Barriers of Circular Economy in Construction Industry

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To facilitate the adoption of the circular economy (CE) in the architecture, engineering and construction (AEC) sector, some authors have demonstrated the potential of recent designs that take into account the sustainable management of an asset's end-of-life (EOL), providing an alternative to the dominant designs that end with demolition. Eighteen approaches related to prefabrication, design for change, design for deconstruction, reverse logistics, waste management and closed-loop systems were found. Researchers has assessed the barriers to those 18 approaches identified in the literature.

Keywords: Environmental barriers ; circular economy (CE) ; Economic barriers ; technical barriers ; Sociological barriers ; political barriers ; organisational barriers

1. Environmental Barriers

The environmental barriers are less prominent than the socio-economic ones. They are mainly limited to the EOL phase of the asset (CDW management and selective demolition). In the cases of deconstruction (De), RL and adaptive reuse (AR), the issue of space for storage is cited by [1]. The site access limitation is also cited by [2]. Some authors have also noticed the existence of lead and asbestos in old buildings when dealing with RL, the 3Rs and CDW management [3][4][5]. Those authors are not linking the high pollutant materials to environmental issues, but to the additional costs of processing such materials. However, the process leads to environmental issues because waste ends up in landfills. The fact that some authors and stakeholders do not directly link pollution to environmental issues but to cost may be related to the lack of awareness of the impact that these processes have on the environment. This is made more apparent with prominence of the economic barriers (cost and market).

Many studies have identified the lack of strong evidence of the environmental and sustainability benefits of using well-designed approaches, such as De, SB (sustainable buildings), the 3Rs (reduce, reuse, recycle), AR and CDW minimisation [6]. Other authors raised the exposure to health and safety risks from encountering contaminated materials as an essential barrier [1][7]. However, this topic is also linked to a social issue because health and safety are determined by the appraisal of the risks by society.

Direct, specific impacts have been identified by Sassi [8] in the recycling process, where the loss of material mass required additional virgin feedstock to be added. Other authors have identified the emissions from transport and reconditioning for the 3Rs and PFA (prefabrication) approaches [9][2].

2. Economic Barriers

The obstacles arising from factors related to the economic context demonstrate that the markets built around sustainable buildings are, in many cases, insufficient. For example, the marketing plan of the industrial, flexible and demountable approach (IFD) is found to be inappropriate [10]. For SB, the lack of client demand is a barrier [6]. These shortcomings include the lack of demand for second-hand, reused and recycled materials and products [11]. The other factor is due to the constrictive search for profitability, which does not permit any risks to arise from innovation or changes to the current processes [12]. Deconstruction faces economic barriers because it is more expensive than demolition, demanding more time and labour to recover comparably low-cost construction materials [13]. Several authors have argued that the low cost of construction materials compared to recovered/recycled materials is the problem in the cases of De and the 3Rs [14]. Moreover, the standard construction and demolition practices are focused on the fastest and most economical way to finish the job in the case of the 3Rs [13]. Lastly, obstacles are caused by the shortcomings of the recycling processes of conventional materials. For example, a building's aluminium scraps are challenging to recover economically [4], and the recycled aggregates have a considerably lower price than that of the natural materials, due to their poorer quality. The relatively low cost of disposing CDW materials in landfills is also cited as a barrier by many authors, in the cases of De, RL, the 3Rs and PFA [4]. Some authors have also noticed the labour-intensive nature of the deconstruction and reuse processes [15]. Moreover, additional time is necessary in the cases of SD, De, and the 3Rs compared to conventional processes. This extra time results in extra costs [15].

The main economic subcategory relates to the costs attributed to the approach. The design phase embodies additional costs due to more work needing to be performed in the case of RL, the 3Rs and PFA [10]. Although no additional costs attributed to the construction phase were found, some costs related to the necessary adaptations to a new approach (or to adopt new approaches) were noted. Several authors have identified such additional costs for adopting the following approaches: De, RL, TB (transformable buildings), Dis (dismantle), the 3Rs, CDWmini (CDW minimisation) and PFA [1]. The additional cost is also due to the management of hazardous components. For example, the existence of lead and asbestos in old buildings makes the process of deconstruction costly and time consuming because the cost of separating the materials to be recycled from contaminating materials is high [4][5]. Another cost of adopting a new approach is the additional initial cost (i.e., the higher cost of the initial investment in the project) cited by many authors, concerning the following approaches: De, RL and PFA [1][16][17][18][2][10][19]. Lastly, the additional costs due to higher insurance fees are a barrier reported by some authors for the 3Rs approach [20].

Some authors have spotted barriers linked to the quantification and sales involved in the approaches. In the case of De, Jaillon and Poon [10] have noticed that the economic benefits are not well established. Similarly, Xanthopoulos et al. [21] highlighted the lack of establishment for the economic and environmental benefits of CDW management. In the case of SB, Häkkinen and Belloni [6] have noticed the lack of understanding of business cases. Finally, in the case of AR, Chileshe et al. [1] have noted the significant differences in the distribution of the construction budget.

Another type of obstacle valid for the 3Rs approach is the necessity of planning and paying upfront early in the asset's lifecycle, which is impossible without the willingness of the client [13]. At this stage, it is often the case that the contractor has not been appointed yet, so the client has to spend money upfront purchasing materials, which many clients will not be willing to do.

3. Sociological Barriers

Sociological barriers deal with social issues, focusing on cultural (societal trends), psychological (human behaviour) and personal characteristics (lack of awareness and demand). The main subcategory is "human behaviour" and the most cited barrier is "resistance to change. Cultural beliefs are involved in the case of sustainable buildings, which notably face the barrier of a low-risk culture [6], as does the case of CDW minimisation [16]. The lack of global vision has also been mentioned in the cases of RL, SB, Disa and CE [7][6]. These authors found that thinking was more linear than circular, with a lack of lateral thinking and an ignorance of life-cycle thinking. The lack of trust in De, RL, the 3Rs, and CDW management is described by [1][20]. Additionally, these authors noticed a lack of acceptance of reclaimed materials. In particular, there is an impatience to get a return on investment quickly, which creates an unfavourable business culture in the case of RL [1]. The last social barrier is the resistance to change, spotted by many authors who focused on the use of Cy (constructability), De, RL, SB, the 3Rs and PFA [18][13][6][2][10][12][22]. Moreover, these authors highlighted scepticism and a preference for traditional methods within the industry, leading to a natural resistance to change from the manufacturers, builders and owners. This resistance to change, common to six approaches, is also seen within the organisations that lack the effort necessary to innovate. Unsurprisingly, the lack of experienced, skilled workers and insufficient knowledge is common to five approaches.

Some barriers are related to "consumer society behaviours". These include, for example, the fear of the additional costs of better waste management [6], or the belief that waste is inevitable [16], or the disbelief in the potential utility of a constructability program [12]. Some authors have added that the consumer culture and attitudes towards the quality of salvaged and used items are also an obstacle [1]. For the RL, 3Rs and PFA approaches, the bad image of salvaged materials was reported to be an important barrier [2]. At a broader level, many authors have noticed a lack of awareness for several approaches, such as SB, the 3Rs and CDW minimisation [6][5]. Other authors have noticed the lack of awareness of the benefits of using Cy, RL and CE [23][22]. A lack of concern was raised by several authors for the De, RL and SB approaches [6][10][19][24]. Moreover, the lack of understanding of deconstruction and SB was reported by Zaman et al. (2018) [19], as well as [6]. In addition, and specifically for deconstruction, the demolition contractor's culture was highlighted as a critical issue [18].

4. Organisational Barriers

Organisational barriers refer to the hindrance to the flow of information between stakeholders and between construction phases that negatively impact the efficiency of a project. Organisational barriers include the extra time, resources and effort necessary for the consideration of sustainability and circularity throughout the asset lifecycle. They are the most documented barriers in the articles studied and are found to be attributed to 14 of the 18 approaches.

4.1. Working Methods and the New Approach

Approximately fifty statements from different authors that deal with issues associated with the current linear approach have been found. The barriers that they detail are raised by the fragmentation of the sector and its inappropriate organisation. The factors cited are the lack of a holistic approach, safety in the deconstruction process, innovation, effective methods, and lifecycle performance focus. When dealing with RL, some authors have noticed the lack of support from the management, as well as immaturity and low investment in knowledge management, information systems, and continuous planning owing to changes in the materials' source location [1]. In addition, some authors reported a lack of specific budgetary allocation for CDW management [5]. Most of the abovementioned barriers are related to the adoption of new approaches and new methods involving more collaboration, communication and holistic and effective strategies. For example, as stressed by some authors, the implementation of RL is a challenge for designers [1]. As a result, multidisciplinary teamwork becomes central and requires appropriate management.

4.2. Multidisciplinary Teamwork and Management

Many authors have highlighted the need for new methods to improve teamwork when addressing the whole lifecycle of a building [13][6][25][10][12][4][8][19]. Those concerns are related to Cy, De, CL (closed loop), RL, SB, the 3Rs and CDW minimisation. For example, some authors identified the need to change the established design and construction processes to promote the reuse of building components [13]. One paper has mentioned the need for systematic cooperation, while a multidisciplinary approach has been discussed in the case of IFD [10][26][27]. This is supported by authors who studied the decision-making framework used in the steel industry, and for the system thinking used in the construction industry [10][26][27].

Some authors have found that there is a lack of communication between the members of the project teams for RL, SB, Disa and PFA [6][2][3]. Specifically, issues related to late communications between the designer and contractor have been identified for RL, SB and PFA, where early collaboration between architects, contractors and manufacturers is required [2].

4.3. Key Players

Other barriers are related to the large number of stakeholders, and these have been outlined for many approaches, such as Cy, De, CL, RL, SB, CE and the 3Rs by [6][10][12][22]. The barriers are mainly specific to architects (although they also impact other stakeholders, such as contractors), where the reuse of materials in buildings requires acceptance and change in the design and construction processes [13]. Additionally, other authors have listed a number of the barriers raised by the contractors when implementing Cy. Most of them are linked to communication issues and a lack of skills/knowledge [12]. The manufacturers' lack of involvement and responsibility to minimise waste is stressed by [9]. The supply chain is also a central concern for many authors, including a lack of suppliers for PFA [2] and supply chain complexity in the case of SB [6]. Kifokeris and Xenidis [12] have also listed several barriers specific to the owners in the case of Cy, among others. Regarding the 3Rs approach, the unwillingness of the client to spend money upfront when purchasing materials, at a stage where the contractor is often not appointed yet, is a real issue for several authors [13][12].

4.4. Training, Skills and Education Support for a Skilled Workforce

The lack of skills, from an organisational point of view, is different from the skills related to social background already cited. Logically, obstacles related to competence improvement were also cited with the lack of lessons learned on:

- The comprehension of SB [6].
- The application of DfDisa (design for disassembly), which is restrained by uncertainties regarding its global benefits and financial viability [28].
- How RL remains unexploited or limited in the construction industry [17].

In complement, some authors have spotted the lack of documentation to support competence improvement, referencing:

- The lack of lessons learned regarding documentation for Cy [12].
- The lack of empirical evidence to support the widespread use of RL [17].

- The need for the identification of demonstration projects to illustrate the potential of the different methods [18][22].
- The lack of IFD studies for high-rise buildings [10].
- The lack of studies providing clear instructions on how BIM could be used for CDW management [10].
- The lack of studies that quantitatively demonstrate the effectiveness of the pre-project definition for buildings in the CE context [22].

From this subsection, the managerial implications involved in the shift to CE can be extracted. They consist in mainly revising the whole lifecycle management of an asset to ensure consistency in management from the early design stage to the EOL phase of the asset. These implications affect the role of all the stakeholders, encouraging them to improve the sharing of the information, even after the EOL phase of the asset, with training/education to help them change their way of working.

5. Technical Barriers

The technical barriers are split into different scales corresponding to subcategories, from the building scale to the material scale and from data management to the technologies used.

5.1. Building-Related Barriers

The long lifecycle of buildings exceeds the lifespan of industrial products and also results in multiple changes of ownership [1][10]. Additionally, the unicity of each building generates a complexity that is difficult to overcome in the modern context [29][17][18][13]. Firstly, in the design phase, some authors emphasise the barriers related to the designs of buildings that were not made with the SEOL in mind [29]. This includes all of the components, even the foundations, which are most of the time made with concrete [21]. The necessity of adapting the construction methods is emphasised when using reclaimed materials because it adds a whole new level of complexity to the project [13]. One example is given with the use of the in situ connection between precast concrete elements [10]. In the in-use phase, building components are updated or replaced at different intervals during the building's lifetime, adding complexity when updating the data related to the building (e.g., finishes at five-year intervals, lighting at ten-year intervals, HVAC systems at twenty-year intervals, etc.) [19].

Deconstruction processes encounter limitations due to the space available to manage the process and, significantly, to store the materials (see also the section on environmental and economic barriers on this point). The lack of recovery facilities and infrastructure is cited by [1][21]. Deconstruction is more complex than demolition, especially in the case of non-prefabricated components [29], sometimes leading to the impossibility of reusing components [3]. Moreover, demountable connections do not always ensure the possibility of deconstruction, and, in general, the poor connection of these elements is an issue [29][30][10]. Lastly, few demonstration projects have been identified that can help illustrate the potential of the different methods [1][13][31]. As a result, all these issues are increasing the risks associated with the deconstruction process [1][7][13].

5.2. Material-Related Barriers (Including Data)

Some barriers are related to the low quality of materials, the poor reliability of the characteristics of recovered materials [1][32][31][33][4][5][19] and the lack of data available for several asset phases. Indeed, in the design phase, the lack of data prevents carrying out an efficient LCA for the EOL phase [34]. In the deconstruction phase, projects and processes are also impacted by a lack of data [29]. At a different level, the behaviour and durability of recycled concrete is difficult to predict accurately without enough data [4]. Importantly, the composition of buildings at the end of their life is essential [11] and the lack of national data on CDW must be overcome [32]. In addition to the lack of data (availability and accessibility), weak data management has also been pointed to by several authors as a concern, especially in the case of national data collection and reporting on CDW [19]. In addition to the general lack of data, there are barriers regarding the limited locations of collection points for recovered materials [29][7][2][10] that generate limitations to material availability [13]. The main source of these issues is the recoverability of construction materials, which is limited by several factors:

- The use of finishes on building materials reduces the possibility of reusing such materials [35].
- The use of concrete [18][10].
- The deconstruction process damages the materials because it is difficult to separate the composites [14][10][3][4][20].

- Contamination with hazardous materials [1][7][14][3].
- The deterioration rates are unknown [36][1][29][18].
- The under-estimation of the resources embedded in the building [22].

5.3. Technology-Related Barriers

Regarding technological barriers, most of them are related to the lack of appropriate tools and procedures. Although one barrier concerning the lack of prefabricated building designs with BIM tools was reported by [37], most of the other issues are not related to BIM, but to the lack of several other elements. For example, some authors pointed to the lack of a common framework and automatic calculation procedures for SB [6], whereas other authors stressed the absence of simple processes to reuse a building project [22]. A lack of science-based, user-friendly tools for De, SB and CE was also reported in many studies [18][6][22], as well as the unavailability of proven alternative technologies [6]. Some authors reported the lack of tools for designers that would otherwise enable efficient deconstruction [1][18][10][4], help with assessing DW generation [16][38][19], promote the inclusion of new techniques for construction [13][6][22], and help with assessing the costs associated with IFD buildings [39]. Lastly, techniques for reusing reclaimed materials are also missing [1][18][14][39]. Meanwhile, down-cycling cannot be regarded as a closed-loop (CL) approach because of the excessive loss of material value [8].

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