BARRIERS OF INCORPORATING CIRCULAR ECONOMY IN BUILDING DESIGN IN A DANISH CONTEXT

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The building sector has the responsibility to influence on recognizing the UN's 17 Sustainable Development Goals (SDGs). By considering SDG goal 12 for responsible consumption and production, buildings in Denmark account for 35% of the total waste and 40% of the energy consumption and CO2 emissions. Circular Economy (CE) Is one of the crucial concepts to reduce environmental impacts, including climate problems by reducing waste and resources. This can be achieved through the choice of alternative materials or solutions, by promoting the life cycle and circular mindset. Previous research has shown that circular design principles are not applied broadly, thus, the study aims to investigate the potential of using CE in building design to provide designers, consultants, and contractors, an insight into the various challenges, when adopting circular strategies to reduce the waste of resources and environmental impact. Semi-structured interviews were conducted, along with questionnaires and evaluation charts, with four respondents involved in building design, from architectural, consulting and developing organizations with different levels of experiences in sustainable buildings, specifically in using circular concepts. The interviews were analysed to investigate how CE is incorporated into building design unfolding barriers and pointing out some key factors to promote CE principles, e.g., organizations behaviour, collaboration, politics, and economy. The results indicate the complexity of the CE transition, as numerous aspects need to be considered. It reveals that actors can improve their interdisciplinary interactions to use circular principles, raising their awareness as true intermediaries in progressing wider sustainability goals. Other barriers are related to a lack of circular materials passports.

Keywords: circular economy, design, sustainability, sustainable development goals

INTRODUCTION

With the global population growth set to continue its rapid development, the need for housing in cities worldwide will similarly expand (State of Green 2020). Buildings are responsible for a very big part of the planet's resources (MacArthur Foundation 2015), they consume 40 % of the resources, and create one-third of the world's waste (Danish Environmental Protection Agency 2014), therefore there is a need for the

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sustainable conversion of the Danish building sector. Circular economy (CE) With no doubt will play a key role in the coming years (Hildebrandt and Brandi 2017) being proposed to tackle urgent problems of environmental degradation and resource scarcity (Almas Heshmati 2015). Thus, we need a real shift in how we typically design and construct buildings, finding solutions that reinforce the shift from linear to CE and promoting waste as a resource for new solutions (State of Green 2016). At the international level, initiatives have already been initiated to promote the transition to a CE. The UN has in 2015 adopted 17 global goals for sustainable development (SDGs) To direct the world in a sustainable direction. Here, CE is a very central and transversal means because it can enable continued economic growth and high prosperity in a way that the globe can keep up with. Entry transformation into a CE will, therefore, help to implement the government's new action plan for the UN's 17 global goals, especially, goal 12 for responsible consumption and production (UNDP 2015). It will also contribute to supporting companies' commitment to the SDGs with a view to both new business opportunities and increased expectations of local and global sustainability. Thus, there is a need for green businesses and actors in the building industry to work closely together to create value for the entire community (State of Green 2020). The concept of CE is not widely understood by the profession. Mobilizing this opportunity will remain a challenge until many more business leaders adopt a "circular mindset" (WBCSD 2018). To some business leaders implementing CE can seem too complex. To others, these complications stand as great challenges as well as grand opportunities (Lendager and Vind 2018: p.193).

Potential of CE in Building Design

Rethinking buildings' design process represents an enormous potential for reducing waste and increasing recycling and reuse. Discarded materials from construction and demolition account for approximately 35 % of waste generated in Denmark (Danish Transport and Construction Agency 2016). The construction sector reuses around 84 % of it from construction sites, but it happens in such a way that most of the value in the materials are taken out by decomposition. Thus, there is a great potential for increased conversion to a CE in the construction industry (Hildebrandt and Brandi 2017). The transition to a CE will catalyse the most transformational economic, social, and environmental changes. This requires enabling conditions that remove existing barriers in circular building design and materials utilization. Solutions that contribute to more circular construction, include a design for disassembly, waste prevention, and design from upgraded waste to be used within the building sector (Danish Cleantech Hub 2018). There is also a great economic potential in CE. Calculations from MacArthur Foundation (2015) show that conversion to CE in Denmark will be able to increase the total production by 0.8-1.4 %, increase exports by 3-6 % and will result in the creation of between 7,000 and 13,000 new jobs by 2035 (Hildebrandt and Brandi 2017). A thoroughly calculated Danish business case by Jensen and Sommer, documents that a demolition, which today would cost DKK 16 million, can be turned into a DKK 35 million business upside in the circular future building industry (2018). Despite positive claims about the potential of CE implementation to simultaneously reduce environmental burden whilst enhancing business benefits, not all circular solutions (or circumstances) Bring the desired positive effects, especially in the broader context of sustainability. For this reason, any decision to adopt a CE strategy ought to be carefully assessed with regards to its potential sustainability performance, before its implementation (Kravchenko, Pigosso and McAloone 2019). Several challenges and barriers that may prevent or slow down

the implementation of CE have been recognized in the literature. In Denmark, no concrete studies exist that investigate current state-of-the-art drivers, barriers, and practices in CE (Govindan and Hasanagic 2018). Adopting CE faces many challenges (Olsen 2019). The main barriers are lack of early-stage chain corporation and partnerships in the building sector, lack of economy of scale, lack of quality assurance marking schemes of reused building materials, and content of hazardous substances in existing building products currently embedded in buildings. From the perspective of policymakers in Denmark, it is expected that new regulations cannot stand alone for overcoming the above-mentioned barriers nor as to the only policy instruments for accelerating a transition toward a CE in the Nordic construction sector. It is expected that companies may need stronger economic incentives to change their existing and often linear business approach (Høibye and Sand 2018). This study aims to assist in strengthening CE to boost sustainable building solutions by investigating barriers that may prevent or slow down its' implementation, which has been recognized in the literature and from experiences presented by involved actors through semi-structured interviews. Thereby, this article seeks to answer the research question: What are the barriers of incorporating a circular economy in building design - in a Danish context?

LITERATURE REVIEW

Economic Barriers

Financial risk is involved where capitalization of the value of recycled elements will happen in 50 years or more from the time of investment, so who can finance the cost for this added feature? The value from improved possibilities will not be gained until the demolition of the building. All stakeholders in the industry will perceive this as a huge risk, as no one knows what the value of the improved elements will be, compared to the traditional elements and a price in the market will be speculative until the elements are available. Only clients with the specific demand to erect buildings designed for disassembly or legal requirements, e.g., in the building code are realistic drivers in the current market. Additionally, the lack of material prices that reflect the real environmental costs and hence economic optimization of building design often leads to results that do not reflect and take the real costs into account. There are also a few legal barriers in CE, related to the consequences of the legal framework e.g., standards and tests are based on virgin materials and not on recycled or upcycled materials and components (Jensen and Sommer 2018). Another barrier is related to the structure of the industry itself, which leads to split incentives along the value chain. There are limited vertical integration and each player, including the investor, architect, developer, engineer, sub-contractor, owner, and tenant - naturally maximizes their profits at the expense of the others. Since designing for circularity requires some alignment of incentives to close the loop in the value chain, not having such incentives makes the economic case for reuse difficult to make (MacArthur Foundation 2015). Results from a survey of 77 companies in the UK show that firms favour practices related to resource and energy utilization efficiency, while practices related to investment recovery, green purchasing, and customer cooperation are less prevalent. The significant investment cost, lack of awareness, or sense of urgency were identified as implementation barriers (Masi *et al.,* 2018).

Collaboration Barriers

A study by Guldmann and Huulgaard (2020) confirms that barriers exist at all socio-technical levels. Most barriers are encountered by companies at the organizational level, followed by the value chain, the employee, and then institutional. A case study on a conventional office building conducted by (Eberhardt, Birgisdottir and Birkved

2019) reveals that the main barriers are identified as complex supply chains, focus on short term goals that create short-term profit that misfit the long-term goals of sustainability. This creates competition among the stakeholders resulting in insufficient collaboration between them, and the absence of a commonly agreed definition of CE within the industry (Jrade and Jalaei 2013). A transition to a CE is a paradigm shift that requires a change of mindset among, the financial sector, policymakers, and companies. Collaboration between various stakeholders will be key to a successful transformation (State of Green 2016). The transition to a functioning CE regime requires systemic multi-level change, including technological innovation, new business models, and stakeholder collaboration (Witjes and Lozano 2016).

Materials Passports (MP) and Digitalization

Identifying the MP after use and disassembly is a challenge. MP contains a huge amount of complex information that needs to be updated regularly and be accessible by many different parties, this creates a complicated security issue. It must be easily accessible and updated when changes happen to the building during its entire lifetime. The main challenge is how to handle and structure the huge amounts of data that are accumulated when mapping out the elements and materials in a building. Building Information Modelling (BIM) Can handle that, but not optimally, due to the extensive amount of data that causes models to become extremely heavy. Existing technologies must be improved, and new ones must be developed to enhance the use of digital MP (Jensen and Sommer 2018: 153). Digital information on the materials used in component production that would be very helpful at the point of refurbishment or demolition is lacking or unevenly distributed: while BIM approaches are developing, they are not yet in widespread use (MacArthur Foundation 2015).

Policies Barriers

The government can act as a market player to stimulate the development of a CE. Current policies and legislation are generally written in and for a linear economy. They may (unintentionally) Hinder the transition to a CE (Bod *et al.,* 2017). Among various stakeholders, the governmental perspective has the maximum positive impact on the implementation of the CE in supply chains. CE can be promoted through laws, policies, risk reduction (through tax levies), and strict governance (Govindan and Hasanagic 2018).

Social Barriers

Social and behavioral aspects of modern consumerism is a challenge, as the psychological bias to value exclusivity and authenticity undermines the principles of recycling and reuse. There are inertia factors, pointed by experts in the construction industry in the form of customs and habits and a lack of the requisite capabilities and skills that make reuse difficult to implement (MacArthur Foundation 2015). Designers use traditional construction approaches which makes it difficult to implement CE (Svendsen and Tang 2018).

Technical Barriers

Buildings traditionally contain a complex mixture of compounds that are often difficult to separate, making material reuse and recycling difficult. There are several challenges when reusing/recycling materials from existing buildings; hazardous chemicals (including those no longer permitted in building materials today); and the technical performance of components/materials not designed for reuse/recycling (MacArthur Foundation 2015). A Nordic study indicates that demolition and proper

material handling can be challenging in terms of problematic and/or unknown content of substances as Nordic building stock tends to be relatively old (Nordic Council of Ministers 2015). Recycling is generally beneficiated by using single pure materials. Another challenge is how to model continuous loops of materials and thus account for the benefits of recycling, including substitution rate and loss of quality (Olsen 2019). A Danish office building "The Four Boards" was designed to be flexible and future proof by using durable and energy-efficient materials. Barriers to CE were many guidelines for designing steel structures in buildings and the extra rules for occupant safety, fire safety, technical installation requirements, and minimum strength requirements which all heavily influence the building process of an office building in general. These regulations could impair circular solutions, which could make it a deterrent. Also, a building is designed with a certain lifespan in mind, which can be achieved through durable materials and/ or maintenance. The balance between costs, durability, and efficiency can be proven to be difficult. It either requires large amounts of technology and resources or compromises to achieve the set life span at maximum efficiency as CE (Optimize) Would entail (Bod *et al.,* 2017). The Circle house is a Danish case that addresses CE challenges by analyzing the project in all its value chains, business models, case studies, and framework conditions. The biggest barrier to building up a market for reuses of bricks is the certification to guarantee the quality of the bricks, as old materials are not subject to the rules on CE marking (3XN Architects 2019). A study in the UK by (Akinade *et al.,* 2019) explores the barriers when Designing for Deconstruction (DfD) Using CE; lack of stringent legislation and policies, lack of adequate information at the design stage, lack of large enough market for recovered components, difficulty in developing a business case, and lack of effective tools.

RESEARCH METHODOLOGY

A mixed-method approach was applied in this study. First, a literature review (presented in the previous literature review chapter) Was conducted, followed by semi-structured interviews (Kvale 1996). The project design aimed to produce information from four respondents, selected through purposive sampling, with profound knowledge in sustainable buildings in the organizations, to capture the controversies and diverging assessments of the single movements undertaken in the organizations. Interviews were conducted with one architect (R1), two consultant engineers (R2) And (R3), and a project manager in an organization for sustainable business development. All respondents support the CE mindset but have various levels of experience and were chosen based on their practical experience of working with CE in construction. An interview guide was prepared, following the strategy for 'semi-structured interviews' (Kvale 1996). The interview guide was structured according to three domains of technology presented by Orlikowski and Gash (1994), the three domains cover what the technology is, why it was introduced and how they were used are: Nature of Technology refers to people's images of the (generic) Technology and their understanding of its capabilities and functionality, benefits and demands. Technology Strategy refers to people's understanding of the motivation behind the adoption and its likely adding value to the organization, concerning actual plans assisting its implementation. Technology in Use refers to people's understanding of how the technology will be used on a day to day basis and the likely or actual condition and consequences associated with such use.

A qualitative questionnaire and a quantitative evaluation chart were sent to the respondents by mail before interviews. The chart depicts some challenges in CE

based on the results of the literature review, to stimulate the respondents to evaluate them according to the Likert Scale (1932), with five responses. The respondents had also an option to identify new challenges. The chart served as a structuring common object during the interview and as an agent for producing insight into the investigation. The interviews were recorded, then transcribed, and analysed using the analytical framework by Orlikowski and Gash (1994). The framework was applied to structure the data. The three domains characterizing the enactments of the subjects acting to make practical use of CE in their position in the building project organization. The domains overlap and interact but are useful for directing questions and interpreting answers.

FINDINGS

The analysis focuses on the sensemaking domains (Orlikowski and Gash 1994).

Nature of Circular Economy

R1 admits the potential of using CE, where big benefits can be achieved, but still many challenges need to be solved when reusing materials. They have recently grown focus on CE, attempting to find new knowledge in it and willing to distribute it further to the entire organization. Actors today are more conscious of using CE, they are trying to find new solutions to recycle and reuse some building materials, such as reusing old bricks. This requires strict requirements and documentation, e.g., which standard is used to fulfil the technical requirements, who is transporting the material, who is constructing it, and what are the expected economic benefits. CE solutions can cost more but can then enhance sustainable developments.

> Most often, builders are constrained by a fixed economic frame that we must deal with. So, it is a matter of whether there is space to adopt CE design solutions and CE estimations or not, thus the economy can be a stopper! R1

R2 is highly experienced in DGNB and CE, his organization supports CE to a large extent, partly about using the right resources in the right place and in terms of proposing or using mechanical assemblies to ease of recycling and reducing the number of components that are difficult to disassemble. R2 mentions that it requires efforts to get everyone to do something different than they usually do and to consider the possibility of CE in a project. CE does not distinct from the DGNB system, apart from being less bulky. However, the development of digital aids to support assessments from an early design phase onwards will be decisive for achieving a value of CE. Especially Life Cycle Assessment (LCA) And Life Cycle Cost analysis (LCC) Tools. The biggest barrier is the lack of understanding of the economic consequences and the harmful effects and environmental consequences of some design choices.

> Benefits of CE can be recognized if CE solutions that others have used and approved are shared, here knowledge and experiences should be gathered and shared. R3

Respondents ensure that the economy is a crucial influencer, contractors focus on financial savings but not on environmental impact. Actors should gain value when working with CE, and this is important to drive CE forward. Actors lack knowledge and experience, in terms of what CE provides in the long run.

Circular Economy Strategy

From R1 experience, many actors are eager to collaborate but have unclear responsibilities, e.g., who is responsible for what and who takes responsibility for these materials and solutions in 10, 20, or 30 years. According to R2, the collaboration challenges are lack of understanding of the environmentally harmful

aspects of recycling or rephrased, everything that cannot be recycled has sometimes met some resistance and using the right material in the right place should be highly prioritized.

> CE can in some cases incorporate the sins of the past or even expose them again. The pursuit of a good CE narrative can overshadow building physical knowledge. R2

All respondents agree that promoting CE is a common responsibility for all actors in the buildings sector. R4 reveals that there are many successive CE cases, that can inspire and motivate actors but are not exploited. Politics and regulations are essential to boost CE. Also, builders have a key rule in promoting CE. Attention must be taken to materials when demolishing buildings as they can include hazardous substances.

Circular Economy in Use

R2 declares that traceability and materials passports will be obvious, and preferably in a public database so it is easy in the future to see what materials have been used and their MP. Similarly, R4 confirms that the availability of MP will improve the adoption of circular materials. The profession lacks knowledge and data regarding which building parts can be recycled without problems and calls for a bigger focus on the overall economic impact. Other challenges are the absence of MP and an unknown lifetime of materials. Almost all respondents mention that tools to document economy and environmental impact are available, but not all actors use them. Thus, simplified tools will make it easier to use. According to the availability of guides and standards, R2 and R3 reveal the lack of guides, while R3 and R4 do not consider it as a barrier.

DISCUSSION

It is evident from the interview analysis that actors in the building industry lack of understanding the economic consequences and hardly recognize the economic benefits of CE. Organizations need clear and strong economic incentives. Designing for circularity requires some incentives to close the loop in the value chain (MacArthur Foundation 2015). Jensen and Sommer (2018) reveal that financial risk is involved when using CE, the value from improved possibilities will not be gained and known until the demolition of a building. All stakeholders in the industry will perceive this as a huge risk (2018). Interviewers inform that there are many positive CE business cases to learn from, which provide economic and environmental benefits, but actors do not utilize these opportunities to learn from. Similarly, knowledge is available but not exploited well. Calculations by the MacArthur Foundation (2015) show that conversion to CE in Denmark can increase the total production and export. A Danish business case, by Jensen and Sommer (2018) documents that economic benefits from demolition can be turned into a profitable business. However, Kravchenko *et al.,* (2019) admit that not all CE solutions bring the desired positive effects. Interviews and literature confirm that changing the behaviour of actors to transfer from linear to CE is a big barrier. Actors are inclined to traditional construction approaches which makes CE difficult to implement (Svendsen and Tang 2018). Customs and habits make reuse and recycling difficult to implement (MacArthur Foundation 2015). Furthermore, all interviewers perceive CE with high complexity, which reflects the complex nature of CE. To some business leaders implementing CE can seem too complex (Lendager and Vind 2018: p.193). All interviewers confirmed that politics and regulations are a big influencer. The Danish government is currently developing the building regulations to include a new voluntary sustainable building class (Nielsen *et al.,* 2018). All respondents strongly believe that politics new action will directly

increase the adoption of CE and in a natural way. The government enables and stimulates actors to use CE, this will both boost and enforce changes. (Bod *et al.,* 2017). However, Høibye and Sand (2018) expect that the new regulations cannot stand alone to overcome CE barriers, companies may need stronger economic incentives to change their existing linear business approach. Interviewers reveal that most actors are willing to collaborate, they confirm the necessity of collaboration between all actors and at all levels and that CE cannot be achieved by one actor but requires collaboration between all actors in the value chain. However, according to Eberhardt, Birgisdottir and Birkved (2019) complex supply chains, focus on short term goals that create short-term profit leading to misfit the long-term goals of sustainability. This creates competition among the stakeholders resulting in insufficient collaboration between them. According to Høibye and Sand (2018), the main barriers are lack of early-stage chain corporations and partnerships in the construction sector. Cooperation between different stakeholders will be key to successful transformation (State of Green 2016), (Witjes and Lozano 2016).

Interviews reveal that lack of MP is a barrier when reusing or recycling materials, due to the unknown contents and hazardous chemicals as well as unclear lifetime of materials. While the literature mentions that identifying the MP after use and disassembly is a challenge due to the digital challenges when processing building materials huge data and BIM (Jensen and Sommer 2018: 153). The reused or recycled materials must fulfill the technical requirements, e.g., strength and fire as these materials/ components were not designed for reuse/ recycling (MacArthur Foundation 2015). Bod *et al. (*2017) mention that technical requirements could hinder CE solutions. Jensen and Sommer mention that once relevant information of an MP is available, it becomes easier to decide if the component is suitable for the intended reuse and can then be included in a circular building (2018). Lack of quality assurance marking schemes of reused building materials and content of hazardous substances in existing building products currently embedded in buildings (Høibye and Sand 2018). Finally, the respondents requested that MP will be obvious, and preferably in a public database so it is easy in the future to see what materials have been used. They also requested more user-friendly analysis tools and guides to simplify the adaption of CE, e.g., LCA and LCC calculations.

CONCLUSION

CE is one of the most promising concepts for more sustainable development, where business benefits go hand in hand with resource efficiency, however, it is considered as a complex approach. The research investigated several CE barriers that include economic, politics, collaboration, social, and technical barriers including lack of materials passports. Other minor barriers refer to a lack of technologies, knowledge, and information. To convert to a more circular economy, we need to strengthen collaboration between everyone involved in the value chain. The CE must become a natural and integrated part of the building sector. Clear and predictable legislation is essential to respond appropriately. It is evident from results that among various stakeholders, the governmental perspective has the maximum positive impact on the implementation of the CE in value chains. This study contributes to existing knowledge by investigating barriers for CE in building design, and the results can be useful/applicable for both researchers and practictioners within the field. The limitation of the study lies in the limited number of interviewees - a larger number of interwiewees would increase the generalizability of the study and improve the valitidy of making general conclusions.

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