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Circular Business Strategies for Modular Construction: A Review

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Abstract **-** This review addresses the integration of circular economy (CE) principles with modular construction (MC), aiming to unveil strategies that bridge these domains. Through exhaustive analysis of various research articles, we identified key strategies and developed an intuitive activity system map to visually guide stakeholders. This map simplifies the process of incorporating CE strategies in MC workflows. Our findings categorize these strategies, providing a structured roadmap for construction professionals. This endeavor seeks to facilitate the seamless infusion of sustainability in modular construction projects, propelling environmentally conscious advancements in the construction industry.

Keywords**:** Circular economy, Modular construction, Circular business strategies, sustainability, Modularity, Activity system map.

1. Introduction

The circular economy (CE) is a systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution [1]. These characteristics lead to several authors defining (CE) as the new future for sustainability through novel flexibility metrics of buildings [2]. The (CE) emerges as an alternative for the replacement of Linear Economy, aiming to extend the useful life of products, components and materials in circulation and without loss of value, as much as possible and eliminate waste [3], [4]. The construction industry is currently the largest global consumer of resources and raw materials [1]. The building construction sector is responsible for the significant consumption of natural resources, energy, and the production of waste. The construction industry is the largest consumer of materials, using 35–45% of the resources and consuming around 25–40% of the global energy [5]. The construction sector is considered one with a high potential to implement CE strategies due to the discrete nature of construction processes and the growing adoption of eco-friendly products and technologies [6]. Modular construction (MC) as a productive and efficient method for construction has a remarkable potential to begin this transition because of its industrial construction and specified characteristics for disassembly and the reuse of materials and components. For transitioning toward circular construction, the adoption of design for disassembly concept, use of modular and prefabricated elements, and development of recovery schemes (take-back system in the manufacturing industry) are necessary [7].

1.1. Literature review

Prefabricated buildings are defined as constructions manufactured at an industrial site and moved and assembled in different degrees on-site [8]. However, in order to utilize these potentials, modular buildings must comply with the following elements of (CE): resource efficiency, preserving and extending what is already made, designing for the future, and rethinking the business model [9]. One of the most effective approaches to incorporating CE into the construction industry is developing circular business models [10], [11].

For the transition to CE, business model redesign is considered essential in delivering environmental and social value while keeping economic benefits (Bocken et al., 2013; Porter and Kramer, 2011). Therefore, transitioning from a linear business model to a CBM is considered as a process of business model innovation [12], [13], [14]. It involves innovation in strategies, product design, processes, and working dynamics (Upadhyay et al., 2019), which are changes impacting the activity system, that is, the key characteristic for business model innovation [15]. The translation enables progress in the business model to be predicted and geared towards realistic scenarios of a potential (CE) [16]. To build the CBMs, it is essential to understand and know their different elements. [12], [17]. CBMs can be defined as "a business model in which the conceptual logic for value creation is based on utilizing economic value retained in products after use in the production of new offerings"[14]. Even though there are several different definitions for a business model, it can be described as a simplified representation of business system elements and their interrelationships, aiming to reveal the business strategy on value proposition, creation, delivery, and capture [18]. The value proposition is a statement of what value the business will offer to customers and other stakeholders (Richardson, 2008). Value creation and delivery refers to how value is created or cocreated through the value network (resources, processes, infrastructure, and partnerships) and how this will be delivered to stakeholders (channels/mechanisms for communication, sales, and distribution [19]. The process or activities companies use to add value to a product/service and thus meet customer needs. Activities are separated into primary value-added activities like operations, logistics, and marketing as well as support activities like information technology and accounting [20].

Nonetheless, to successfully incorporate CE principles into business models, it is necessary to identify the importance and influence of different CE strategies for managing the many building blocks of a business [18]. Michael Porter defines strategy as competitive position, "deliberately choosing a different set of activities to deliver a unique mix of value."[21]. In other words, A business strategy is about creating the sustainable competitive advantages. True strategy involves differentiation through activity fit, limited product offerings, focusing on what your firm does best, and trade-offs [21]. If we consider MC as a distinct industry that has its own attributes that can be different from conventional construction, then it will need unique strategies and business models to design or architecture of the value creation, delivery, and capture mechanisms it employs (Teece, 2010). Consequently, if MC is going to shift from a linear model (make, use, dispose) to a circular model, it will necessarily need to have strategies and business models that are circular and help to reach the preset goals of the modular construction companies (Lauten-Weiss & Ramesohl, 2021). Indeed, business strategies are the basis for building a business model, and consequently, building a CBM needs to have suitable circular business strategies (CBSs) [22]. Currently, a range of frameworks exists that propose a vision for how to operate in a CE, by identifying and organizing relevant circular strategies. However, these frameworks have a limited applicability for specific business types, in particular manufacturing, and are unsuitable for use in CE oriented innovation, due to a lacking ability to support innovation processes through: 1) creating a comprehensive understanding of circular strategies, 2) mapping strategies currently applied and 3) finding opportunities for improved circularity across a range of business processes [23]. Therefore, there is a necessary need to review the existing literature and practices to find the identified circular strategies by authors that could be useful for the transition and can be tailored to MC.

1.2. Gap Identified and Objectives

CE adoption in different industries has been addressed by many authors and every study has focused on certain aspects in terms of different elements of CBMs. Moreover, several authors have developed circular strategies without concentrating on a specific industry [18], [24], [25], and other ones identified circular strategies exclusively designed for certain a business including built environment or construction and even MC [16], [26], [27], [28]. However, those strategies are technical strategies to gain environmental advantages or mitigate the environmental impacts of business which are not necessarily applicable for MC. Indeed, this article explores circular business strategies that are applicable to the construction industry, particularly to modular construction. These strategies are distinct from technical strategies, which focus on decreasing environmental impacts while disregarding the economic effects. Circular business strategies, on the other hand, seek to create economic value for stakeholders who can implement them in practice [29]. They are also a sustainable and strong justification for the application of modular construction, providing assurance for those who follow and implement such strategies can benefit financially. Therefore, the identified strategies have not addressed the economic aspects of the circular business

activists or proposed technical circular strategies and then by adding the word "business" to circular strategies, the article's focus has been shifted to the economic aspects of the strategies. [18] identified the sixteen potential CE strategies with the most influence for managing each business model building block in circular businesses which is proposed for all businesses. Nevertheless, these strategies do not have embedded economic values and need to be expanded in order to develop activities to create value [23]. In other words, each circular strategy should have a business aspect to create value which means having economic benefits for stakeholders to convince them to implement the strategy. Additionally, strategies are always a rather general concept that needs to have specified and practical solutions which are applicable to a certain business or industry sector. These solutions are activities that have been designed for implementing a specific strategy in a certain business. In fact, for implementing strategies on a business scale, it is needed to define activities to achieve the determined goals for that strategy and this is another issue that has not been addressed for circular strategies. These are the uncovered gaps that this article is going to address by answering the below questions:

1. What are the circular business strategies applicable for circular economy adoption in modular construction?
2. How do the circular business strategies create value for all stakeholders within the value chain?

To answer the first question, a systematic review of the literature will be conducted to explore and identify the most relevant CBSs that are essential for building the future CBMs and could be applicable to MC as well. In response to the second question, the article will propose tailored key activities for implementing each identified strategy and then link the activities to produce a map in which the activities have been fitted together to demonstrate how values will be created and delivered to the stakeholders within value chain to assure the sustainable and economic function of CBMs.

2. Methods

The research method of the paper has two main phases. In the first phase, a literature review was conducted to identify circular strategies with the potential to implement CE in MC. In the second phase, a content analysis was conducted to analyze the extracted data from the final filtered articles. The process for the literature was illustrated in Figure 1 and Figure 2.

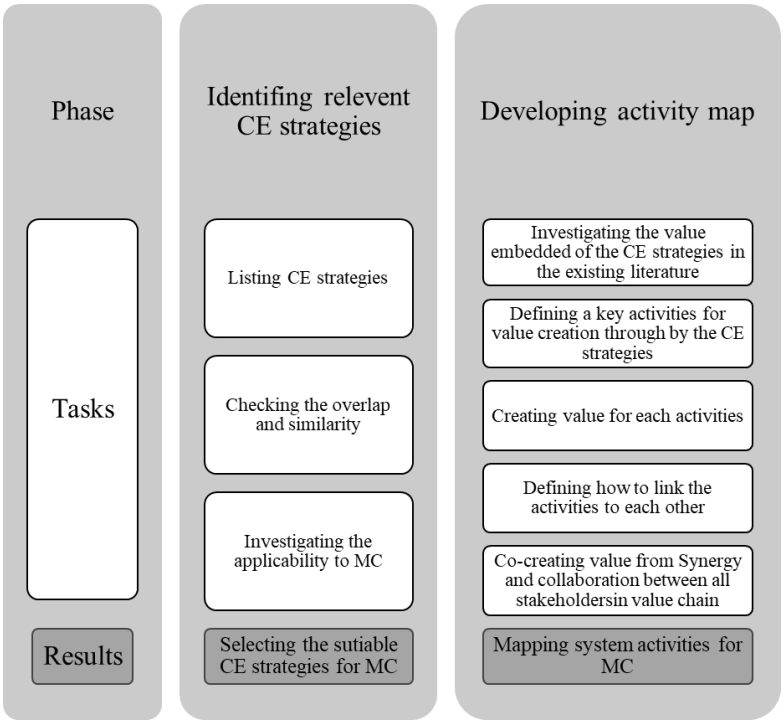

Figure 1. Overview of the methodology.

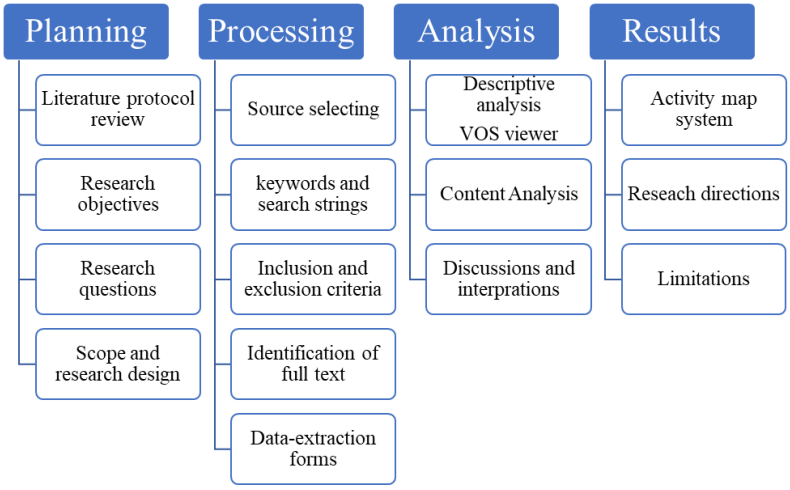

Figure 2. Flow and structure of the article.

The systematic literature review (SLR) method will be used to identify what circular business strategies may apply to modular construction. SLR is a transparent and reproducible method [30] that provides the contributions from previous research in the area [31], being carried out in three stages: (i) review planning, (ii) followed by the execution of the review and, finally, (iii) reports and dissemination [30]. The summary of the three steps adopted follows as shown in Figure 3.

<table>
<tr><th>Planning</th><th colspan="2">Execution</th><th>Results</th></tr>
<tr><td rowspan="5">Research gap

Few studies on applying CBMs to MC</td><td>Database
Google Scholar
Web of Science</td><td>Search period
2012 - Present</td><td rowspan="8">Synthesis

Analyses</td></tr>
<tr><td colspan="2">Keywords

Topic: “Circular business strategies” OR
“Circular business models” OR
“Circular economy”
AND
Topic: “Modular construction” OR
“Prefabricated buildings” OR
“Off-site construction” OR</td></tr>
<tr><td colspan="2">Research
Articles and reviews</td></tr>
<tr><td colspan="2">Total – Beginning
89 research</td></tr>
<tr><td></td></tr>
<tr><td rowspan="3">Goal
Identify CBSs applicable to MC and activity map system</td><td>Filter 1- initial reading
Restricted to title and abstract</td><td>Filter 2- Reading full
Definition of inclusion and exclusion criteria</td></tr>
<tr><td>Total – Middle
60 research</td><td>Total – End
29 research</td></tr>
<tr><td colspan="2">Data extraction
Title, author, publication details, research method, objectives, results, contributions, and research gaps that are recommended for future studies.</td></tr>
</table>
Figure 3. Stages of systematic literature review

To answer the research questions, a comprehensive search of the literature published within the last 10 years was conducted, focusing on the application of circular business strategies in modular construction. Our review included studies conducted on a global scale.

The article used the following databases and search engines to search for relevant literature: MDPI, Web of Science, and Google Scholar. Our search strategy employed the following keywords:

- Topic: "Circular business strategy" OR "Circular business models" OR "Circular economy"

AND

- Topic: "Modular construction" OR "Prefabricated buildings" OR "Off-site construction"

The inclusion criteria for this review were articles that focused on developing circular strategies or circular business models for the built environment, construction industry, and modular construction. The article excluded articles related to other industries or those focused on non-circular business strategies.

To extract data from the selected articles, this paper used extraction forms in Excel, which contained information such as title, author, publication details, research method, objectives, results, contributions, and research gaps recommended for future studies.

The research method of the article consisted of two main phases. In the first phase, we conducted a literature review to identify circular strategies with the potential to implement a circular economy in modular construction. In the second phase, we performed analysis to analyze the extracted data from the final filtered articles.

Some potential limitations of our methodology include the limited databases and search engines used, which may have impacted the comprehensiveness of the search. Despite these limitations, our systematic approach to searching, extracting, and analyzing the literature provides valuable insights into the application of circular business strategies in modular construction and their value creation for stakeholders within the value chain.

3. Results

This The initial review was limited to articles and reviews, with no time restrictions and resulted in 89 searches. The first reading of the papers was restricted to the title and abstract and resulted in 60 papers that were aligned with the research objective. Inclusion and exclusion criteria were developed to specify which searches would be carried out after reading the full text, focusing on introduction, method, and conclusion. The inclusion criteria were:

- Conceptual studies that explore MC and CE or their variations
- Studies that integrate MC with CE or CBSs or CBMs.
- Studies exploring MC as a facilitator of CE.
- Studies exploring CBS as an interface or integrator of CE and MC

Similarly, exclusion criteria were developed:

- Studies on MC or CE do not address the integration between both. Although these studies provide insights into the topic, they are not useful for meeting the research objective.
- Studies that address MC outside the context of circular economy.
- Studies that address CBMs outside the construction industry.

The application of the inclusion and exclusion criteria resulted in the final sample of 29 papers.

3.1. keywords network

The co-occurrence diagram presents a comprehensive visualization of the primary keywords identified in the descriptive analysis of extant literature. Central to the diagram is the term "circular economy," which bridges various topics ranging from business model innovations to environmental impact assessments. Notably, while the "construction industry" appears as a significant node connected to the circular economy, the specific term "modular construction" is conspicuously absent. This suggests a potential research gap, indicating that previous studies may not have extensively explored the interrelation between the circular economy and modular construction.

Furthermore, the connections between "circular economy" and its related terms, such as "circular business models," "lean startup approach," and "business model transition," hint at a dominant trend in literature focusing on business model

adaptation to sustainable practices. However, the tangential emphasis on the broader "construction industry" without a specific delve into "modular construction" underscores the need for further research in this niche intersection. The results highlight an opportunity for academic inquiry into how modular construction can integrate and benefit from circular economy principles (Figure 4).

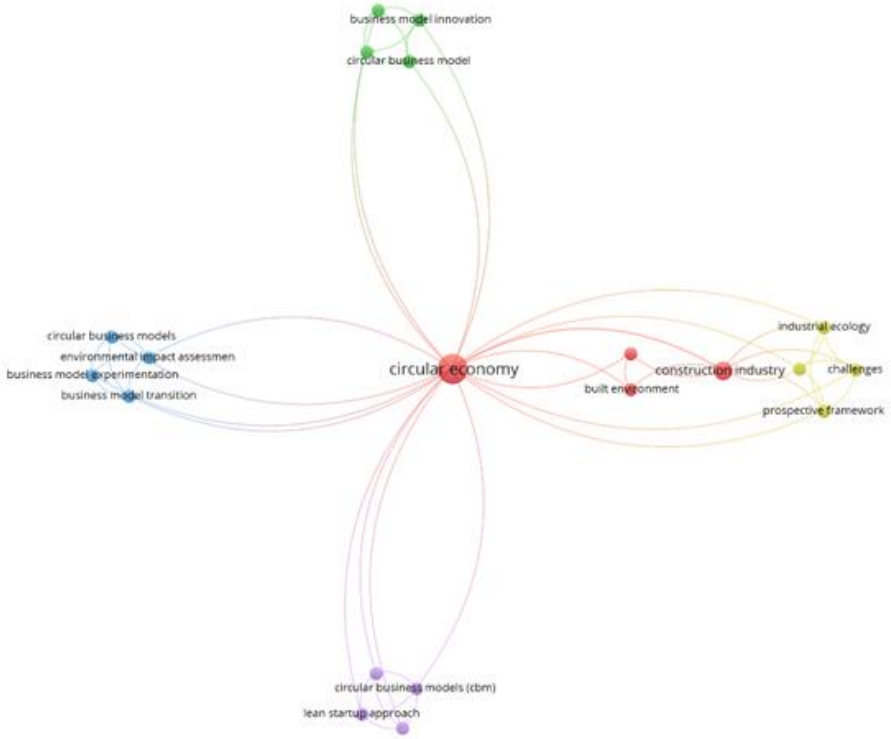

Figure 4. Co-occurrence of keywords

3.2. Circular business strategies (CBSs)

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn (Figure 5).

3.2.1. Strategic partnerships for circularity and engaging stakeholders along the value chain

This strategy involves building relationships with other organizations that can help to promote circularity in modular construction. This could include material suppliers, waste management companies, other modular construction companies, and end-users. By working together, these organizations can share resources and expertise, and develop new products and processes that reduce waste and promote reuse and recycling.

3.2.2. Design for circularity

This strategy involves designing modular buildings that are easy to disassemble, reuse, and recycle. This could involve using modular components that are standardized and can be easily connected and disconnected, and using materials that are recyclable or biodegradable.

3.2.3. Designing out waste

This strategy involves designing modular buildings that produce as little waste as possible. This could involve using waste materials in the construction process, or it could involve designing the modular building in a way that minimizes waste.

3.2.4. Industrial symbiosis

This strategy involves collaborating with other organizations to share resources and waste. This could involve exchanging waste materials with other organizations, or it could involve co-locating with other organizations so that waste can be easily shared.

3.2.5. Reuse

This strategy involves using modular buildings that have been used before. This could involve buying used modular buildings, or it could involve renting modular buildings that are no longer needed by their original owners.

3.2.6. Recycling

This strategy involves breaking down modular buildings into their component parts and then recycling those parts. This could involve recycling the materials used to construct the modular building, or it could involve recycling the modular building itself.

3.2.7. Reconditioning

This strategy involves repairing and restoring modular buildings so that they can be reused. This could involve repairing damaged components, or it could involve upgrading the modular building to meet new standards.

3.2.8. Environmentally friendly material usage-driven practices

This strategy involves using materials that are environmentally friendly, such as recycled materials or materials that are made from renewable sources.

3.2.9. Extending product life

This strategy involves designing modular buildings that can last for a long time. This could involve using durable materials, or it could involve designing the modular building in a way that makes it easy to repair and maintain.

3.2.10. Take-back system (TBS)

This strategy involves setting up a system for taking back modular buildings after they are no longer needed. This could involve collecting the modular buildings from the owners, or it could involve providing a financial incentive for the owners to return the modular buildings.

3.2.11. Product-service systems (PSS)

This strategy involves selling modular buildings as a service rather than as a product. This could involve providing a maintenance service, or it could involve providing a financing service.

3.2.12. Refurbishment

This strategy involves restoring modular buildings to their original condition. This could involve repairing and replacing damaged components, or it could involve upgrading the modular building to meet new standards.

3.2.13. Remanufacturing

This strategy involves rebuilding modular buildings from used components. This could involve repairing and reusing damaged components, or it could involve using new components to replace damaged components.

3.2.14. Repair and maintenance

This strategy involves repairing and maintaining modular buildings so that they can last for a long time. This could involve regular inspections and maintenance, or it could involve providing a maintenance contract to the owners of the modular building.

3.2.15. Dematerialization

This strategy involves reducing the amount of material used in the construction of modular buildings. This can be done by using lighter-weight materials, using materials that are more efficient in terms of their use of space, and designing modular buildings in a way that is efficient in terms of their use of materials.

3.2.16. Digital technologies to enable circularity.

This strategy involves using digital technologies to track the flow of materials and resources in the modular construction process. This could involve using blockchain or other technologies to track the materials used in the construction of the modular building.

Figure 5. Identified circular strategies.

Modular construction, when intertwined with circular strategies, holds immense promise for sustainability and efficiency in the construction industry. From the engagement of stakeholders along the value chain to the utilization of digital technologies, these strategies present a roadmap towards creating a more eco-conscious and waste-minimized built environment. These approaches, ranging from design innovations that prioritize circularity to system-level strategies like product-service systems, underscore the need for a holistic and integrated approach. Embracing these circular strategies in modular construction not only champions environmental stewardship but also fosters collaborations and innovations that can revolutionize how buildings are designed, constructed, and repurposed.

3.3. Activity system map

To implement and tailor these strategies to MC, it is needed to define key activities for each strategy. In other words, key activities are the practical solutions to apply the strategies and accordingly CE into MC.

3.3.1. Strategic partnerships for circularity and engaging stakeholders along the value chain

For the strategy of developing strategic partnerships for circularity and engaging stakeholders along the value chain, the steps are to identify and engage key stakeholders in the modular construction value chain, foster collaboration among these stakeholders for joint circular projects, and form strategic partnerships with suppliers, manufacturers, and waste management entities.

3.3.2. Design for circularity

When focusing on design for circularity, one needs to incorporate modular and flexible design principles that support easy disassembly, repair, and upgradability. It's equally important to design components with material recovery in mind, employing standardized, durable, and non-toxic materials. In addition, integrating design for disassembly (DfD) principles in modular construction components is crucial.

3.3.3. Designing out waste

For designing out waste, the goal is to perfect material usage during the design and production processes of modular components. Waste reduction strategies should be in place during construction, and digital technologies should track material consumption and waste production.

3.3.4. Industrial symbiosis

Industrial symbiosis requires an understanding of material and energy flows between businesses to recognize potential exchanges. Facilitating events or platforms that encourage companies to delve into industrial symbiosis is a good approach, as is fostering collaborations with other sectors for the exchange of byproducts, materials, or energy.

3.3.5. Reuse

The strategy of reuse involves designing modular components versatile enough for varied applications and configurations. A systematic approach to tracking, storing, and redistributing reusable components is needed, along with a push for incorporating reused components in new projects through either incentives or regulations.

3.3.6. Recycling

Recycling efforts should zero in on creating modular components from recyclable materials. A tracking system for material recycling as components reach the end of their life cycle is essential. It's also vital to work alongside recycling centers to guarantee the correct treatment and processing of these materials.

3.3.7. Reconditioning

Reconditioning involves assessing the potential of modular components to be reconditioned. A system for tracking, reconditioning, and redistributing such components should be set up. Proper handling and processing of these components can be ensured through collaboration with refurbishment centers.

3.3.8. Environmentally friendly material usage-driven practices

Environmentally friendly material usage-driven practices require an assessment of materials based on their environmental ramifications and potential for circularity. Sourcing from sustainable suppliers and adopting techniques that minimize material wastage during construction are also central to this strategy.

3.3.9. Extend product life

To extend product life, employ durable and enduring materials in the design of modular components. Regular maintenance and repair initiatives will further extend component life. Promoting modular construction as a malleable solution responsive to evolving needs is also beneficial.

3.3.10. Take-back systems (TBS)

Take-back systems (TBS) revolve around the idea of retrieving modular components at the conclusion of their life cycle. Providing incentives for customers to return these components and ensuring their proper treatment through collaboration with waste management companies is essential.

3.3.11. Product-service systems (PSS)

Product-service systems (PSS) involve alternative models like leasing or renting out modular construction components. Focusing on performance-based contracts and having a system in place to manage leased or rented components are key aspects of this approach.

3.3.12. Refurbishment

Refurbishment calls for an assessment of modular components to determine their potential for being refurbished. Proper handling and processing can be ensured by working alongside refurbishment facilities.

3.3.13. Remanufacturing

Remanufacturing is much like refurbishment but requires components to be reconstructed from used parts. Similar systems of tracking and processing are applicable here, along with collaborating with remanufacturing centers.

3.3.14. Repair and maintenance

When focusing on repair and maintenance, components should be designed for easy accessibility and repair. Implementing a program for these purposes and equipping construction personnel with the needed skills for modular component repair is essential.

3.3.15. Dematerialization

Dematerialization means considering digital or virtual alternatives to physical components. Optimizing material usage in design and production and promoting digital collaboration tools can minimize physical resource needs.

3.3.16. Digital technologies to enable circularity

Digital technologies for promoting circularity include using such technologies to manage material flows and waste production. Adopting Building Information Modeling (BIM) and other design tools can optimize resource use in modular construction. Collaboration, resource-sharing, and information exchange among stakeholders can be facilitated by specialized digital platforms or tools.

When determining the optimal strategies for integrating modular construction, it's crucial to identify the ones that offer the most value to all stakeholders. Drawing inspiration from Porter's method, we start by pinpointing the five paramount strategies and positioning them centrally on our map. Following this, we choose the activities that are best suited for actualizing these strategies, focusing on those that can bolster the system and deliver maximum value to the stakeholders. Finally, we establish connections between the strategies and activities where they complement or bolster each other, ensuring a cohesive fit. The selected strategies and activities are below:

To summarize, the secondary nodes (key activities) serve as actionable steps under each primary node (strategy). Their connections illustrate how each activity informs or depends on another within the framework of the overarching strategy. Mapping these visually would provide a clearer overview of how the strategies can be operationalized through interconnected activities. The primary strategies have been shown by bigger circles and key activities have been depicted by smaller nodes as illustrated in Figure 6. The lines have illustrated the connections and dependencies between strategies and key activities. Consequently, we have a unique interdependent and interconnected mapping system that allows the strategies and activities to work efficiently and effectively to deliver value to all stakeholders appropriately.

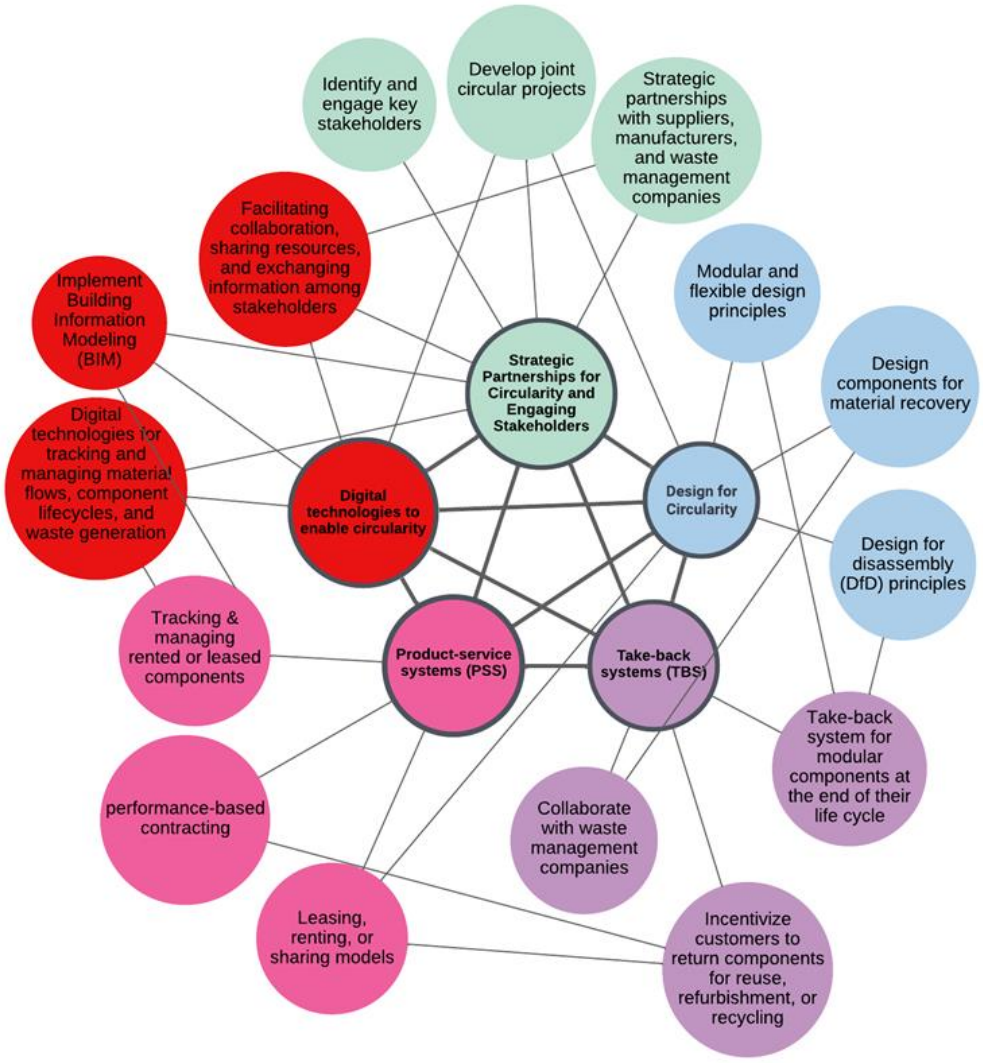

Figure 6. Activity system map.

4. Discussion

This review process highlighted a pivotal juncture in the convergence of Modular Construction (MC) and the Circular Economy (CE). From the initial 89 articles sourced, only 29 were deemed pertinent to the research objective, indicating a selective yet comprehensive approach. The absence of "modular construction" in keyword co-occurrence underscores an apparent research gap, emphasizing the need for academia and industry to focus on its integration with circular economy principles.

Circular Business Strategies (CBSs) delineated in the review depict a roadmap for incorporating sustainability and efficiency into the modular construction sector. The emphasis on strategies such as design for circularity, waste reduction, and strategic partnerships accentuates the paradigm shift towards creating sustainable built environments. The practical implications of these findings are vast. Stakeholders across the construction value chain, including architects, developers, material suppliers, and policymakers, can harness these strategies to champion environmental stewardship. Specifically, adopting these strategies will likely result in reduced construction waste, extended building lifespans, and optimized resource

utilization. Furthermore, a shift towards a service-oriented approach, as seen in Product-service systems (PSS), could revolutionize the business models of construction firms, promoting sustainability and long-term customer engagement.

The Activity System Map further operationalizes these strategies, presenting actionable steps for stakeholders to integrate circularity into MC practices. From fostering collaborations across the value chain to leveraging digital technologies, these activities not only facilitate the implementation of CBSs but also provide a structured framework for stakeholders to navigate the complexities of integrating MC with CE principles. In particular, strategies like "Design for Circularity" and "Digital Technologies to Enable Circularity" signify the synergy of design innovation and technological advancements, offering construction firms a dual approach to embed sustainability into their operations.

Moreover, the identified strategies have direct implications for policymakers and regulatory bodies. By understanding the potential of modular construction in promoting circular economy principles, regulatory frameworks can be developed to incentivize or mandate the adoption of these strategies. This can pave the way for a construction industry that not only meets housing and infrastructure needs but also does so in an environmentally responsible manner.

In conclusion, the insights garnered from this review are pivotal for the future of modular construction and its alignment with circular economy principles. As the construction industry grapples with the challenges of sustainability, waste reduction, and resource optimization, the strategies and activities outlined in this research offer a beacon, illuminating the path forward. It is incumbent upon all stakeholders to harness these insights, championing a future where buildings are not just constructed but crafted with a vision of circularity and sustainability.

Future research should focus on devising innovative strategies and essential activities tailored for specific types of modular construction (MC) in various countries, taking into account the legal and governmental requirements for collaboration among stakeholders. Additionally, researchers can explore new technologies and platforms for information and component sharing, which would enhance collaborative efforts. Designers, architects, and engineers should also aim to create universally acceptable modules and components that can be shared more easily.

5. Conclusion

The landscape of circular economy (CE) principles within modular construction (MC) is vast and multi-faceted. Through an extensive review of the prevailing literature, this paper not only consolidates existing knowledge but also makes a distinct and substantive contribution: the development of an intricate activity system mapping. While numerous studies have tackled aspects of CE and MC separately, our research stands out for its deep dive into the synergy between the two. The devised activity map bridges conceptual understandings with actionable insights, serving as a visual representation that delineates how high-level CE strategies can be operationalized within the modular construction framework.

By providing a clear and structured overview of interconnected strategies and activities, this mapping becomes an invaluable tool for stakeholders. It aids in recognizing gaps, understanding dependencies, and facilitating more informed decision-making in the practical application of CE principles to MC. Furthermore, the adaptability and dynamism of this framework ensures its relevance across different MC projects, underscoring its utility as a universally applicable tool. In essence, the article's primary contribution lies in this comprehensive activity system mapping. This endeavor distills a vast body of knowledge into a coherent and actionable framework, providing a roadmap for those at the forefront of integrating sustainability into modular construction. Through this review and mapping, we aim to inspire and guide future research, practice, and innovation in this promising confluence of CE and MC.

The primary limitation of this paper is its general approach to MC mapping, given that each MC project possesses its unique specifications, requirements, and constraints. In essence, every MC project requires a tailored map that aligns with its distinct features. Moreover, crafting such maps for MC projects demands profound understanding of modular design, business models, and circularity. These factors can influence the relationships or connections between strategies and activities. Consequently, the development of such a mapping system necessitates a team comprising diverse experts. Each member should not only have a broad understanding of their domain but also possess specialized knowledge in their particular field.

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