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ANALYSING THE ALIGNMENT BETWEEN LEAN CONSTRUCTION AND CIRCULAR ECONOMY IN PREFABRICATED CONSTRUCTION

Jaeden Mourmourakis[1], Wenchi Shou[2], Jun Wang[3] and Yu Bai[4]

ABSTRACT

With the recurring challenge of resources scarcity in the world, the construction industry needs to shift its attention towards sustainable practices. Prefabricated construction (PC) or modular construction has become increasingly popular in recent with its potential solution for the challenges faced, through increase of efficiency and reduction of waste. Some researchers have explored the integration of lean construction (LE) and circular economy (CE) into PC projects and highlights the benefits. However, they conclude that the implementation is in its early days and require a need for research as it holds significant potential in transition into a sustainable industry. This paper aims to exploring the alignment between CE and LC in PC through relevant resources to understand the full extent on this topic. The paper presents the research findings of 25 relevant publications that met the inclusion criteria in a statistical manner. This is to identify and summarise the known body of knowledge relevant to the topic. It shows that there is a strong link between focusing on the whole process for design, construction, and end-of-life of a building. Content was examined to discover what type and application of PC and relevant benefits and/or limitations.

KEYWORDS

Lean construction, circular economy, prefabricated construction, alignment, review.

INTRODUCTION

Generational waste and high consumption of natural resources is a global issue that the construction industry is currently facing due to its contribution from traditional construction methods (Akhimien et al. 2021). Factors include minimal exploration, lack of research and reluctance in embracing new sustainable concepts that the industry can transition into (Ayarkwa et al. 2022). However, as newly emerged methodologies and concepts arise, there has been interests in all parties to the possibilities and adaptations from just thinking of sustainability practices as recycling. A focus is seen on lean construction (LC) principles and circular economy (CE) applications through prefabricated construction (PC) (Luo et al. 2021).

1 Undergraduate student, School of Engineering Design and Built Environment, Western Sydney University, Sydney, Australia, 20231545@student.westernsydney.edu.au

2 Senior Lecturer, School of Engineering Design and Built Environment, Western Sydney University, Sydney, Australia, w.shou@westernsydney.edu.au , https://orcid.org/0000-0001-8724-8807

3 Senior Lecturer, School of Engineering Design and Built Environment, Western Sydney University, Sydney, Australia, jun.wang@westernsydney.edu.au , https://orcid.org/0000-0003-3384-4050

4 Professor, Department of Civil Engineering, Faculty of Engineering, Monash University, Melbourne, Australia, yu.bai@monash.edu , https://orcid.org/0000-0002-0742-0708

PC is a process where components of a building are manufactured in specialised facilities (off-site) other than the site location, then specifically designed to be transported and assembled on-site (Ferdous et al. 2019; Innella et al. 2019). The integration of the two concepts is compliable as they aim to reduce waste and shorten the project life cycle, resulting in a more efficient and sustainable way (Du et al. 2023). It optimises the production process and has a high potential to effectively address resource wastage and inefficiency (Ferdous et al. 2019). The research found that various LC tools aim to cut waste and shorten project cycle have been used in lean prefabricated construction, they were: (1) kanban that is a visual card system displays steps and materials, (2) value stream mapping (VSM) which is a visualisation of a process and, (3) last planner system (Du et al. 2023; El Sakka et al. 2016; Innella et al. 2019). Furthermore, Caldarelli et al. (2022) conceptualised the application of LC and PC through focusing on modular construction as a hybrid production system. It treated off-site construction as a manufacturing system, as it reorganised the sequences of the construction as a layout of stages, which led to reduction of waste and efficient usage of time. However, it also mentioned that this concept is within its initial stages. Nahmens and Ikuma (2012) identified the effects of LC on modular homebuilding, where the barriers faced in widespread application of sustainable construction is the high initial costs, lack of education in the industry and applications of technologies. It was found through seven case studies that LC resulted in reduction of material waste by 65% and production hours by 31%. Innella et al. (2019) reviewed application of lean methodologies and indicated that techniques to modular construction has the potential to reach new levels of productivity while has yet to be achieved. It highlighted that the challenges faced is how to fully integrate lean strategies to all production process stages of PC. Du et al. (2023) pointed out future direction of the integration of LC and PC through a new concept called lean prefabricated construction. Although there is limited research on the application of the integration of LC through PC applications, they all aim to aid practitioners with an overview of potential benefits and suggest further research is needed.

CE concept derived from the opposed of traditional economy which has not evolved since the industrial revolution (Benachio et al. 2020). The traditional model or linear economy uses the concept of take-make-disposal, where raw materials are extracted from the environment, processed, and are transformed into products and discarded once they have reached their end of life or no use of them (Afteni et al. 2021). Pomponi and Moncaster (2017) stated that although the implementation of CE model is within infancy in the construction industry, there is momentum and support, and examples can be drawn from the Netherlands where European nations are at the forefront of circularity. Benachio et al. (2021) and Munaro et al. (2020) concluded that the CE was involved within the industry which shine a spotlight on research themes, findings, and gaps. In result, they found that there was a need for standardised practices to benchmark the concept and government incentives to promote CE models.

The integration of the CE practices and PC is compliable as PC has the potential to reduce costs and times, whereas CE promotes building resilience and reducing waste (Zairul 2021). Xu and Sun (2019) found that PC have contributed to green building literature through integrating CE applications. Although the integration of CE in PC is a newly emerged concept, there has been research conducted on how the alignment can not only achieve circularity but an efficient construction process. Dams et al. (2021) suggested a framework towards on how the built environment can transition into circularity through integrating modular construction as an application for CE. 15 guidelines were created tailored around achieving Sustainable Development Goals that foster the applications of CE to buildings. Furthermore, Machado and Morioka (2021) extended the idea of integration through how modular construction can further contribute to CE benefits and the link between them has become more evident. It found that most research papers did not mention circular economy directly, but rather the benefits within the implementation of modular construction practices. Zairul (2021) investigated the recent trends within the built environment on PC with the integration of CE. The paper identified that there is an absence of research of the integration as the concept has recently emerged. The research objective of this paper is to investigate the alignment between LC & CE in PC and the potential synergies, challenges and opportunities of integrating in the industry.

The existing body of literature highlighted the importance of the LC and CE concepts and how they can be integrated into PC to achieve further sustainable benefits. The main agreement in the literature displayed that each concept has benefits individually but can be achieve further from integrating them as a collective. Gaps exist such as minimal research and full integration of these theoretical concepts to be implemented practically in the built environment. There is area for future research in collecting data, applying, and implementing the researched ideas in a project. These concepts require additional exploration and how to manage the industry being reluctant to apply these ideas.

RESARCH METHOD

A systematic literature review is a research methodology that identifies, selects, and critically evaluate material to address a specific formulated question. This is thought to be an effective strategy to execute extensive review and identify the research gaps on the topic(Innella et al. 2019).

DATA COLLECTION

For the literature research, the Scopus database has been implemented as it is one of the most accurate, high quality, creditable, and peer-reviewed databases. A three-stage criteria was developed to accurately capture relevant data, which aimed at focusing on papers that demonstrated strong contributions to the three concepts and topic.

In Stage one, the research was conducted using keywords in ‘Article title, Abstract, Keywords’ field and limited to articles and review papers. The keywords that were implemented in the research field was “Lean Construction* AND Modular* OR Prefabrication* OR circular*”. The search result found that there was a total of 223 documents matching these keywords. The research was limited for publication years for a 10-year range between 2023 to 2013 to ensure relevant literature for the topic. There were 158 documents matching the research parameters. The research was further refined through subject area, in this case the relevant area is “Engineering”, “Environmental Science” and “Business, Management and Accounting” reducing the number of articles to 138 documents.

In Stage two, the 138 papers were reviewed by evaluating the title and abstract to discover relevant papers concentrating on the alignment of LC and CE in PC within the built environment. A total of 90 publication which do not contain the key terms in titles, author keywords and abstracts were excluded or was not accessible to the public.

In Stage 3, the remaining 48 papers were deeply analysed by reading the full paper to fully understand the relevance towards completing the research aim. A total of 16 paper were found that had relevance towards the paper. Additionally, a manual search was conducted to include the possible omission of CE, LC, and PC archive by the search engine. There are 9 papers were added to the total number of research papers from references. As shown in Figure 1 of the flowchart of data collection, 25 papers were selected for review and analysis.

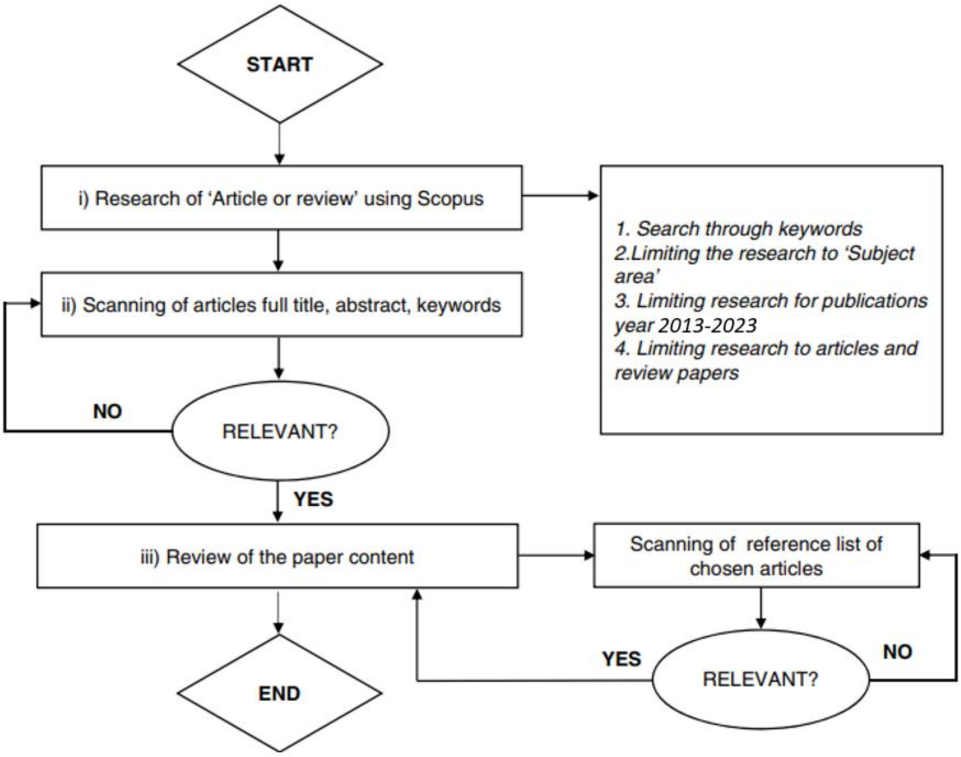

Figure 1: The Flowchart of Data Collection

DATA ANALYSIS

A content analysis was conducted to determine the presence of certain words, themes or concepts surrounding the papers titles. As shown in Table 1, this paper explored the interactions between lean and modular, modular and circular, lean and circular, and the integration of three concepts and the barriers of the integration. The table below

Table 1: Code of Analysis

Code	Definition of code
Alignment of themes	Research contribution and connection and/or explicitly stated in the source.
Analysis of barriers	Addresses or explores the barriers that the concepts may face.

RESEARCH FINDINGS

The researching findings subheading and tables were established to directly address practical challenges of waste cause, stringent construction programmes and budgets involved with traditional construction.

ALIGNMENT OF CE & LC IN PREFABRICATED CONSTRUCTION

A table of alignment was created to explore the alignment of LC principles and CE practices. As shown in Table 2, it is structured to present key components of LC principles and CE practice, along with the specific life cycle stages of a building that the integration has applied. The purpose of the table is to create a visual representation of the relationships between the alignment of these concepts, which allows for a clear understanding of where they overlap and how they complement one another. The life cycle stages, depicted below in the first column represents the different stages that a building undergoes, from a concept to a tangible operative building, to the deconstruction of a building. There are four main stages of a building's construction, project design, construction phase, operations, and end-of-life.

From the created matrix it is possible to obtain a series of results to help understand the relationship between the studied subjects. The number of occurrences refers to when a paper mentioned the alignment between the two areas, regardless of if positive or negative. The alignment of LC principles and CE practices which has the most interactions were "focus on the complete process" with 11 occurrences for LC principles and "deconstruction, reuse, waste management" for CE practices. This was mentioned almost two times than all other alignments. This was followed by "focus on the complete process" with 6 occurrences for LC principles and "prefabricated construction, disassembly and adaptability" with CE practices. The alignment that occurred the least was "Build continuous improvement" with 1 occurrence for LC principles and "prefabricated construction, disassembly and adaptability" for CE practices. Similarly, the life cycle stage that occurred the most was "End-of-life" with 17 occurrences collectively, followed by "Project Design" with 12 occurrences collectively, showing that these are the vital stages where the alignment appears. Whereas the least occurred life cycle stage was operations with 0 (zero) occurrences. This furthers supports how the operations stage of a building is not considered for LC principles and CE practices can be applied to.

Table 2: The Alignment of LC Principles and CE Practices in Lifecycle Stages

		LC Principles			
Life Cycle Stage	**CE Practices**	**Reduce on non-valuing adding activities**	**Reduce cycle times**	**Focus on the complete process**	**Build continuous improvement**
Project Design	Prefabricated construction, disassembly, adaptability	3	2	6	1
Construction	Reuse, waste reduction, off-site construction	2		5	
Operation	Minimise maintenance				
End-of-Life	Deconstruction, reuse, waste management and refurbishment	2		11	4

Table 3 was created to show the alignment between LC principles and CE practices as they are applied to PC. The table lists the alignment that occurred within the Table 2 and outlines their corresponding connections and how they are applied further in PC.

Table 3: the Alignments of LC&CE in PC Application (data extracted from the 25 filtered papers)

Number of publications	Alignment of LC & CE	PC Application
11	Focus on the complete process & Deconstruction, reuse, waste management and refurbishment.	Focusing on the manufacturing process to reduce steps needed while applying disassembly design and allowing the use of reuse materials
6	Focus on the complete process & Design for disassembly and adaptability.	Mapping out the entire process of the production process (Waste & material handling) and focusing on modular and standardized components
5	Focus on the complete process & Reuse, waste reduction and off-site.	Evaluating and refining the off-site prefabricated process layout and activities to implement reclaim materials and waste management
4	Build continuous improvement & Deconstruction, reuse, waste management and refurbishment.	Adopting a life cycle approach to manufacturing methods of PC which achieves waste reduction.
3	Reduce on non-valuing adding activities & Design for disassembly and adaptability.	Optimising a production process of modular construction through eliminating unnecessary transport or material usage.
2	Reduce cycle times & Design for disassembly and adaptability.	Shorting the design phase of PC through standardising the designs and incorporating disassembly principles
2	Reduce on non-valuing adding activities & Reuse, waste reduction and off-site.	Removing activities through the off-site manufacturing production of modular panels, where exact amounts of materials are ordered.
2	Reduce on non-valuing adding activities & Deconstruction, reuse, waste management and refurbishment.	Optimising the production process through eliminating nonvalues activities within the prefabricated construction process and reuse of reclaimed materials in a controlled environment
1	Build continuous improvement & Design for disassembly and adaptability.	Designing modular building components that can be removed and producing them in an offsite location where it is easier to introduce continuous improvement.

BENEFITS AND LIMITATIONS OF THE INTERACTIONS IN PREFABRICATED BUILDINGS

Table 4 shows the main benefits that were mentioned within the papers. The papers were analysed completely and any main points taken regarding the benefits were noted. The results showed that the benefit of PC was "Shorter construction time" and "Design for disassembly" occurred the most frequency with the occurrence of 2. Whereas the least mentioned was the "Higher quality of work".

Table 4: Definition of identified benefits

Benefit items	Definition	No.
Higher quality work	Refers to fabricating building components with precision and accuracy with small tolerances which results in a consistent quality product. This can be strong, durable, uniform dimensions higher resistance items. In the context of PC refers to: precise dimensional accuracy, consistent finishes, improved safety and stringent quality control.	1
Shorter construction time	Refers to the reduction in time in which is needed to construct or complete a project. In the context of PC it refers to using off-site fabrication in a controlled environment.	2
Design for disassembly	Refers to designing a building to be disassembled at the end of the life of the building. In the context of PC refers to modularisation sections such as façade panels.	2

Table 5 was structured to present the three main limitations mentioned, which was captured from the filtered 25 papers. The results showed that the limitations of PC were “Limited Knowledge known in the field / Uncertainty” had the most frequency with the occurrence of 3. Whereas the least mentioned was “Design Restriction”.

Table 5: Definition of identified Limitations

Limitation items	Definition	No.
Limited Knowledge known in the field / Uncertainty	Refers to a situation where there is lack of information or understanding about a certain topic or element. In this context, PC.	3
Design Restriction	Refers to the limitations or constraints that the designer must consider while creating a product or system. This can include cost, material availability, and aesthetics.	1
Need for business model innovation / Lack of technology	Refers to the necessity in which a business needs to develop new strategies and approaches to either have a competitive advantage or maintain their position. Whereas lack of technology refers to where businesses or individuals have limited access, or unable to utilise, modern tools and processes.	2

DISCUSSION

THE ANALYSIS OF THE ALIGNMENT OF LC & CE IN PC

Analysing the created matrix of the alignment of the interactions of LC and EC and how these can be applied to PC results, it is possible to interpret what those results mean for the relationships of the alignment and applying it to PC in the built environment.

First in the table 2, shows the alignment of LC application and CE practices had the greatest number of mentions of interaction with “Focus on the complete process" & “Deconstruction, reuse, waste management and refurbishment” with 11 occurrences throughout within the 25 papers. This happen mostly because they are interrelated and are crucial for promoting circularity and achieving sustainable construction practices. A comprehensive approach or focusing on the complete process guarantees that every phase of the building process, from design to demolition, is efficient and optimises minimisation of waste and use of available resources (Benachio et al. 2021). Reuse, deconstruction, waste management, and refurbishing are examples of circular economy techniques that are crucial for reducing waste and fostering resource efficiency (Akhimien et al. 2021). Table 3 and the supporting citations further support and explain how this interaction of aligning LC principles and CE applications can be optimised to construct sustainable and efficient buildings through utilising resources and focusing on the complete process.

The other alignment of LC application and CE practices had the second highest number of interactions with "Focus on the complete process" & "Design for disassembly and adaptability" having occurred 6 times throughout the 25 papers. This happened because they are essential to implementing life cycle optimisation and resource efficiency in the built environment. By focusing on the entire process ensures that all the stages of construction process from design to disposal are streamlined to optimise reduction of waste and improve overall resource utilisation (Ghisellini et al. 2018), whereas, designing for disassembly and adaptability is an essential part of CE practices to promote the effective use of resources and reducing waste. This is through creating structures and building systems that are simple to disassemble and reuse at end-of-life stage or when buildings no longer fulfil their purpose. By aligning this LC principle and CE practice they can work together to opposite the goal of resource utilisation and waste generation can be minimised.

The other alignment of LC application and CE practices had the third highest number of interactions with "Focus on the complete process" & "Reuse, waste reduction and off-site" having occurred 5 times throughout the 25 papers. This happened because they are both essential in optimising resource utilisation and reducing waste generation in the built environment. As mentioned previously, focusing on the complete process is an essential part in achieving maximisation of resources used and in reducing waste production. Whereas, reuse, waste reduction and off-site construction focuses on the construction process by minimizing on-site waste generation, promoting efficient resource utilization, and reducing the carbon footprint (Parker et al. 2023). While these practices are essential for encouraging sustainability in the built environment, they have a less effect than procedures such as deconstruction and refurbishment that lead to more optimal resource utilisation (Johns et al. 2023). Additionally, off-site construction may contribute to the reduction of on-site waste, and it can have an impact of increasing transportation of module components which relate emissions produced, thereby partially offsetting the benefits. In result, the synergy between the alignment of LC and CE remains a crucial part to reducing waste generation and promote sustainability, hence why there is less emphasis than the other alignments ranked higher.

THE BENEFITS AND LIMITATIONS

Table 4 lists out three benefits of PC that were found within the analysed 25 papers and the occurrences of them. It is noted that not all 25 papers explored nor mentioned PC in them. The highest occurrence of the benefit of applying PC in the built environment was both "shorter construction time" and "design for disassembly" with 2 occurrences. Shorter construction times occurred the most as prefabrication enables the manufacturing of components off-site, whereby contractors can put together the structures simultaneously on-site without interfering with other on-site activities. This happened because PC components are constructed off-site away from the site location and generally in enclosed environments, enabling works to be completed favourable without weather-related delays, leading to less delays. The controlled environment of a warehouse eliminates weather rated interruptions such as rain, heat and other extreme conditions that would stop works using conventional techniques on site, as they are deemed unsafe for workers that frequently contribute to delays. Although there are allowances within the construction program for weather delays, this factor is unpredictable as weather conditions can vary (Purchase et al. 2022)**.** This leads to more controlled and predictable delivery programs, ultimately contributing to accurate constructions times. Additionally, using PC streamlines the site process, thus reducing the time of equipment and materials movement on site. Traditional on-site construction can vary from project to project as how the site is operated is up to the Principal Contractor. However, items such as Crane time, Manitou bookings and delivery slots are all items that can contribute to delaying materials for workers to be able to install/build. Therefore, factories can design layouts specifically for assembling components to reduce non-valuing adding activities such as material movement on site and deliveries. Design for disassembly occurred the most as it has become a popular concept of PC in the built environment as it promotes the ideology of considering a buildings whole life cycle not just its purpose during the operation stage. This happen because all contributors in the built environment such as architects, engineers, consultants, clients, and principal contractors are more conscious of the negative impacts construction has to the environment and how resource extraction is not sustainable. Designing for disassembly has been seen and applied within the Australian construction industry, through Design for Manufacturing and Assembly (DfMA). A principal contractor, Built Pty Ltd, has implemented DfMA in a recent project for a 200-worker office for Sydney Metro and who is delivering the new airport project. Built incorporated CE thinking, through an innovative modular structure design. This allowed the building to be disassembled and reassembled (relocated), providing a successful example of the possibilities and opportunities of PC (Graham 2023).

While prefabricated building provides numerous advantages in the built environment, there are certain drawbacks that must be addressed. Understanding and managing these constraints can lead to more successful and efficient construction projects. This talk will delve deeper into some of the key constraints of using prefabricated building in the built world. Table 5 lists out three limitations of PC that were found within the analysed 25 papers and the occurrences of them. It is noted that not all 25 papers explore nor mention PC in them. The limitation that had the most occurrences was “Limited Knowledge known in the field / Uncertainty” having occurred 3 times throughout the 25 papers. A significant limitation in the application of PC to the built environment is the lack of knowledge and uncertainty surrounding the field. This is because although the PC method is a sustainable solution to reduce labour and materials demand, PC methods are less preferred over conventional construction. This results from a lack of understanding regarding the advantages, restrictions, design, and construction of PC within the industry. From the lack of knowledge and experience about PC design, logistics and installation of PC and influenced by the lack of technical standards, contributes to the limitation of implementing this method in the built environment (Navaratnam et al. 2022). Due to the lack of knowledge and experience of PC within the built environment, it can cause clients and stakeholders wary of the concept and result in oversights or omissions in implementing it.

CONCLUSION

Through the systemic review, this paper collected, analysed, and interpret the credibility of academia and industry materials. This process provided a comprehensive understanding of the current state of knowledge regarding the alignment of LC and CE principles in prefabricated construction within the built environment. The research paper, as a result of this review, successfully identified the key benefits and limitations associated with the integration of lean and circular economy principles in prefabricated buildings. The research findings succinctly presented the most frequently occurring alignment of LC principles and CE applications concerning various stages of a building’s life cycle. This information was utilised to determine how the alignment influences prefabricated construction applications, thereby contributing to the strengthening and evolution of prefabricated construction practices within the industry.

However, it's crucial to recognise the inherent limitations of a systematic literature review. The effectiveness of such a review is contingent upon the quality of the research it incorporates. Despite the availability of various techniques for quality evaluation, this paper utilized Scopus as a singular source to obtain filtered papers, employing several steps to refine the selection. While Scopus is a reputable source, it is not without potential limitations. Human errors or the unavailability of all relevant resources from this single source can introduce biases. Additionally, the process of selecting materials meeting the paper's requirements might inadvertently include or omit low-quality resources, impacting the overall validity of the study's conclusions.

Future research should focus on examining specific materials or elements of prefabricated construction that could benefit from circular economy approach while meeting lean construction principles. Here are some areas to be considered for further research and avenues:

Case Studies: Conduct case studies on prefabricated construction projects that integrate the concepts of lean construction and the circular economy. Such case studies can provide insights into the practical application of these ideas in real building projects.

Comparative analysis: Contrast prefabricated construction projects applying circular economy and lean concepts with traditional construction projects to demonstrate the advantages of each strategy and identify potential areas for improvement.

Integration of life-cycle assessment: Explore the inclusion of life-cycle assessments (LCA) in the examination of lean construction and circular economy principles in prefabricated buildings. LCA allows for a comprehensive evaluation of the environmental impact of a system or product throughout its entire lifecycle.

Sustainability assessment: Further investigate the sustainability benefits of incorporating lean and circular economy concepts in prefabricated construction. Evaluations could assess the advantages in terms of the economy, society, and the environment, including reduced waste, lower material usage, and increased productivity.

Furthermore, recognising the potential and difficulties in aligning lean and circular principles could direct the creation of creative solutions to integration roadblocks. The potential effects of applying lean and circular economy principles to prefabricated construction within the broader context of sustainable construction practises could also be explored in more detail. This would highlight the chances to cut waste, boost efficiency, and improve the environmental, social, and economic impact of the construction industry.

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REFERENCES

Afteni, C., Păunoiu, V., and Afteni, M. (2021). "Study on the Transition from the Linear Economy to the Circular Economy." *Annals of" Dunarea de Jos" University of Galati, Fascicle V, Technologies in machine building*, 39(1), 49-55.

Akhimien, N. G., Latif, E., and Hou, S. S. (2021). "Application of circular economy principles in buildings: A systematic review." *Journal of Building Engineering*, 38, 102041.

Ayarkwa, J., Opoku, D.-G. J., Antwi-Afari, P., and Li, R. Y. M. (2022). "Sustainable building processes' challenges and strategies: The relative important index approach." *Cleaner Engineering and Technology*, 7, 100455.

Benachio, G. L. F., Freitas, M. d. C. D., and Tavares, S. F. (2020). "Circular economy in the construction industry: A systematic literature review." *Journal of cleaner production*, 260, 121046.

Benachio, G. L. F., Freitas, M. d. C. D., and Tavares, S. F. (2021). "Interactions between lean construction principles and circular economy practices for the construction industry." *Journal of Construction Engineering and Management*, 147(7), 04021068.

Caldarelli, V., Filipponi, M., Saetta, S., and Rossi, F. (2022). "Lean and green production for the modular construction." *Procedia Computer Science*, 200, 1298-1307.

Dams, B., Maskell, D., Shea, A., Allen, S., Driesser, M., Kretschmann, T., Walker, P., and Emmitt, S. (2021). "A circular construction evaluation framework to promote designing for disassembly and adaptability." *Journal of Cleaner Production*, 316, 128122.

Du, J., Zhang, J., Castro-Lacouture, D., and Hu, Y. (2023). "Lean manufacturing applications in prefabricated construction projects." *Automation in Construction*, 150, 104790.

El Sakka, F., Eid, K., Narciss, T., and Hamzeh, F. "Integrating lean into modular construction: a detailed case study of company X." *Proc., Proceedings of the 24th Annual Conference of the International Group for Lean Construction*, 23-33.

Ferdous, W., Bai, Y., Ngo, T. D., Manalo, A., and Mendis, P. (2019). "New advancements, challenges and opportunities of multi-storey modular buildings–A state-of-the-art review." *Engineering structures*, 183, 883-893.

Ghisellini, P., Ripa, M., and Ulgiati, S. (2018). "Exploring environmental and economic costs and benefits of a circular economy approach to the construction and demolition sector. A literature review." *Journal of Cleaner Production*, 178, 618-643.

Innella, F., Arashpour, M., and Bai, Y. (2019). "Lean methodologies and techniques for modular construction: chronological and critical review." *Journal of Construction Engineering and Management*, 145(12), 04019076.

Johns, N. G. O., Talebi, S., Shelbourn, M., Roberts, C., and Kagioglou, M. "The Circu-Lean Revolution: A Review of the Synergies Between Lean and the Circular Economy." *Proc., Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31)*, Lille, France, 540-559.

Luo, T., Xue, X., Tan, Y., Wang, Y., and Zhang, Y. (2021). "Exploring a body of knowledge for promoting the sustainable transition to prefabricated construction." *Engineering, Construction and Architectural Management*, 28(9), 2637-2666.

Machado, N., and Morioka, S. N. (2021). "Contributions of modularity to the circular economy: A systematic review of literature." *Journal of Building Engineering*, 44, 103322.

Munaro, M. R., Tavares, S. F., and Bragança, L. (2020). "Towards circular and more sustainable buildings: A systematic literature review on the circular economy in the built environment." *Journal of Cleaner Production*, 260, 121134.

Nahmens, I., and Ikuma, L. H. (2012). "Effects of lean construction on sustainability of modular homebuilding." *Journal of architectural engineering*, 18(2), 155-163.

Parker, D., Jylhä, T. E., Bortel, G. A. v., and Schraven, D. F. J. "Lean Co-Acting With Circularity? An Investigation in Product-Service Systems in Rental Housing." *Proc., Proceedings of the 31st Annual Conference of the International Group for Lean Construction (IGLC31)*, Lille, France, 486-497.

Pomponi, F., and Moncaster, A. (2017). "Circular economy for the built environment: A research framework." *Journal of cleaner production*, 143, 710-718.

Xu, Q., and Sun, L. (2019). "Application Analysis of Prefabricated Buildings under Green Construction." *ICCREM 2019: Innovative Construction Project Management and Construction Industrialization*, American Society of Civil Engineers Reston, VA, 527-534.

Zairul, M. (2021). "The recent trends on prefabricated buildings with circular economy (CE) approach." *Cleaner Engineering and Technology*, 4, 100239.