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Challenges facing components reuse in industrialized housing: A literature review

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Abstract

Natural resources points towards sustainable development. Since a large proportion of human consumption is linked to buildings and construction, this means managing the construction process in more sustainable ways. Strategies that target greater material efficiency and which promote circular economy concepts are among several approaches that are gaining in popularity. The adoption of life-cycle thinking and practices in design, construction and end of life through the reuse of construction components and materials is one such action to achieve a sustainable built environment. Reuse is not a new concept and technical solutions do exist; however, practical realization is hampered by many interrelated challenges. This review paper is the result of a literature review for an exploratory study that aims to identify obstacles to the reuse of building components and materials. The context is industrialized housing, particularly timber-based construction, as this is a sector where modern manufacturing and onsite practices have become established. The main obstacles identified and corroborated in the literature, along with their potential solutions, are summarized and conclusions drawn on the future direction of research needs.

Keywords

Design for reuse; building components reuse; industrialized housing; timber; circular economy; sustainable developments ;

1. Introduction

The global condition of climate change is a consequence of human consumption of natural resources when the earth's resilience goes beyond the boundary of ability to sustain itself over the long term. A large proportion of this consumption is linked to buildings and construction where one solution is to adapt the concept of sustainable development to the construction industry and to manage the construction process in sustainable ways (Jonasson et al, 2020). Defining sustainability for a construction project is a complex task. The term consists of many different and connected parts during the process, involving the client, project team members, other stakeholders, issues of aesthetics, functionality and material interactions. The construction industry is more responsible than other industries for global CO_2 emissions (UNEP, 2018). In 2014, the European Commission noted that circular economic systems were of immense benefit for sustainable development across Europe and encouraged member states to adopt them (COM, 2014). Subsequently, the United Nations Organisation framed the goals for sustainable development in its Agenda 2030, where goals 9, 11 and 12 mostly concern the construction industry. Construction, among other activities of human behavior, also generates a huge amount of waste (Iacovidou and Purnell, 2016). Over the past decade, concerns about the impact of climate change on the built environment have increased. Zero-carbon performance has been highlighted, together with a shift from solely the performance of the product, i.e. the building, to the construction process and a whole life-cycle perspective. These concerns have recently evolved to a focus on zero carbon, zero energy and, in the long run, to "retrieve what we lost" or "doing more good" by adopting a net-positive impact view that is defined as regenerative development (Cole, 2020). During the transformation to a zero-carbon, resilient, sustainable and regenerative society, buildings in most countries play a major part in the use of energy and the impact of carbon emissions. Globally, buildings consume about 35% of the total available energy, responsible for roughly 38% of total carbon emissions, and generate about 36-40% of all man-made waste (UNEP 2020).

The adoption of strategies for material efficiency, promoting circular economy concepts using life-cycle approaches in design, construction and end of life by re-using construction components or materials, is among the most critical of actions to achieve a sustainable built environment as stated in the latest Global Status Report for buildings and construction (UNEP, 2020). Furthermore, in order to meet the multiple criteria of sustainability, industrialized construction could be a part of the solution that also contributes to solving the housing shortage. A benefit of off-site construction is the production of decent quality, affordable housing that can be rapidly assembled on-site. Prefabrication can improve environmental performance considering that the building is designed to be reused (Aye et al., 2012). Industrialized housing construction (IHC) consists of different approaches (i.e. prefabrication, modularization, off-site fabrication, or modern methods of construction) (Kedir and Hall, 2021). The possibility to build parts of the structural frame as planar structural modules (walls, floors, etc.) contributes to a reduction in construction time. Moreover, the reuse potential of prefabricated timber-based structures is claimed to be at least 69% (Aye et al., 2012). The global consumption of natural resources by the construction industry is not sustainable. It is, therefore, essential to re-think the construction process in terms of the efficient utilization of natural resources, their reuse and the recycling of demolition waste, as a minimum. Construction professionals, including practicing architects, engineers and construction managers, as well as environmentalists, researchers and academics should be called upon to play a major role in helping to sustain our environment (Khatib, 2016). Hence, due to an increasing urban population and the need for affordable housing, our study focuses on the reuse of building components. This paper aims to identify enablers and challenges for the reuse of building components in industrialized housing with a focus on timber-based construction.

2. Method

In order to determine drivers and barriers for reuse of building components, a literature review has been conducted. The search engines used to retrieve the articles are, Web of Science and Scopus. The keyworks used to retrieve the articles included reuse, building components, building elements, construction, and industrialized timber construction. The search was done from 2000 to 2021. A total of 136 articles were retrived and 30 were selected for the review, because of their relevance for the study. Starting by briefly analyzing resource and waste management, the study describes the issue of housing shortage in Sweden and identifies a possible solution in Industrialized Housing. The focus, thereafter, is on demolition and deconstruction phases in a project, which are considered crucial to re-think the entire construction process. While exploring the common enablers and barriers in buildings construction, the attention is shifted to specific obstacles and opportunities to enable a reuse approach in industrialized housing concentrating on timber buildings. The latter are thereafter demonstrated to be suitable to fulfill the sustainable goals and the principles of circular economy in construction.

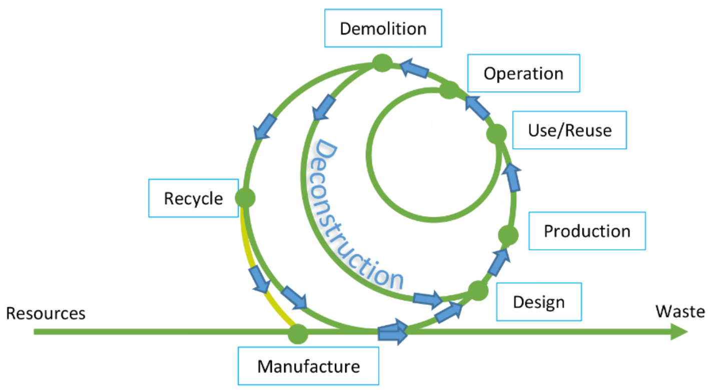

Figure 1 – Implementation of Circular Economy in construction.

3. Literature review

3.1. Resource and waste management

The circular economy (CE) and sustainability concepts are becoming a matter of great importance among policy makers, academia and industry. CE is defined "as a regenerative system in which resource input and waste, emission and energy leakage are minimized by slowing, closing and narrowing material and energy loops" (Geissdoerfer et al., 2017). To promote the concept of CE in the built environment, the Waste and Resources Action Programme (WRAP), has published considerable good practice guidance to be adopted by the industry (WRAP, 2013). This includes BIM, designing-out waste, designing for disassembly, off-site construction and sustainable procurement, as well as adopting fairness, inclusion and respect. In creating an effective CE in construction, a significant majority of building materials must be recoverable for reuse and recycling (Pan et al., 2015; Tukker, 2015). There is a shared understanding that the reuse of building components is preferable to recycling (Rakhshan et al., 2020; Arora et al., 2019; Mayer et al., 2019; Cooper and Gutowski, 2017; Hoornweg et al., 2015; Park and Chertow, 2014) since energy requirements for recovering building components for reuse are less than when recycled (Iacovidou and Purnell, 2016). Although recycling is a common practice, a more value-driven approach is reuse. As noted by Iacovidou and Purnell (2016), the production of new construction materials in Europe consumes 5-10% of total energy use. Landfill resources are limited and natural resources are scarce and when the ecological impact of the increased extraction of raw materials is taken into account, it seems fairly obvious that traditional construction methods have to give way to more sustainable processes and practices. The construction components need to be seen not as problematic waste, but as an investment opportunity to achieve the big change required to make the construction industry more "sustainable, smarter and resourceful" (Iacovidou and Purnell, 2016).

Buildings are made by assembling components (e.g. foundations, columns, beams, façades, windows, doors and appliances). According to Niu et al. (2021), cascading construction and demolition (C&D) materials is imperative. The authors define the term "cascading" as the combination of reusing, recycling and material recovery of C&D and divide the elements in a building suitable for cascading into two main categories: load-bearing elements (e.g. foundations, walls, floor slabs, columns and beams) and non-load-bearing elements (e.g. light/partition walls and facades). Reuse has the highest priority among all cascading scenarios (i.e. reduction, reuse and recycling) (Niu et al., 2021). It is, therefore, important to change the terminology and thinking from *material stock* to *components stock*, and from *waste management* to *building components management* (Arora et al., 2019).

3.2. Housing shortage in Sweden

A shortage of housing is not uncommon in developed countries; see, for example, Boverket (2020). In common with other countries, the shortage is due to a lack of investment in new and refurbished housing stock. The situation has been made worse by substantial immigration. In 2020, 212 of Sweden's 286 municipalities (i.e. 74%) reported housing shortages. Even though this number has been decreasing slightly over recent years, it indicates a persistent problem. Iacovidou and Purnell (2016) have proposed initiatives to enforce changes that can lead to more sustainable construction management and less production of construction and demolition waste (CDW). According to Iacovidou and Purnell (2016), such initiatives are: re-thinking the design of buildings by using materials that are both durable and recyclable, and therefore carrying low embodied energy; reducing the use of materials with a high carbon footprint and promoting manufacturing practices that take resource efficiency into account; and enabling reuse of construction components. To improve the potential for reuse in construction, it is first necessary to prove its technical feasibility in a holistic way. In other words, there is a need to re-think the way we plan, design, construct and deconstruct in order to make the entire process "more resource efficient and reduce its carbon footprint" (Iacovidou and Purnell, 2016).

3.3. Industrialized housing

The need for new housing calls for increased productivity and affordable, sustainable and cost-effective buildings. Industrialized housing (IH) has long been promoted as a solution to house shortages, in many countries, including Sweden, where the arrival of prefabrication was identified in the Portable Colonial Cottage for Emigrants advertised in 1833 (Ågren and Wing, 2014). A more recent proposal is Horden's helicopter-delivered home in 2012 (ibid). With the advent of newer digital technologies, IH could increase substantially given a reduction in the time needed to design and build multiple units as a result of repetitive processes and the pre-determined use of different materials and layouts. An example of what can now be achieved is Svenska Allmännyttans Kombohus, where a cost reduction of up to 25% is possible (Svenska Allmännyttan, 2020). Moreover, IH does not have to be devoid of architectural or aesthetic quality; it simply has to be among its primary objectives. Even if standardization of design work in house-building has, for the last 20 years focused on production, economics and sustainability (Aitchison, 2017; Lessing and Brege, 2018), it is important to have "the involvement of architects in [the] industrialized house-building processes to meet future demands for aesthetics and functionality that satisfy end-user and client values and requirements and to ensure the creative work of artistic and engineering design" (Jansson, 2018). Indeed, over much of the 20th century, architects such as Wright, Le Corbusier, Fuller and Gropius have contributed their interpretation of prefabrication to housing, proving that it is the result of sociological, economic and political constraints and requires more than just technical know-how to become successful (Ågren and Wing, 2014). Industrialized house builders prefabricate building modules for assembly on-site, are responsible for almost the entire building process and can control and improve the quality of building manufacture in a better way than conventional construction companies (Johnsson and Melling, 2009). Moreover, introducing more industrialized methods into the construction industry could increase efficiency and reduce defects, closing the gap between manufacturing and construction based traditionally on craftsmanship (ibid). There is therefore a need to shift from project-based to process-based production as argued by Winch (2006). IH also provides opportunities for the reuse of building components instead of recycling, which equates to a higher level in the waste hierarchy (WRAP, 2008a) and contributes to a reduction in CDW. The latter represents a significant benefit from the perspective of the CE. A building's life-cycle and the possibility to reuse building components rather than recycle materials is a crucial aspect of "circularity". According to Tavares et al. (2021), the benefits of prefabrication are waste reduction, cost and time saving, growth of productivity and better building performance. A few studies have compared prefabricated buildings with traditional buildings. The results reveal a reduction of 5-40% in environmental impacts when using prefabrication methods, and an investment cost reduction of 30% compared with traditional construction (Tavares et al., 2021). In IHC, structures can be manufactured off-site "as a volumetric element (3D) or as a panelized system (2D)". Unfortunately, there is a lack of literature concerning resource efficiency with respect to IHC (Kedir and Hall, 2021). So far, our literature review has not revealed any cases where the reuse of building components in IHC has been explored. This confirms the need for further research in the field, which could support the thesis that a new design concept, based on the reuse of building components, is crucial to satisfying the criteria of sustainability and the global goals of Agenda 2030.

3.4. Deconstruction and reuse

Iacovidou and Purnell (2016) define deconstruction as "the careful dismantling of a building or structure to maximize the recovery of its components for reuse". They identify various strategies that promote component reuse in construction.

Design for Deconstruction: a design approach that aims to "close the construction components loops" also named as Design for Adaptability and Deconstruction (DfAD). Among the advantages, we can count the extended duration of the structure which leads to economic and environmental benefits. There are, unfortunately, challenges connected to "technical, economic and logistical barriers".

Design for Reuse (DfR). When designing a new structure, reclaimed components are included in the project. If the layout is similar to the previous building then DfR can be successful. Otherwise, many design adjustments are required. It is critical to form a close collaboration between all stakeholders, for instance, architects, other designers, engineers, contractors and trades.

Design for Manufacture and Assembly (DfMA). The construction components are fully manufactured off-site and assembled on-site. Assembly and disassembly are fundamental in order to enable deconstruction and recovery of components and therefore sustainability of the products and structures.

Van den Berg et al. (2020) identify, in the practice of Design for Disassembly (DfD), some principles for building components to be suitable for reuse, namely that building connections should be minimized, accessible and reversible. In addition, their study defines economic demand, proper disassembly routines and element control performance as conditions for element recovery. The most suitable definition for the purpose of this study is the one suggested by (Cristescu et al., 2021), i.e. Design for Deconstruction and Reuse (DfDR). The main principle supported by both definitions is a new way of designing a building, allowing the reuse of its parts, repaired or properly dismantled, in new applications. This can be for the original purpose or a different purpose, while prolonging the life-cycle of the building components and materials (Cristescu et al., 2021). The difference between Design for Deconstruction or DfAD and DfD, as described by Long (2014), among others, is that the latter involves recycling building materials and components and so preserves just a small amount of embodied energy. It is, therefore, less environmentally friendly and sustainable than DfAD, where the building components are reused directly or relocated in a new or existing building. Awareness about buildings changes over time and proper planning is required to re-think current approaches to construction in order to reach environmental goals (ibid). Further support for the reuse of components as a way to save more energy, when compared to recycled materials, is to be found in da Rocha and Sattler (2009). Moreover, the reuse and recovery of elements and components are good practices according to the European Waste Framework Directive since 2008. Even so, the reuse of building components in a systematic way is far from being a common procedure in the construction industry.

3.5. Reuse in construction: enablers and barriers

Rakhshan et al. (2020) suggest that reuse drivers are "economic (25%), organizational (23%), environmental (17%) and social (15%)". Economic drivers are the lower price of reused components and the higher price of landfilling, although they might differ depending on the geographic location. Reducing CDW generated by construction companies and "promoting the green image of the companies" are the most important organizational drivers. In reducing CDW during renovation and demolition of buildings, reuse of building components appears to be a preferable solution which allows for recovery of functional components, e.g. tiles, bricks and windows (da Rocha, and Sattler, 2009), interior walls, panels and doors. Rakhshan et al. (2020) identify the scarcity of landfill sites as a major environmental driver. Among the social drivers are society's environmental concerns and a better understanding of the advantages of reuse among stakeholders. Rakhshan et al. (2020) state that practices that prefer deconstruction over demolition could lend themselves to the reuse of recovered components. Considering the entire building process, deconstruction and reuse appear to be preferable over demolition and recycling, by offering higher environmental and economic benefits. Nonetheless, training in deconstruction techniques together with policies and, possibly, legislation that promote such practices are probably required to achieve the durable benefits of deconstruction.

Rakhshan et al. (2020) identify the economic, social, and technical barriers when reusing building components. Economic barriers are further categorized into supply chain level by identifying the lack of reuse market, component level and project level, the latter highlighting the need for a financial risk assessment in the early planning phase of a project. According to Rakhshan et al. (2020), overcoming these barriers is possible if collaboration between construction and demolition firms is established and financial incentives are available. Moreover, the cost of reclaimed components should be sufficiently attractive. One possible solution is offered in the UK where the tax for landfilling has increased in order to encourage reuse practices.

According to Rakhshan et al. (2020), social barriers can be classified into perception, awareness and risks. Studies mostly focus on the negative approach of stakeholders towards reuse practices which hinder its adoption in the construction industry. Arora et al. (2019) define the way evaluations about material stock and outflows are made and introduced to the public as one of the major obstacles which hinders the suitability of the results. The authors state that, usually, those reports focus on single material-type results, whereas a representation as *component-type* could increase interest on the part of policy makers and decision makers (Arora et al., 2019). Developing "standard test procedures to test, evaluate and certify the recovered building components" (Rakhshan et al., 2020) is the proposed solution to overcome these barriers, which could expand the reuse market.

Lastly, technical barriers are categorized into deconstruction level, performance level, and health and safety level. Presently, buildings are not considered or designed for deconstruction and this represents a challenge; however, this barrier can be overcome by adopting innovative designs for new buildings. At the performance level, reusability of the element represents a barrier to the reuse of building components at their end of life as a consequence of damage, design changes, etc. At the health and safety level, precautions necessary to increase health and safety during deconstruction activities could also increase the total cost of the project (Rakhshan et al., 2020). To promote reuse and environmental efficiency, it is necessary to reduce material excess in new building components and optimize the design, which could save a considerable amount of material (Iacovidou and Purnell, 2016). The goal of the stakeholders involved in the construction process should be to ensure adaptable design, to optimize recovery of building components for reuse and to apply new design strategies. Enabling assessment of the reuse potential of components during the manufacturing phase of a project would save time that would otherwise be spent during on-site assessment (Iacovidou and Purnell, 2016).

3.6. Industrialized timber housing (ITH)

Cristescu et al. (2021) describe a long history of timber building techniques; however, timber's popularity as a construction material on a significant scale in Europe has been mostly confined to the second half of the last and present century where the primary use is for housing. Currently, in Sweden, 80% of single-family houses are built off-site, as a result of a long development history of prefabrication, which has led to a reduction of 20-25% against the cost of traditionally constructed buildings and an 80% saving in time (ibid). While the use of light-frame prefabricated structures has become more common for multi-storey housing, cross-laminated timber construction is the most widely used. Timber for multi-storey buildings has, however, increased from 13% in 2018 to 20% at the end of 2019 (ibid). In Sweden, as in Finland, Slovenia and the UK, panels with the insulation layer inserted between studs and joists is the most common practice (ibid).

As a widely available and biodegradable material that grows naturally, timber is considered crucial to achieve the environmental goals of the European Union, even though its reuse can be problematic (Huuhka et al., 2015). Indeed, as a natural material, reclaimed components demand special care and control if they are to be reused (Cristescu et al., 2021). The benefits of using timber in housing are identified in a reduction of the carbon footprint, by extending the life-cycle of building materials, and in a reduction of the environmental burden, by reusing structural components. The growth of off-site construction is expected to contribute to the diffusion of timber-based construction because of waste reduction, as well as material and time efficiency. Despite these encouraging signs, timber-based construction is not following the principles of the circular economy neither is it taking into account the whole life-cycle cost of the buildings, suggesting a further field for research (ibid).

Currently, the reuse of timber structural components is hindered by a lack of design standards (for example, demolition practices that prevent damage to components); the lack of a sufficient market for recovered materials; restrictive building regulations and constraints imposed by the fixed dimensions of available components, negatively impacting the flexibility of a design (Cristescu et al., 2021). Concerns about technical performance and safety, when reusing structural timber components, would suggest that policy and regulation should drive the CE with respect to structural timber (Niu et al., 2021). Glue laminated timber in common with traditional timber framing has a high reuse potential and both offer environmental benefits (Huuhka et al., 2015). The literature has documented those barriers commonly obstructing the development of timber reuse in construction. The obstacles are mainly to do with cost, inconsistent quality, inconsistent quantity, perception and trust. As reported by Huuhka et al. (2015), the highest reuse potential is offered by prefabricated steel components while the lowest is concrete. Nevertheless, timber's potential is relatively close to that of steel. In identifying reuse potential and barriers, local issues such as structural systems, climate and societal conditions should be taken into consideration, since they vary from country to country (ibid).

According to Iacovidou and Purnell (2016), reuse potential measures "the ability of a construction component to retain its functionality after the end of its primary life". When considering timber construction, timber trusses have a low reuse potential of <50%, while timber floorboards have a medium reuse potential of 50% and structural timber has the highest >50% if properly deconstructed. It seems to be difficult to deconstruct timber components correctly when cleaning, de-nailing and sizing. Design interventions such as holes for wiring have made timber components more reusable, allowing for efficient deconstruction (Iacovidou and Purnell, 2016). A recent study showed that timber-based structures are mostly reusable: 65% of building materials are reusable and 35% are recyclable (Akanbi et al., 2018). This value could be increased by, for example, designing for deconstruction and using demountable connections (e.g. dowels and bolts) in the process (ibid). Rakhshan et al., (2020) argue that structural and non-structural timber components can, if properly deconstructed, have a high potential for reuse. However, timber components are difficult to deconstruct, require specialist skills and equipment during reclamation of components, and are exposed to decay. Hence, efficient deconstruction is essential and, consequently, special design features to reduce damage are needed to promote the reuse of timber sections and contribute to decreasing the environmental impacts, which Rakhshan et al. (2020) estimate to be 83%.

In Sweden, there is an ongoing development of reusable products database by the Center for circular construction (Centrum för cirkulärt byggande). By creating such a systematic database of components with unique IDs, and by utilizing available digital tools and building information modeling the acceptance of reused components in the construction industry could increase.

4. Discussion

Despite the economic, social and technical barriers, reuse in construction seems inevitable in the future, because of global population growth, scarcity of resources and housing shortages. As Iacovidou and Purnell (2016) have argued, a research commitment is necessary to demonstrate the economic, environmental, technical and social benefits of reuse. Doing so will lead to a better understanding of how to optimize the recovery of value for stakeholders through deconstruction and reuse, by simply changing current practices. There is an inevitable concern about the availability of timber for industrialized timber construction in the future, which could undermine the sustainability of the entire process (Mantau et al., 2010). Therefore, the concept of cascading is being used more and more to indicate the need to prolong the use of the same resource (i.e. building material or component), placing recycling for energy purposes last (Niu et al., 2021). Chisholm (2012), in recognizing the environmental benefits of using timber as a construction material for housing (e.g. carbon dioxide reduction, availability of timber in Europe, less energy to process timber components, high strenght-to-weight ratio, good thermal performance and carbon capture), emphasizes how “timber contained in the housing stock can act as an urban forest for harvesting” if the practice of reuse becomes popular. Moreover, the strategy of DfDR should be centered around modular and component deconstruction (e.g. floors, roofs and walls), rather than single parts or materials to support a reuse approach (Chisholm, 2012). Our literature review confirms the need for a holistic approach to the entire construction process, which should examine the conception and design phase and current demolition procedures. In addition, digital solutions are required to develop an efficient virtual building components’ database for a growing market. Furthermore, a decision-making tool and global, as well as regional, regulations need to be adapted to these newer forms of construction. Last, enabling reuse practices could easily and rapidly contribute to a reduction in CDW. Nevertheless, to demonstrate the above, further studies must be conducted to examine the economic value of reuse of building components by manufacturers, particularly planar and volumetric elements (Cristescu et al., 2021), rather than recycle building materials. Figure 1 shows how increased knowledge of the construction process while involving all stakeholders in the different phases, develops and improves the entire process and can generate, as a result, a reduced amount of CDW. Further education and training in new skills for all stakeholders, together with incentives, would encourage active participation in reusability strategies. There is a need to implement the enablers and overcome the barriers to reuse. It is evident that in order to overcome many of the barriers pointed out in this research, strong collaboration is needed among the different stakeholders involved in the construction process. For example, construction firms and architecture design firms could learn from deconstruction firms on the reuse of building components. Furthermore, the implementation of platforms for knowledge sharing are needed to be able to spread the knowledge about reusing practices.

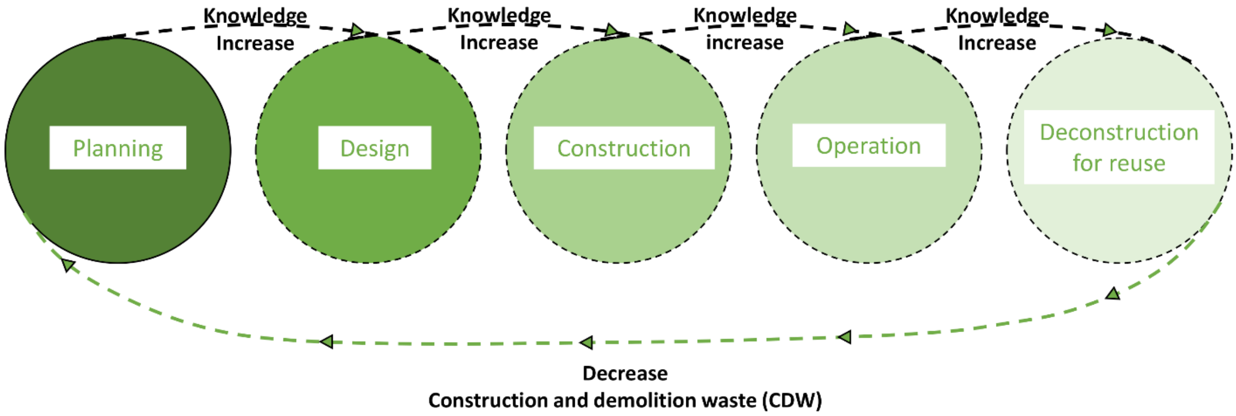

Figure 2 – Re-thinking the construction process.

5. Conclusions

Most political decisions and legislation focus on waste management when trying to solve sustainability in construction. This is agreeable since the amount of waste generated is a significant concern and the availability of landfill is increasingly scarce. However, attention should be directed to the design phase, which is the most influential stage in the delivery of decent, affordable housing, where change is necessary to ensure circularity is achieved. Once the reusability of building components andelements is introduced in the design process, a major contribution to solving the problem of waste will have been found.

Resource efficiency in housing construction should be able to fill the gap between housing demand and current construction methods. Furthermore, the demolition phase of the construction process has to be better analyzed and improved to reduce the amount of CDW and, consequently, the carbon footprint of the construction industry. Reuse of building components is a recommended practice from a circularity perspective. It seems necessary, therefore, to reintroduce building components in the supply chain, replacing the perception of a waste problem with an opportunity to make the construction industry more sustainable and resourceful. ITH has much to offer as a solution to housing shortages and has less environmental impact than traditional construction, which could be reduced even more through the reuse of building components. Unfortunately, a lack of quantitative and qualitative data about the benefits of reuse in construction hinders the spread of this practice. With this in mind, it is evident that reuse of building components needs to be adopted on a large scale and embraced by all stakeholders in a project. It is crucial to change attitudes towards reuse in construction and to establish a broader involvement and stronger collaboration between all the stakeholders responsible for the different phases of the construction process, starting with planning and design, and continuing with manufacture, construction, handover and maintenance to the point of refurbishment or deconstruction for reuse from a holistic perspective. Industrialized timber housing construction is a potential area which provides many opportunities for reusing building components. There is a need to study the reuse practices of building components in industrialized timber housing construction, thus, this study will further explore the field by analyzing multiple cases. This study will explore the barriers to, and enablers of, reuse in ITH from the perspectives of clients, building contractors, designers and demolition contractors.

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