17	Transportation - The material be shipped directly from the vendor to the location in the assembly line
18	Waiting - Material is not being transported or processed
19	Over Processing - eworking, deburring, and extra work undertaken
20	Defects - Production defects and service errors waste resources i. Materials ii. Labour iii. Time vi. Reworking labour
21	Motion - This waste deals with ergonomics and health issues with respect to the workers and their job

LEAN CONSTRUCTION

The 11 Lean Construction (LC) principles were derived by Koskela (2002) (Table 3) to adjust for the differences within the construction industry's lifecycle structure. The priciples of Lean construction utilise those of the Lean philosophy within a construction context to better suit the structure of the industry. It was identified within construction that there are activities that create process flow within the system preparing resources and conversion activities that transform resources into products of value (Alarcón, 1997; Koskela *et al.*, 2002). The flow and conversion activities within construction are a complex mix of materials, components, and discipline-specific labour (Alarcón, 1997; Babalola *et al.*, 2019). Thus, the application of the Lean philosophy is increasingly difficult as opposed to manufacturing due to the size and complexity of construction (Alarcón, 1997; Koskela *et al.*, 2002). Koskela's (2002) LC principles focus on managing the complexity of the construction system in order to better apply Lean production principles (Alarcón, 1997; Koskela *et al.*, 2002). Communicating information, benchmarking, and evaluating activities are key in understanding the flow and conversion of resources to reduce the wastes identified by Lean (Koskela *et al.*, 2002). Furthermore, simplifying the process assists in the application of management strategies (Alarcón, 1997; Koskela *et al.*, 2002). LC aims to lower the complexity of the system with standardisation and simplification in order to reduce the waste caused by complex systems (Alarcón, 1997; Koskela *et al.*, 2002). Within construction the application of the Lean philosophy has shown similar promises of value as those found in manufacturing (Babalola *et al.*, 2019; Carvajal-Arango *et al.*, 2019). In summary, LC advances upon Lean production in an attempt to increase adoption within the vast and complex industrial system that is construction.

Table 3: Lean Construction Principles by Koskela *et al.* (2002)

KEY	LEAN CONSTRUCTION PRINCIPLE
22	Reduce the share of non-value-adding activities
23	Reduce the cycle time
24	Reduce variability
25	Simplify by minimizing the number of steps, parts, and linkages
26	Increase output flexibility
27	Increase process transparency
28	Increase value through the consideration of customer's requirements
29	Focus control on the complete process
30	Build continuous improvement into the process
31	Balance flow improvement with conversion improvement
32	Benchmark

THE CIRCULAR ECONOMY

The Circular Economy (CE) is a new structure for construction and production, becoming popular around the millennium (Govindan and Hasanagic, 2018). Now the CE is being proposed around the globe by organisations and governments as a solution to economic waste (McDowall *et al.*, 2017; Huang *et al.*, 2018). The CE is part of the most recent industrial revolution, Industry 5.0, the human-centric focus of industrial practice (MacArthur, 2013; Geisendorf and Pietrulla, 2018). The CE aims to reduce waste within the lifecycle of products by promoting value and reducing waste (Geisendorf and Pietrulla, 2018; Govindan and Hasanagic, 2018). This is achieved by creating a pull-system and closing the loop on linear waste removing value from the system (Geisendorf and Pietrulla, 2018; Govindan and Hasanagic, 2018). The CE has several principles in which to reduce waste and promote value within the lifecycle known as the 3Rs, 6Rs, or the 12Rs (MacArthur, 2013; Geisendorf and Pietrulla, 2018). The 3Rs are simply reduce, reuse, and recycle (MacArthur, 2013; Huang *et al.*, 2018). These outline the aims of the CE, to reduce the quantity of resources consumed, to reuse products and components, and finally, recycle waste back into the system to gain the maximum value from resources (MacArthur, 2013; Huang *et al.*, 2018). The 6Rs and 12Rs go further into detail, elaborating on the 3Rs with refuse, reduce, repair, reuse, repurpose, regenerate, rethink, remanufacture, recycle, recover, rot, and re-evaluate (MacArthur, 2013). Overall, the principles of the CE aim to consider the implications of the supply chain to avoid, manage, evaluate, and recover material waste within the supply chain.

Table 4: Circular Economic Principles

KEY	CE PRINCIPLE	DESCRIPTION
A	Reduce	The reduction of resources and waste at every stage possible. From design through to the end-of-life stage.
B	Reuse	The reuse of materials and components in new products or projects.
C	Remanufacture	The restoration of materials or components.
D	Recover	The collection of materials in their end-of-life period.
E	Recycle	The incorporation of recovered materials in new products.
F	Redesign	The reduction of waste and incorporation of recovered materials through product design.

CIRCULAR CONSTRUCTION

The CE within the construction industry is still relatively new, only appearing significantly within the literature since 2015 (Adams *et al.*, 2017; Benachio *et al.*, 2020). The construction industry has naturally developed a human-centric pull-system in some sectors as the

requirements of the client are stated for the function of the project (Ghisellini *et al.*, 2016; Hart *et al.*, 2019). Though a higher level of consideration for the human element in the built environment is emerging in the fifth industrial revolution (Geisendorf and Pietrulla, 2018; Çimen, 2021). However, the manufacturing of materials and components for the construction industry still follows a linear mass production structure to supply projects (Hart *et al.*, 2019; Hossain *et al.*, 2020). Furthermore, the construction industry is one of the largest waste producing industries, making construction a target for CE innovation (Adams *et al.*, 2017; McDowall *et al.*, 2017; Benachio *et al.*, 2020). The practices used by the construction industry to implement closed-loop circular economic flows have been coalesced in Table 5. The practices utilized by the construction industry are focused on communication within the industry, simplification of the systems processes and components, and design according to the 3Rs. In totality, the CE within the construction industry collaborates, evaluates, and redesigns.

Table 5: Circular Economic Practices in Construction

KEY	CE PRACTICE	DESCRIPTION
G	Pull-system	Produce the number of products to the required demand to avoid materials and products requiring inventory space or being wasted.
H	Lifecycle Analysis	Evaluation of the activities and events in the lifespan of a given process or material.
I	Design for Maintenance	The consideration of maintenance within the design of the product to reduce depreciation of the value.
J	Design for Recovery	The consideration of resource and component recovery to reclaim value lost from the linear wasting of products.
K	Standardisation	The use of common designs, materials, or processes to reduce the amount of variation within the market. Overall, it simplifies the application of higher strategies.
L	Modularisation	The design of a product in sections to allow for the interchangeability of components/modules.
M	Supply-chain Management	The collaboration and management of members of the supply chain for better synchronisation of the project's supply.
N	Knowledge Management	The management of data and knowledge in regard to the project for a better understanding of the completed work and the proposed.
O	Stakeholder Management	The management of stakeholders for better communication and direction for the project's operational functionality.
P	Material Passports	The creation of passports for resources to communicate the resource's information and designed lifecycle strategy.

The initial practice for CE innovations is the analysis of the lifecycle to view the waste produced by industrial activities (Benachio *et al.*, 2020; Çimen, 2021). This evaluation is key to understand the problem within the system (Hossain *et al.*, 2020; Munaro *et al.*, 2020). Once identified, the waste can be considered within the design stage (Adams *et al.*, 2017; Benachio *et al.*, 2020). The waste can be designed out and reduced, designed for reuse, and designed for recovery (Adams *et al.*, 2017; Benachio *et al.*, 2020). Material passports are used to communicate the designed strategy for maintenance and recovery to enable its application (Hossain *et al.*, 2020; Munaro *et al.*, 2020). Designing for maintenance and recovery can be assisted by practices such as modularisation and standardisation of components to reduce complexity within the design (Adams *et al.*, 2017; Hossain *et al.*, 2020). These methods of production are also less wasteful as components are prefabricated in factory conditions (Hart *et al.*, 2019). Additionally, collaboration with the wider supply chain better enables the creation of a closed-loop CE structure within the industry (Govindan and Hasanagic, 2018; Çimen, 2021). SCM is therefore a core practice of the CE to design for and recover materials in the lifecycle (Govindan and Hasanagic, 2018; Munaro *et al.*, 2020). The management of

stakeholders is also key to create a uniform direction for the design and application of the given strategy (Govindan and Hasanagic, 2018; Çimen, 2021). Altogether, the knowledge generated through the communication within the supply chain and stakeholders requires management and evaluation to further apply the 3Rs, 6Rs, or 12Rs (Munaro *et al.*, 2020). Ultimately, creating more value from the production and operation of the product.

CIRCU-LEAN SYNERGIES

The popularity of Lean and the CE in literature as solutions to unsustainable consumption naturally brought forth comparisons to determine their qualities. However, the topic is not yet saturated within the literature with only eight papers identified with both topics mentioned in the title, abstract, or keywords. Of the eight papers identified within the literature, four were based on manufacturing. Firstly, Ciliberto *et al.* (2021) conducted an initial study creating a series of matrixes comparing Lean and the CE finding strong correlations in the reduction of waste through evaluation and collaboration. Kjersem *et al.* (2022) found that Lean and the CE have many similarities within the process and production stages in terms of waste reduction and environmental/economic impacts. Schmitt *et al.* (2021) investigated the synergy with the aim of creating a three-level system for the strategies to be combined and incorporated into the product, process, and system levels of the economy. Schmitt *et al.* (2021) found that Lean compliments the process level of the CE strategy whilst the CE promotes long-term value. Kalemkerian *et al.* (2022) found similar results as Schmitt *et al.* (2021) in their investigation into Green Lean management which had limitations compared to the long-term environmental and economic gains of the CE. Overall, the initial investigations into the synergy between Lean and the CE are positive.

Within the construction industry the investigation of synergies between LC and the CE are fewer still. Several papers mention Lean and the CE though do not investigate or elaborate on the relationship. Sanchez and Haas (2018) suggested some initial benefits from the application of a CE with the Last-planner system. Sanchez and Haas (2018) proposed that Lean's last-planner pull-system and management strategies provided a beneficial structure for the application of a CE though did not specifically focus on investigating the relationship. Chen *et al.* (2021) found that the use of Lean can benefit the CE in the construction stage by mitigating the waste produced by activities and process. Furthermore, Ogunmakinde *et al.* (2022) hypothesised the use of modular prefabrication within LC can assist in developing CE methods within construction supply chains. Benachio *et al.* (2021) investigated the interactions between the two strategies within the construction lifecycle finding seventy-four positive and four negative interactions. Benachio *et al.* (2021) found the highest number of interactions surround off-site construction and prefabrication where Lean is better applied. Benachio *et al.* (2021) also investigated the interactions based on the stage in the construction lifecycle. Benachio *et al.* (2021) found that the construction stage has the highest number of interactions between the strategies. In summary, some synergies between Lean and the CE have been identified within the literature but only Benachio *et al.* (2021) conducted an investigation specifically into the synergy within the construction sector.

FINDINGS AND DISCUSSION

This research found that the synergies identified between Lean and the CE within the literature are positive overall but still in the early stages of investigation. The sample of literature identified for the study was minimal and largely focused on manufacturing and production over construction specific investigations of the synergy. The eight papers used within the matrix were analysed individually to understand the identify the synergies discussed within the literature, then coalesced in Table 6 for cross-examination.

Table 6: Synergies between Lean and the Circular Economy. Positive Interactions (Light Blue to Dark 1-4), Negative Interactions (Red).

LEAN KEY																	
	32	+	+		+		+		+	+	+	+	+				+
	31											+	+				
	30								+	+	+	+	+				+
	29	+	+		+	+	+			+	+	+	+				
	28						+			+	+						+
	27	+	+		+	+	+		+	+	+	+	+				+
	26																+
	25						+			+	+						
	24						+			+	+	+	+				+
	23	+	+		+	+	+			+	+	+	+				
	22	+	+	+	+	+	+			+	+	+	+				+
	21																
	20	+	+	+	+	+											
	19	+	+	+	+	+		+									
	18	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+
	17	+	+	+	+	+		+									
	16	+	+	+	+	+		+									
	15	+	+	+	+	+	+	+	+	+	+		+				
	14	+	+	+	+	+	+			+	+		+	+	+	+	+
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	7	+	+	+	+	+	+			+	+			+	+	+	+
	6	+	+	+	+	+	+			+	+		+				+
	5	+	+	+	+	+	+			+	+			+	+	+	+
	4	+	+	+	+	+	+	+		+	+			+	+	+	+
	3	+	+	+	+	+	+	+	+	+	+		+				+
	2	+	+	+	+	+	+		+	+	+		+	+	+	+	+
	1				+					+	+						
CE KEY		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P

The in the cross-examination of the literature on CE and Lean synergies, it was identified that the largest number of interactions were identified within the waste reduction principles and practices. This is supported by Benachio *et al.* (2021), who identified the most interactions between the two concepts which are within the manufacturing and construction stages. This further supports waste reduction as the core similarity between the topics. This further suggests that manufacturing and construction are perceived the most immediate stages in which waste can be reduced. In this effort, the pull system is utilised for the reduction of waste such as overproduction and inventory space in both strategies but was originally developed within Lean's philosophy (Liker, 2004). The human-centric pull-system of both strategies creates consumer-led value and was commonly identified as a similarity between the two strategies. The considerations present within both strategies for the consumers requirements assist in reducing waste caused by unwanted or unneeded products or elements. This is underpinned by another similarity between the two topics, the focus on long-term value and prioritisation of the big picture. By prioritising the long-term outcome, both strategies increase value, sometimes at the cost of short-term performance (Liker, 2004; Govindan and Hasanagic, 2018). In this regard, both strategies evaluate practice to improve the system. The Lean philosophy creates continuous improvement, benchmarking, and aims to increase transparency in order to identify

and understand inefficiencies or wastes within the system for redesign. Similarly, the CE aims to analyse the impacts of the lifecycle with LCA to understand the material wastes produced and their impacts for redesign and reduction or strategic recovery of the waste. Overall, the reduction of waste is largely similar in terms of output though differs slightly in methodology.

There are also several differences between the two strategies. The distinct difference identified within the literature are the well-defined principles and wastes within the Lean philosophy that are more developed than the CE. The advantage of Lean's established practice enables granular waste reduction within the system's processes and activities whilst cultivating the workforce. The CE on the other hand is a more recent strategy that is still developing and therefore has not yet reached a level of maturity to specifically target wastes on a granular level. However, the CE also provides innovations to the Lean philosophy that can further increase waste reduction and value promotion within the system. The closed-loop structure of the CE strategy adds value from waste that cannot be designed out or reduced. The longitudinal nature of the CE strategy adds a system level consideration for value and waste which increases value retention over the lifecycle. The holistic closed-loop nature of the CE lifecycle compliments the Lean philosophy by elucidating on the long-term benefits of managing value and waste. Both points highlight deficiencies in which the other compliments. This suggests that not only are there significant similarities between the two strategies but complimentary difference in which the strategies support and develop one another. Furthermore, the Lean philosophy also aims to promote value from the workforce and their experience, knowledge, and skills. The management of human resources has shown to further increase value within the production and construction of products. In comparison to Lean, the CE has few practices for the enrichment of the human resources within the system. Additionally, Lean aims to educate and advance the workforce to better the overall organization and the extended supply chain. Thus, it is suggested that the use of Lean's human resource management could support the development of the CE's management philosophy. In summary, Lean's principles of collaboration between management and the workforce could help promote a culture of closed-loop recycling within management for construction and production and are not negative differences between the strategies. Overall, there are some differences between the strategies, though they are not necessarily negative and could be used to develop a new Circu-Lean philosophy for economic production. One study highlighted negative interactions between the CE and Lean strategies conducted by Ciliberto *et al.* (2021). Which identified the CE's innovative use of materials for new sources of value contradicted Lean's desire for thoroughly tested and simplified systems (Ciliberto *et al.*, 2021). There are no doubt further negative interactions between the two topics however there is no extant studies investigating this factor and therefore should be the focus of future studies.

The investigation into the literature for synergies between Lean and the CE found that there are many similarities and differences (Table 6). Primarily, a human-centric pull-system, the promotion of value, the reduction of waste, the simplification of processes, the long-term focus of the strategies, and evaluation for redesign. Through cross examination of the similarities within Table 6, areas in which the two strategies differ are highlighted by the lack of interactions between the strategies. Initially, the infancy of the CE management philosophy in contrast to Lean's, which has developed several management principles for the extraction and promotion of value from management and the workforce. Secondly, both strategies approach value promotion and waste reduction differently. Lean's reduction of process waste within flow and conversion activities provides a granular approach. Whereas the CE focuses on general material waste reduction and recovery through a holistic closed-loop approach. This suggests that where the strategies are lacking interactions within Table 6, said differences could be beneficial to the developing the opposing strategy.

CONCLUSION

In totality, the literature specifically on Lean and the CE in the construction industry is still within its early investigation of the synergy between the management strategies. Benachio *et al.* (2021) have conducted the most sophisticated study into the synergy and have identified multiple areas where positive interaction between the strategies exists. However, within the literature there is yet to be a publication of sufficient quality to support or contradict the study conducted Benachio *et al.* (2021). Furthermore, if the initial findings within the literature for production and construction are correct. The synergy between Lean and the CE could be extremely valuable for construction in the effort of meeting SDGs. Overall, the similarities between the strategies within the design and production/construction stages are vast and positive. Likewise, the differences, although stark, suggest a complimentary contrast if combined. Ultimately, providing guidance and structure for one another to innovate where the other is successful.

The novelty of this work is twofold, a review to coalesce and critique of the extant knowledge on the Circu-Lean synergy, and guidance for future research into the synergy between Lean and the CE. Future research would continue the investigation into the strategies' synergies within the construction industry to better understand the similarities and differences. Furthermore, the investigation into the similarities between waste reduction can provide an interesting platform for researchers to identify the best practice for waste reduction in the construction industry. Moreover, further research into the differences between the two strategies can elucidate on the shortfalls and areas in which the contrast between the two strategies can complement one another (E.g., HRM in the CE). The limitations of this study are largely due to the lack of construction specific research on the synergies between Lean and the CE. As the literature progresses the qualitative synergy within the matrix would become richer as the sample increases in size. Furthermore, at present there is little contradictory literature for the review of contrasting opinions within the research community

In summary, this research reviewed a newly founded body of knowledge on the synergies between Lean and the CE. The vast majority of interactions between the two strategies are positive and concentrated on waste reduction. And finally, it is suggested that the development of the literature surrounding the synergy between CE and Lean could converge into a Circu-Lean philosophy of economic production and construction.

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