A Roadmap towards Circularity - Modular Construction as a Tool for Circular Economy in the Built Environment

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Abstract. The concept of Circular Economy (CE) is a novel economic model aiming to foster sustainable economic growth, increase a company’s economic value added, boost global competitiveness, and achieve the Sustainable Development Goals (SDG). The modular construction has a high potential to embody a starting point for this transition because of its industrial construction and predestined characteristics for disassembly and reuse. In this paper, a circular economy framework is applied to the modular construction industry to develop a roadmap within the scope of Circular Business Models (CBM). In the first part, a literature review is conducted to identify the current CBMs in terms of applicability, usability and adaptability to the sector. The four business models maintenance and repair, reuse and refurbishment, upcycling, and product-as-a-service emerged. In a second step, a qualitative approach with international experts in modular construction, circular economy in the built environment and consultancy is used to explore the opportunities, challenges and barriers in the industry to accelerate the transformation to circularity within the holistic building life cycle. To overcome the barriers, 15 guidelines are distilled and through additional expert interviews verified. Subsequently, this roadmap supports responsible consumption and production through the building life cycle and enables benefits concerning the triple bottom line paradigm. While some of the guidelines refer to specific CBMs, the majority represents a comprehensive approach. Applying the roadmap is a first step to activate the identified potential of the CE in the modular construction industry in order to enhance an innovative and sustainable industrialization within the built environment and to contribute to a cleaner, more resilient economy.

1. Introduction

The concept of Circular Economy (CE) is a novel economic model aiming to foster sustainable economic growth, increase a company’s economic value added, boost global competitiveness, and achieve the Sustainable Development Goals (SDG) [1]. CE aims to overcome the take-make-dispose linear pattern of production and consumption, resulting in value retention of products, materials and resources [2].

The modular construction has a high potential to embody a starting point for this transition because of its industrial construction and predestined characteristics for disassembly and reuse [3]. In terms of a construction-based definition, modular construction refers to factory-built building units completely assembled or fabricated in a manufacturing plant away from the construction site, then transported and assembled on site [4]. Despite its predestination,
CE is hardly applied in the modular construction industry and is limited to the use of by-products in concrete production and recycled concrete, which generally represents a downcycling of materials [5]. This paper aims to analyze the contemporary challenges and barriers for adopting CE in the modular construction industry and seeks to overcome these barriers with a roadmap for the sector.

2. Methodology

In order to answer the question how the principles of the circular economy can be applied to the modular construction industry, and which circular business models (CBM) are generally established, the research is conducted in three steps. In the first step, a systematic review of research articles is carried out to identify the current state of academic insight with regards to the established CBMs. Published articles were extracted from the Web of Science and Scopus using the keywords "circular business model" as well as "circular economy" AND "business model" for the years 1950 until 2018. In the second step, a qualitative approach with semi-structured expert interviews was conducted to specify the opportunities, contemporary challenges and barriers in the industry in order to accelerate the transformation to circularity within the holistic building life cycle through CBMs. Seven experts in modular construction from Germany and the Netherlands were interviewed. Based on the identified challenges and barriers 20 measures emerged to promote CE within the scope of CBMs in the modular construction industry. Subsequently, in a third step, five additional experts in CE in the built environment were interviewed to verify the preliminary measures. Fifteen guidelines were distilled providing a roadmap for stakeholders and policymakers.

2.1. First Step - Circular Business Models

From a review of literature on CBMs, and how they are applied, the most relevant ones for the building sector were outlined. In general, a business model represents the rationale of how an organization creates, delivers, and captures value [6]. Adopting the concept of CE, CBMs can be defined as the rationale of how an organization creates, delivers, and captures value with and within closed material loops [7]. In terms of applicability, usability and adaptability to the modular construction sector the subsequent CBMs were outlined: Maintenance and Repair, Reuse and Refurbishment, Upcycling, and Product-as-a-Service.

2.2. Second Step - Opportunities, Challenges, Barriers for the Modular Construction Industry

The most frequently mentioned challenges and barriers for the sector are largely linear patterns, individuality and composite materials of building units, complexity of the supply chain, long lifecycle of buildings, lack of profitability and legal uncertainties as well as a lack of demand on the part of the building-owner.

The indicated opportunities are more corporate resilience, the chance to extend the share of value added of a company and the integration of the triple bottom line framework at a corporate level, e.g. resource conservation, climate protection, and promote inclusive and sustainable industrialization.

2.3. Third Step - Roadmap for Circularity in the Modular Construction Industry

The review of literature and interviews reveal that the integration of CBMs has high potential to improve the business performance. However, the extracted challenges and barriers hinder the integration in the modular construction industry. Among the experts, it is generally noted that there is a need for a roadmap to facilitate the integration of CBMs to exploit business opportunities. Based on the identified challenges and barriers 15 guidelines emerged. Table 1 and 2 summarize the guidelines with a short description as well as the overcome barriers and
provide the roadmap towards circularity. Table 1 outlines comprehensive guidelines which can be integrated into all CBMs. Table 2 shows specific guidelines for the CBMs Reuse and Refurbishment (1), Upcycling (2), and Product-as-a-Service (3). The guidelines for Maintenance and Repair are presented as comprehensive guidelines as all of them relate to other business models as well.

**Table 1. Comprehensive Guidelines**

| Guideline                  | Description                                                                                     | Overcome Barrier                                      |
|----------------------------|-------------------------------------------------------------------------------------------------|--------------------------------------------------------|
| Outsourcing of CE activities | Incorporate subsidiaries and internal departments in order to relieve the day-to-day business | Short-term perspective, lack of capacity, novel business activities |
| Promote circular innovation | Challenge current processes, products and concepts uncoupling obsolete structures to exploit and generate competitive advantages as well as profit increases due to nature of modular construction | Conservative mindset                                 |
| Orientation towards other industries | Overcome obsolete perspectives within the construction industry through integrating and orientation towards other industries, e.g. the automotive industry | Conservative mindset                                 |
| Customer involvement | Explanatory work regarding involvement of customers in an early stage of the planning process to highlight the advantages and foster acceptance as well as interest in CE | Short-term perspective, lack of acceptance and demand |
| Cohesion policy support | Set out measures to provide incentives to all stakeholders, support explanatory work through lighthouse projects, develop a consistent policy framework and promote sustainable public procurement practices | Lack of policy measures, inconsistent rules.          |
| Holistic modular approach | Inclusion of the advantages of modular construction over the entire life cycle, such as non-destructive dismantling and interchangeability | Short-term perspective, lack of profitability        |
| Enhance degree of standardization | Achieving economies of scale, schedule reliability, and enhanced quality | Lack of profitability, complex buildings, individual projects |
| Take-back concept | Realization of reverse logistics to benefit from profit increase through BAMB from the manufacturers knowledge and customer access as well as more efficient processes | Loss of ownership, short-term perspective             |
| Design Thinking | Considering the demolition process during an early planning phase and redesign the products according to circular principles, i.e. no use of composite materials, accessibility of the installed components, enabling a non-destructive demolition | Lack of profitability                                |
Table 2. Specific Guidelines

| Guideline | Description | Overcome Barrier |
|-----------|-------------|------------------|
| (1) Increase flexibility to enhance longevity | Provide as much flexibility as possible for the building owner to manage future uncertainties during the operational phase and to facilitate reuse | Lack of profitability |
| (1) Eliminate redundant work and movements | Reducing resources (e.g. time, cost, planning effort) through tools like material passports, cooperation with local suppliers and comprehensive take-back concepts | Lack of capacity, necessity of refurbishing, additional transport |
| (2) Promote Upcycling | Take responsibility for proper recycling at the end of the operational phase | Novel business activities, lack of capacity |
| (2) Sustainable Supply Chain Management | Knowledge exchange and cooperation within the supply chain in order to benefit in terms of better matching materials, reduced itineraries and less errors due to a more lucid supply chain within the factory production | Fragmented supply chain, inconsistent rules |
| (3) Internal price system | Defining and pricing of provided services in order to be consistent and transparent | Inconsistent price setting |
| (3) Development of new contract types and operator models | Provide dynamic contracts and business models regarding alterations due to customers’ needs during the operational phase | Loss of ownership, conservative mindset, lack of acceptance/demand |

3. Conclusion

In this paper, several challenges and barriers were identified. The research highlights that the modular construction industry offers the opportunity to facilitate the implementation of CE in the construction industry and CBMs can provide both economic efficiency as well as sustainability. Among the stakeholders, however, a strategic plan for the implementation of CE is still lacking. Hence, 15 guidelines are proposed to foster the application of CE to buildings. The developed roadmap can support a sustainable industrialization, foster innovation as well as ensure sustainable consumption and production. In doing so, it can be seen as a contribution to achieve the SDGs, especially Goal 9: Industry, Innovation, and Infrastructure, 12: Responsible Consumption and Production, and 13: Climate Action.

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