BARRIERS TO CIRCULARITY IN CONSTRUCTION: AN ANALYSIS OF EXPERTS' PERSPECTIVES

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Abstract

Adopting Circularity in Construction (CiC) is complicated and requires the transition from demolition to deconstruction of the built environment. Although industry practitioners have mentioned the barriers to the implementation of CiC several times, its application remains in its infancy stage. This study aims to identify and classify the barriers to implementing CiC in a comprehensive yet straightforward way. A three-stage methodology was adopted: data collection, content analysis, as well as barriers analysis and categorization. A total of 37 consolidated barriers were identified and grouped into six categories that could assist in developing action plans and effective strategies to adopt CiC.

Introduction

The construction industry plays a significant role in the economic development of countries (Assaad and El-Adaway 2020). Given the high rate of consumption of virgin materials for urban development and the significant contribution of Construction, Renovation, and Demolition (CRD) waste to landfills, there is a need to re-evaluate and change current practices in the construction industry (Allam and Nik-Bakht 2023; Guerra and Leite 2021). The current practices in the construction industry follow the linear economy (take-make-dispose) with minimum consideration of the End-of-Life (EoL) phase of the built facilities (Nik-Bakht et al. 2021). The linear model not only negatively affects the environment but puts businesses at risk due to potential disruptions in raw material supply and fluctuations in prices (Guerra and Leite 2021). The Circular Economy (CE) model, (i.e., maximizing the reuse of resources to minimize the consumption of virgin input resources, as well as to control waste, emissions, and energy leakage) has been recently gaining momentum in the construction industry (Pomponi and Moncaster 2017). Implementing a 'smart' growth strategy, i.e., maximum utilization of the resources that we already used in the construction sector through reuse, is the best favor that can be done for the environment (Building Technology Inc. 2001; Langston 2008).

Adopting the CE in the construction industry is highly dependent on the way of handling the components of the built facility at the EoL stage (Queheille et al. 2019). Two EoL scenarios can be implemented, namely, demolition and deconstruction (Akinade et al. 2015).

Demolition is the act of destroying a built facility regardless of the recoverability of its components/ materials; most of the generated waste is landfilled with little consideration for recycling. On the contrary, the resource-friendly scenario is deconstruction, which is a planned disassembly of components and materials of the built facility. The output of this scenario can serve several purposes such as building/systems relocation, component reuse, and recycling (Akinade et al. 2015).

Yet, the transition from demolition to the deconstruction of the built environment to achieve Circularity in Construction (CiC) is complicated and requires considering the deconstruction at different stages of the built facility, as shown in Figure 1. (i) starting from the design stage by applying Design for Deconstruction (DfD) principles; (ii) Planning for Deconstruction (PfD) from both strategic and operational viewpoints; (iii) managing the post-deconstruction activities including sorting, storing, transporting, processing, and delivering the reclaimed/ reused products to the new customer, as well as design with salvaged/ reused products in the second-life phase (Allam and Nik-Bakht 2023).

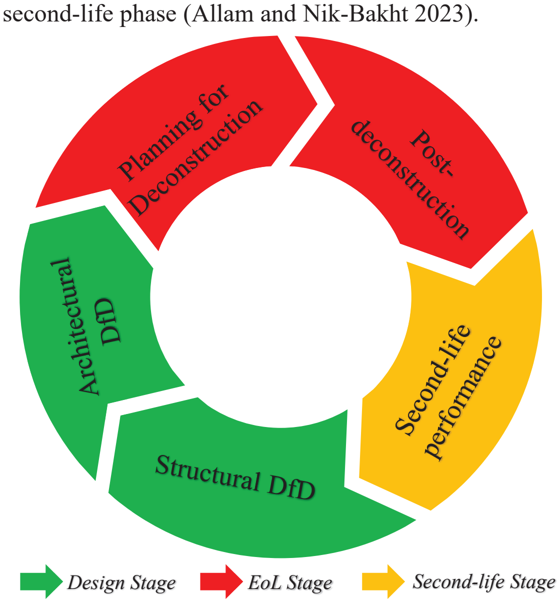

Figure 1. Deconstruction over the facility's lifecycle

Implementing the CiC is still in its infancy stage and the traditional linear method is widely used in practice (Nik-Bakht et al. 2021). Researchers have explored the reasons for the slow adoption of CiC by conducting empirical studies, i.e., interviewing and surveying industry practitioners to identify any barriers (Cruz Rios et al. 2021). Knowing the barriers will help in developing action plans (Correia et al. 2021). A comprehensive list of keywords covering the deconstruction body of knowledge was extracted from previous research (Allam and Nik-Bakht 2023), to quest Scopus database for empirical research studies. In 2014, an article investigated the opinions of Australian contractors on the barriers of 'reverse logistics' in the construction industry (i.e., diverting waste from landfills and incorporating it back into the construction supply chain through reuse and recovery) (Chileshe et al. 2014). The results included (i) incorporation of salvaged materials is not always considered by designers; (ii) regulations may limit the use of recovered materials and components; (iii) potential legal liabilities could be an obstacle; (iv) higher costs and (v) longer duration of deconstruction (compared to demolition); (vi) the government does not always provide financial incentives to make the use of reclaimed materials more competitive in the market; (vii) supervisors, designers, and some authorities may have a negative perception of using reclaimed materials; (viii) technical barriers can make it difficult to use reclaimed materials. The barriers that were identified by practitioners in the construction industry 9 years ago, still persist today (Akinade et al. 2020; Correia et al. 2021; Cruz-Rios and Grau 2020; Cruz Rios et al. 2021; Guerra and Leite 2021; Hartwell et al. 2021; Ottosen et al. 2021; Tleuken et al. 2022; Torgautov et al. 2021).

The barriers that have been identified by industry practitioners for nearly a decade, persist not only because they are unsolvable but also because the methods used by researchers to address them need to be reevaluated and changed. For instance, the initial cost of deconstruction might be higher than demolition, however, the revenue from reusing the component could lead to financial benefits (Sanchez et al. 2020). Yet, some studies prefer to ignore reuse because of the complexity of estimating its associated costs (Vázquez-López et al. 2020); this ignorance leads to a shortage of models predicting the cost of applying circularity strategies (i.e. deconstructing the built facilities and diverting the components from landfill to the construction supply chain) (Tatiya et al. 2018). Thereby the stakeholders' fears of spending more money by applying circularity strategies at the EoL are doubtable.

The inability to provide action plans to overcome these barriers and implement CiC makes it imperative to provide the practitioners' barriers in a more efficient way to be able to assign roles and responsibilities. To better understand the barriers to CIC, it is important to categorize them. Categorizing the barriers is essential to address them effectively, as it allows for a more targeted and efficient approach to problem-solving.

To bring an end to the procrastination in addressing and comprehending the barriers mentioned by the practitioners, this research aims to develop a comprehensive yet straightforward list of barriers under standard categories to identify common themes and patterns, assign roles to stakeholders and policymakers, and thereby facilitate the implementation of circularity in construction.

Data Collection and Analysis Method

The authors adopted a three-stage research methodology. In the first stage "data collection", a database search was conducted through Scopus ("Scopus" n.d.). A refined list of keywords covering the deconstruction body of knowledge was extracted from a previous study (Allam and Nik-Bakht 2023), and used for questing articles. The database search was undertaken in April 2022 and limited to articles published after 2019. Then, the abstract of the resulting articles was reviewed to identify the empirically-based research, i.e., research articles utilized interviews, surveys, or focus groups in their research.

In the second stage "content analysis", the collected empirically-based articles were divided into three regional groups, based on the location of the study namely European, Asian, and North American practitioners-based studies. Afterward, a qualitative analysis was conducted by fully reviewing the collected articles to extract the barriers from each study; similar barriers from different studies were matched into one barrier.

In the final stage "barriers analysis", two steps were performed. The first step was to apply a 'PESTLE analysis', barriers were classified into Political, Economic, Social, Technological, Legal, and Environmental (PESTLE) barriers. PESTLE analysis has been formerly used in various fields such as green buildings (Assylbekov et al. 2021; Dalirazar and Sabzi 2020) and electric vehicles (Anastasiadou and Gavanas 2022), as a framework for categorizing and understanding the deployment barriers related to multiple aspect. To quantitively analyze the barriers, co-occurrence network analysis (CNA) was undertaken. CNA categorized the collected empirical studies based on the co-occurred barriers. To develop the CNA in this study, the node's weight (i.e., the number of barriers mentioned in the article) and the link's weight (i.e., the number of similar barriers mentioned in a pair of articles) should be identified. Degree centrality is one of the measures to identify the importance of the nodes in graphs by counting the number of links connected to the node (Nik-Bakht and El-Diraby 2017). To take into account the number of barriers mentioned in the articles, the weighted degree centrality was utilized, which is the sum of links' weights connected to the node (Elbashbishy et al. 2022; Hosseini et al. 2018).

PESTLE Analysis Results

After conducting the database search, nine 'empirical research studies' were obtained, as listed in Table 1. These studies have identified the barriers to implementing deconstruction/ circularity in the construction industry through analyzing surveys, interviews, and focus group results with industry professionals. The most commonly used method for collecting expert opinions was semi-structured interviews (SSI), as it allows for flexibility and adaptability based on the interviewee's experience and background.

As a result of analyzing the collected articles and consolidating their identified barriers, thereby (37) unified barriers were resulted and grouped under six categories using PESTLE analysis, as shown in Figure 2. Technological and social barriers make up the majority of the barriers to implementing CiC. The technological barriers primarily include three areas: (i) the quality of the salvaged products; (ii) barriers related to the needed knowledge, skills, and infrastructure to implement the circularity; and (iii) barriers related to the current practices in the construction. Manufacturers, suppliers, contractors, architects/ designers, and the government have the power to overcome technological barriers. Researchers also have the power to develop new technologies and techniques that can make deconstruction more efficient and cost-effective.

Table 1. Empirical research studies that investigated the barriers for circularity in construction

Code	Article	Method	Country
P1	(Akinade et al. 2020)	Focus Group Interviews	UK
P2	(Cruz-Rios and Grau 2020)	Semi-structured interviews (SSI)	US
P3	(Correia et al. 2021)	Survey and SSI	Multiple
P4	(Hartwell et al. 2021)	Survey and SSI	UK*
P5	(Cruz Rios et al. 2021)	SSI	US
P6	(Ottosen et al. 2021)	SSI	Denmark*
P7	(Guerra and Leite 2021)	Survey and SSI	US
P8	(Torgautov et al. 2021)	SSI	Kazakhstan
P9	(Tleuken et al. 2022)	Interviews	Central Asia

** The majority of the interviewees were from the mentioned country, very few were from other countries*

The social barriers were mainly focusing on how the mentality of the stakeholders could promote CiC as well as the needed support from the public. Also, community members and advocacy groups can influence public opinion and support deconstruction. They can mobilize public support for policies and regulations imposed by the government that promote circularity strategies. They also have the power to influence the demand for salvaged products by changing the negative perception of the public about salvaged products.

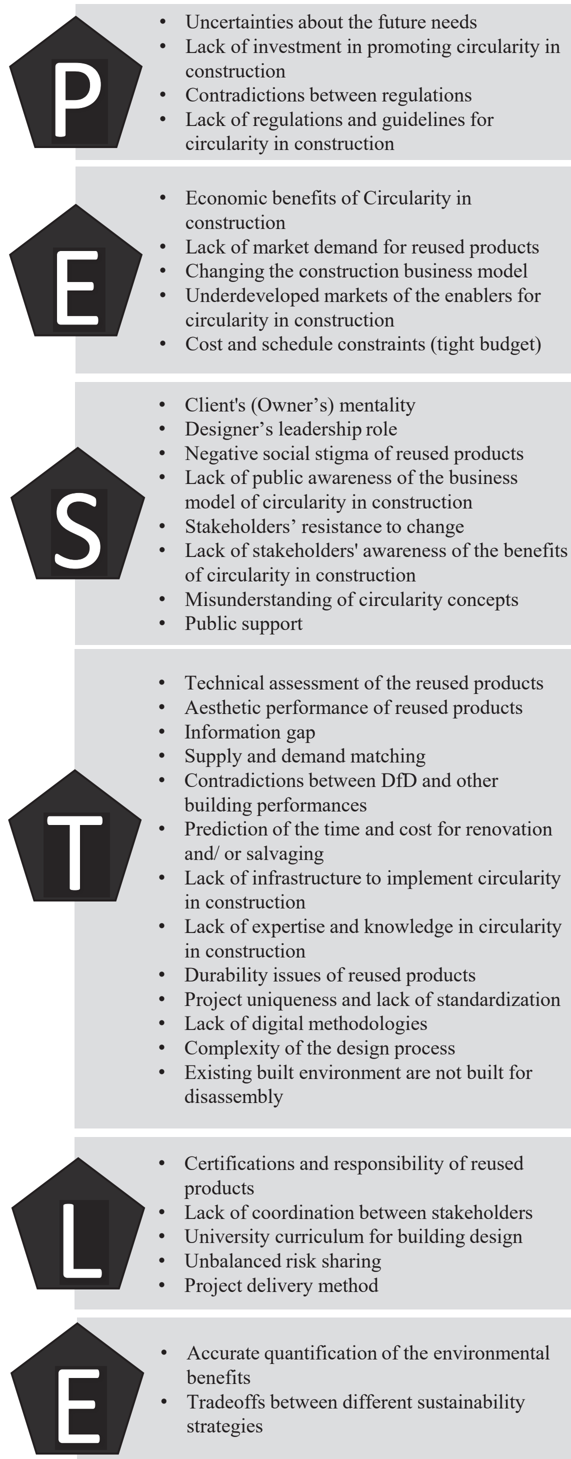

Figure 2. Barriers to adopting deconstruction and circularity in the construction industry based on PESTLE analysis

For economic barriers, the main concerns were (i) proving the economic feasibility of the circularity; (ii) considering the market condition of the salvaged products and prefabricated products; (iii) the need to change the business model of the construction industry. Clients (owners), contractors, and architects/ designers have financial incentives to prioritize traditional practices over circularity strategies. As a results, it is recommended that the government maintain the profitability of the main stakeholders to encourage them to adopt circular business models.

The government has the power to assist stakeholders and other entities in overcoming the barriers under all PESTLE categories. Yet, political barriers are all the responsibility of the government. The political barriers show the worries of the practitioners on the lack of financial support from the government for circularity strategies, the contradiction between regulations, and changes in legislation, regulations, or standards that might make the materials, components, or systems of today obsolete in the future.

Certification of the salvaged products, the legal liabilities between the stakeholders, and reconsidering the curriculum in architecture schools were the main directions of legal barriers. A lot of efforts need to be done by manufacturers, governments, and universities to provide liabilities to the consumers of salvaged products as well as provide the appropriate education to the architects/ designers of tomorrow.

Although circularity in construction (CiC) is intended to support Sustainable Development Goal (SDG) 12 "Responsible Consumption and Production" ("SDG12" n.d.), there are contradictions in the strategies used that can lead to doubts about the environmental benefits of circularity. For instance, increasing the durability of components may lead to higher embodied carbon emissions (Cruz Rios et al. 2021), the use of non-organic materials can have better characteristics than biodegradable ones (Torgautov et al. 2021), and the additional environmental damages for recycling and preparing the component for reuse (Correia et al. 2021).

Co-occurrence Network Analysis Results

The identified barriers represent the obstacles to adopting deconstruction/ circularity in the European, North American, and Asian construction industries. Figure 3 shows the co-occurrence network of the 9 empirical studies, listed in Table 1. In this graph, each node represents an article and a connection between nodes A and B shows that these articles mentioned the same barrier. The weight of links (shown by the edges' thickness) represents the number of similar barriers mentioned in the two articles. A node's size represents the weighted degree centrality, i.e., the summation of weights associated with the links connected to the node. The color of the node shows the continent of each article; i.e., Europe (in orange), North America (in red), Asia (in green), or multiple continents (in cyan). An objective method was used to cluster the articles based on the mentioned barriers. Applying community detection based on modularity through Louvain algorithm extracted one community, which means that the similarities between the barriers identified by practitioners from different continents are more than the dissimilarities.

With the inability to quantitatively cluster the articles, a qualitative approach was used to analyze the dissimilarities and similarities between the articles. The contribution of each continent to the comprehensive list of barriers is shown in Figure 4. Some barriers were exclusive to a certain continent. On the one hand, practitioners from North America pointed at *"Lack of stakeholders' awareness of the benefits of circularity in construction"*. They mentioned that designers might apply circularity strategies in their design as proof of concept but not in real projects. *"Prediction of the timing and cost for renovation and/ or salvaging"* was the second exclusive barrier in North America. The interviewees stated that the inability to apply life cycle cost analysis makes it difficult to convince clients of the economic feasibility of CiC. In this realm, the third barrier came up, i.e., "*University curriculum for building design"*. The interviewees mentioned that the problem is the designers/ architects have not been educated in the University to promote new ideas to clients.

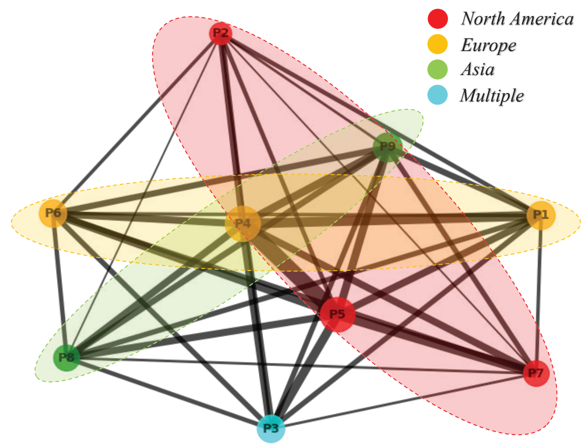

Figure 3. Co-occurrence network of barriers

On the other hand, "*Lack of infrastructure to implement circularity in construction" and "Lack of digital methodologies*" were considered barriers by practitioners in Europe and Asia. The former barrier is related to the availability of storage places, recovering plants, and organized markets for second-hand products. Not considering this issue as a barrier in North America is justifiable because of the availability of land in the US (Cruz Rios et al. 2021).

The latter barrier includes utilizing Building Information Modeling (BIM) compliant tools for deconstruction, building/ material passports, and Extended Reality. It has been mentioned in the literature that the construction industry in Europe is more advanced than in North America in the implementation of circularity (Guerra and Leite 2021). Pointing out this barrier shows the advancement of Europe as well as Asia in adopting CiC by trying to develop methodologies to utilize digital technologies in the implementation of circularity in the construction industry. It is worth mentioning that the process of creating digital twins of entire cities is ongoing, with Singapore being one example (Bertin et al. 2020). Still, in Singapore, a group of researchers investigated the utilization of BIM to overcome the *"Supply and demand matching"* barrier (Yeoh et al. 2018).

Twelve barriers out of 37 were common between the three continents. Most of the practitioners were worried about having technical methods to document the quality of the reused products as well as quality control procedures, which relates to the *"Technical assessment of the reused products"*. Also, they agreed on that bad perception about the salvaged products i.e., the assumptions by consumers that the salvaged products are of poor quality, is a major obstacle to implementing CiC which raises the necessity to overcome the *"Negative social stigma of reused products"*. Moreover, the lack of available information about the built facility, *"Information gap"*, makes the decision-making process at the EoL more challenging. Further, the practitioners believe that even though they overcome the technical and social barriers, market conditions will impede the implementation of the CiC because of the hurdles of reaching the *"Supply and demand matching"*, and the *"Lack of market demand for reused products"*.

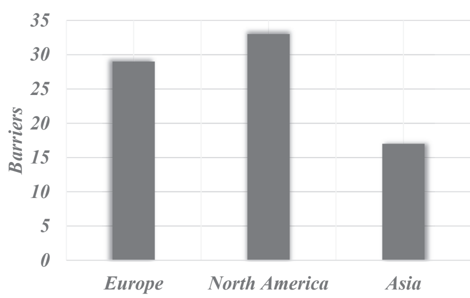

Figure 4. The number of identified barriers (continent level)

They attributed the reasons for the immature market for salvaged products to the lack of government support, i.e., *"Lack of regulations and guidelines for circularity in construction"* and *"Lack of investment in promoting circularity in construction"*. In addition, they see that the *"Stakeholders' resistance to change"*, i.e., the reluctance to adapt to the CiC procedures is another reason for slowing down the development of the salvaged products market in the construction industry. They agreed that stakeholders have reasons for adhering to traditional methods in the construction industry. Firstly, the stakeholders need objective proof of the profitability of deconstruction and circularity (*"Economic benefits of circularity in construction"*). Secondly, applying circularity strategies requires designers' mandate to provide Design for Deconstruction (DfD) designs or dematerialization; asking contractors to execute such designs; and asking demolition contactors to implement deconstruction over demolition. The *"Cost and schedule constraints"* is, accordingly a barrier since such practices may not fit the tight schedules and limited budgets offered by the clients. Thirdly, the *"Project uniqueness and lack of standardization"* applies to the unique nature of construction projects that makes it harder for stakeholders to follow a specific framework to apply circularity strategies. Finally, *"Unbalanced risk sharing", i.e.,* lack of responsibility and the non-controllable waste management environment impede the stakeholders from the transition towards circularity.

Conclusion

This study analyzed the barriers to implementing circularity in construction by reviewing 9 empirical research studies from Europe, North America, and Asia. The study identified 37 unified barriers, which were grouped under six categories using PESTLE analysis. The study found that technological and social barriers made up the majority of the barriers to implementing CiC. The study also found that the barriers to CiC were similar across different continents and that few barriers were exclusive to certain continents. The fact that practitioners with diverse backgrounds almost repeatedly mention the same barriers proves that the era of exploring the circularity barriers is saturated. As such, clear understanding of exiting barriers is necessary to progress to the next stage for implementing circularity by taking actions to overcome these barriers.

The contribution of this study is that it provides a comprehensive but straightforward list of barriers to implementing CiC and groups them into categories, which can be useful for researchers, practitioners, and stakeholders in understanding the obstacles to implementing CiC. Furthermore, by identifying the similarities and differences in the barriers across different continents, this study can provide valuable insights on how to overcome the barriers to implementing CiC, as it highlights the areas where the most efforts should be directed to overcome the barriers. Despite the contributions, this work has a few limitations. The study did not objectively appraise the performance of existing strategies for circularity, especially in Europe. Also, the reviewed empirical studies representing North America and Asia were limited to practitioners from the US and central Asia. Future research may: (i) explore strategies to overcome the barriers to implementing CiC; and (i)develop a comprehensive framework to address these barriers over the facility lifecycle.

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