Transitioning the Swedish building sector toward reuse and circularity

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Abstract. A transition toward a circular building sector, in which built-in construction products with remaining technical life are reused, would decrease the amount of waste generated, improve resource utilization and reduce greenhouse gas emissions related to the built environment. Based on this premise, this study (1) identifies key barriers to the increased reuse of high-quality construction products in the Swedish building sector and, based on these barriers (2) presents a set of new working practices that enable reuse in building and deconstruction projects. The study uses an explorative research approach based on data from ten case studies of Swedish building and deconstruction projects, semi-structured interviews and a survey conducted with key building-sector stakeholders. The results identify a lack of knowledge and an immature market as key barriers that must be removed in order to enable increased reuse in the Swedish building sector. Key working practices identified as solutions for increased reuse are (1) materials inventories, (2) targets for reuse, (3) circular building design, (4) planning for reuse, (5) incentives for reuse in procurement and (6) long-term documentation strategies enabling future reuse.

1. Introduction

Population growth and urbanization leads to an increased demand for housing and the construction of new buildings [1]; at the same time, the global building sector is currently facing major challenges in terms of reducing its climate impact, waste generation and utilization of virgin material resources. Estimates suggest that between 25 and 30% of the waste generated within the European Union (EU) is derived from the building sector [2]. In Sweden, the waste volumes generated from building construction and deconstruction in 2016 was estimated at almost 10 million tons, corresponding to more than 30% of the country’s total waste, excluding mining waste [3]. A transition toward a circular building sector, where existing construction products are recovered, recycled and reused, provides an opportunity to achieve a more sustainable built environment, limiting the environmental impact of fulfilling the increasing demand for housing and new construction [4]. Such a development is also in line with the EU waste hierarchy [5], which states that when waste cannot be prevented, the main priority should be reuse. Previous studies [6]-[9] indicate that the application of circular principles in the building sector provides opportunities to minimize the sectors’ costs, extraction of virgin material resources, generation of waste and emissions of greenhouse gases; for example, a study by Lu and Yuan [6] suggests that the application of circular principles in the building sector would reduce costs and environmental impact associated with waste transports, disposal and recycling processes. A study by Marzouk and Azab [7]
analysed the economic and environmental impact of circularity in Egypt’s building sector and found that recycling is to be preferred to landfill, given its potential to reduce environmental impact, energy consumption and the cost of mitigating air pollution. A Swedish study [8] shows a potential reduction in waste generation by 18,000 tons/year, greenhouse gas emissions by 21,000 tons CO$_{2eq}$/year and procurement costs by almost €60 million/year by reusing four common interior construction products when renovating Swedish office premises. Another Swedish study [9] has evaluated the cost effects of reusing interior construction products and furniture in two case studies of office renovations. The study showed that, despite an increase in working hours due to more time-consuming processes, the overall project cost for the case studies was reduced by almost €100,000 (€50/m$^2$) as a result of reuse.

Although reuse and circularity offer several potential benefits, their practical application in the building sector is currently limited due to a number of barriers [10]; for example, in Australia and Japan, the high price of recycled concrete material is a barrier to practical implementation [10]. Oydele et al. [11] found that in the United Kingdom (UK) construction industry, the main barrier to adopting circular principles is the designers’ lack of knowledge and preferences for the project design. A study by Ajayi et al. [12] asserts that a focus on end-of-pipe solutions rather than preventive measures is the main managerial barrier with respect to circular construction in the UK. Lu and Yuan [6] reported that one of the main barriers for adopting circular principles in China’s construction industry is the lack of an adequate policy system that guides and enforces circularity.

1.1. Research gap, aim and scope

Previous studies have investigated the barriers to and solutions for adopting circular principles in the building sector in other countries (mainly the UK and China); however, not enough studies provide an insight into the barriers to and solutions needed for obtaining a circular building sector in the Swedish context. Similarly, existing studies on circularity in the building sector focus largely on materials recycling, rather than reuse, where barriers may differ from other aspects of circularity [10]. Given this gap in the research, the aim of this paper is to (1) explore the barriers to adopting the practice of reusing high-quality construction products in the Swedish building sector and, based on these barriers, (2) present a set of new working practices that enable reuse in building and deconstruction projects. The focus of this paper is on the reuse of existing construction products, rather than the design of future reuse and circularity (design for deconstruction). The study is mainly linked to the United Nation’s (UN) Sustainable Development Goals [13] focusing on sustainable cities and communities (SDG 11) and responsible consumption and production (SDG 12), as it aims to increase reuse in relation to the built environment.

2. Research approach

2.1. Case studies

The research method used in this paper is based on a case-study approach. Case studies have been recognized as a valuable method for exploratory investigations, given their potential for providing rich seams of information and insights regarding complex interactions and behaviour, as well as in identifying key elements of focal phenomena [14]. It has been reported that the empirical basis of the research is likely to be unconvincing when using fewer than four case studies, while using more than 10 cases may be problematic in terms of managing the complexity and volume of data [15]. For the purposes of our research, 10 case studies have been conducted and evaluated in order to obtain an in-depth understanding of the barriers to and solutions needed to increase reuse in the Swedish building sector. The case studies include new builds, renovations and deconstruction, as well as a case study of storage facilities for reuse. Building types include hospitals, preschools, residential buildings, offices and educational facilities. Table 1 presents the detail of these case studies. Several case studies are ongoing and will be subject to further evaluation once the projects are completed; however, experiences from these case studies are regularly collected through meetings, meaning that they can still provide useful input for this paper.
The main barriers for reuse mentioned by the stakeholders participating in the survey relate to (1) current habits and attitudes (19%), (2) a lack of time and resources (17%), (3) limited knowledge and experience (14%), (4) a limited market (12%) and (5) the uncertain quality of and lack of warranties for reusable products (12%). Many of these barriers are interconnected, meaning that if one barrier is overcome there is likely to be a concomitant impact on the others (Figure 1).
Figure 1. The main barriers to reuse are interconnected; increased knowledge and experience and the development of a mature market are key to transitioning the Swedish building sector toward increased reuse.

The increase of knowledge and experience would in all likelihood decrease the time and resources needed to implement reuse, as well as reducing uncertainties related to the quality and reusability of existing construction products. Similarly, if a more mature market for reuse is developed, it would probably increase the efficiency of the processes related to reuse and could also help to drive the development of a quality-assurance system for reusable products. It is also likely that resolving the aforementioned barriers would create a more positive attitude toward reuse, increasing the incentives to change current habits. The lack of knowledge and experience, as well as the immature market for reuse, are therefore to be viewed as key barriers hindering increased reuse in the Swedish building sector.

The barrier of lack of knowledge and experience includes (1) a lack of competence regarding how to reuse, (2) a lack of existing examples showing that it is possible to successfully work with reused building materials and products, (3) a lack of awareness of the effects of reuse and (4) uncertainties regarding the quality and reusability of built-in construction products.

The barrier of immature market for reuse includes (1) a limited supply of reusable construction products with desired qualities and characteristics, (2) an inefficient marketplace for the distribution of supply and (3) an underdeveloped value chain of stakeholders providing services; e.g. handling, storage, reconditioning and sale.

3.2. Solutions for increased reuse in the Swedish building sector

To increase knowledge and disseminate experience of reuse; working practices enabling reuse in building and deconstruction projects have been identified based on case studies and interviews with stakeholders along the value chain. The identified working practices enabling reuse in building and deconstruction projects are (1) a materials inventory, (2) targets for reuse, (3) circular building design, (4) planning for new processes resulting from reuse, (5) incentives for reuse in procurement and (6) long-term documentation strategies enabling future reuse. Figure 2 shows a generalized description of a building and deconstruction process adapted to these new working practices. Sections 3.2.1 to 3.2.6 below describe the identified working practices in further detail.

Figure 2. A generalized description of a building and deconstruction process enabling reuse.
To enable the transition to these new working practices, a set of digital services have been developed in relation to a digital platform called Centrum för cirkulärt byggande (The Centre for Circular Building) [16]. The services include a marketplace for reusable construction products and related services [17], aiming at reducing barrier of an immature market with limited supply and underdeveloped value chain described in 3.1. It also includes a set of quality criteria for reusable products, an open-access inventory app [18] and a tool calculating the reuse effects regarding waste volumes, greenhouse gas emissions and costs. The calculated reuse effects can be used in decision making and prioritizing of reuse as well as for sustainability reporting of reuse results. Lastly, in order to facilitate collaboration a local network has been established, where actors share knowledge and collaborate on how to enable reuse in practice.

3.2.1. Materials inventory as a basis for decision-making. Performing a materials inventory at an early stage is key to documenting and quantifying the different values and potential inherent in built-in material resources. The property owner is recommended to initiate a materials inventory as early as possible, as this will provide a valuable basis for decision-making regarding reuse and circularity during the remainder of the process. Inventory results are used when designing the new building concept to ensure the greatest possible utilization of built-in construction products. High-quality products that cannot be reused within the project should be made available on the reuse market as early as possible, providing time for potential buyers to find the products and plan for their dismantling, transport and storage. The inventory results also provide valuable input when planning the project (3.2.3) and help to set realistic targets (3.2.2) and requirements for reuse in procurement (3.2.5). If the inventory is to provide results that successfully facilitate decision-making, it should aim to map all of the various potentials and barriers related to reusing the built-in construction products. In order to capture all relevant values and barriers, it is recommended that consideration be given to the various aspects of reuse such as aesthetic, cultural and environmental, as well as financial, technical and functional.

3.2.2. Setting targets and measuring reuse. The current national and international sustainability targets (UN SDGs [13], Swedish national environmental objectives [19], etc.) have the potential to provide incentives for reuse in Swedish building and deconstruction projects; however, these targets are rarely formulated according to the SMART criteria for goal formulation, which states that goals should be specific, measurable, attainable, realistic and time-bound [20]. High-level targets often have a lack of specificity and measurability, making them suitable from a global or national perspective but preventing them from serving as clear incentives in specific projects and organizations. Stakeholders who want to increase their reuse are therefore recommended to complement these global and national targets with organizational and project-level targets that fulfill the criteria specific, measurable, attainable, realistic and time-bound. It is also recommended that the targets are measured, evaluated and reported on a regular basis, as well as revised if they fail to fulfill the desired function (Figure 3).

Figure 3. Targets for reuse serve separate functions in different parts the process.
Reuse targets can be both direct, specifying desired reuse levels, and indirect, related to routines that enable reuse. To ensure that direct reuse targets are realistic, they can be formulated based on the results of a materials inventory (3.2.1) and then used when formulating procurement requirements (3.2.5). Examples of indirect targets include requirements that all projects should perform materials inventories (3.2.1) or that all projects should use specific documentation practices (3.2.6).

3.2.3. Designing for long-term circularity. A crucial step for enabling increased reuse in the building sector is to adopt new methods of designing our buildings and construction products. A building designed with circularity and reuse in mind should use limited material resources to fulfil the desired function – with the resources used being mainly recycled, renewable and reused. The resource efficiency of the building should be seen in relation to how many years the building will be able to fulfil its function. The potential for sharing resources – for example, by using one building to fulfil several functions – should always be explored. Furthermore, a circular building should be designed with flexibility in mind, allowing the building to be adapted to changing circumstances without creating waste. This flexible building design entails using construction products and methods that enable the products to be dismantled with their quality and functionality intact. Before undertaking renovation and deconstruction projects, one should ask whether it is necessary to carry out the project or if the building could continue serving a function in its current state. A decision not to deconstruct or renovate a building represents waste prevention, which is the highest priority according to the EU waste hierarchy [5]. If a renovation or deconstruction is judged to be necessary, the planning of the project should be based on a materials inventory (3.2.1), with a focus on minimizing the renovation measures and reusing the built-in products within the project.

3.2.4. Distributing project resources with reuse in mind. Building and deconstruction projects incorporating reuse will differ from the linear project processes commonly used today. New steps that will arise include dismantling, reconditioning, storage, new types of transports and time to search for, market and select products for reuse. In order to enable reuse, it is important to plan for these steps, distributing the project time and resources accordingly. It may also be useful to establish a list of responsibilities for involved stakeholders, as well as deciding on one stakeholder or group to focus specifically on reuse during the project process. The evaluated case studies indicate that the main source of increased working time in projects due to reuse relate to time spent on searching for reusable products, adapting the building design to available products and verifying that the products fulfil all necessary requirements. Another major difference in those projects that implement reuse is the uncertainty regarding whether the desired amounts and types of products will be available on the market for delivery at a specific time. Because of this, it is important that the architect’s building instructions include a level of flexibility, allowing for some decisions to be made when the reusable products are to be purchased and delivered. Previous evaluations indicate that the construction phase of the project need not be more time consuming than a regular project; although additional steps may be added due to reuse, other processes, such as delivery times, unpacking and waste handling may decrease as a result of reuse.

3.2.5. Creating incentives for reuse in procurement. As the owner of the building, the property owner has a great potential to create incentives for other stakeholders involved in the process to work with reuse. These stakeholders may be less likely to take the initiative to reuse, as their primary responsibility is to meet the requirement specifications set out in the procurement process. Incorporating reuse when it is not requested in procurement may represent a significant risk, given the uncertain quality of and lack of warranties for reusable products, expressed as a barrier in 3.1. Because of this, encouraging and removing barriers to reuse in procurement is central to enabling increased reuse; for example, by (1) providing financial incentives for reuse, (2) demanding specific levels of reuse (based on reuse targets (3.2.2)), (3) scheduling the necessary time to undertake reuse (3.2.4), (4) lowering requirement specifications for reused products (when possible), (5) placing specific requirements on the documentation of new products purchased for the building (3.2.6), (6) assisting with premises for storage.
and other services that facilitate reuse and (7) providing information that facilitates reuse (e.g. inventory results, 3.2.1).

3.2.6. Long-term documentation strategies. As expressed in 3.1, a key barrier to increased reuse is the uncertainty regarding the quality of built-in products due to the lack of available documentation. In order to enable future reuse, it is therefore crucial to develop long-term organizational documentation strategies that facilitate uninterrupted digital information flows that gather and continuously update data that can be made available to future operations, renovations and deconstruction projects. Existing information sources such as Construction Product Declarations (eBVD), safety data sheets and Declarations of Performance (DoP) [21] can be utilized when developing these strategies.

It is recommended that the property owner, as the stakeholder ultimately responsible for the building’s operation, should take charge of developing this documentation strategy; for example, by incorporating a digital logbook into the existing building management system. The property owner is also recommended to develop routines and formulate goals related to the long-term documentation of construction product information, in order to ensure that digital documentation becomes common practice within the organization.

4. Conclusion

This study has identified the key barriers to reuse in the Swedish building sector, along with solutions in the form of new working practices that facilitate reuse in building and deconstruction projects.

In line with the results presented by Oydele et al. [11], the findings show that lack of knowledge is a key barrier to reuse in the Swedish building sector. An immature market with an underdeveloped value chain and insufficient supply is identified as another key barrier to reuse in the Swedish context.

In order to increase knowledge and spread experience regarding reuse, a number of working practices enabling reuse in building and deconstruction projects have been identified, based on experiences from case studies and interviews with stakeholders along the value chain. The identified working practices are (1) materials inventories, (2) targets for reuse, (3) circular building design, (4) planning for new processes resulting from reuse, (5) incentives for reuse in procurement and (6) long-term documentation strategies to facilitate future reuse. To support a transition toward these working practices, several services [17][18] have been developed and gathered on a digital platform [16].

Although the 10 cases studies have provided an in-depth understanding of the studied context [12], the exploratory nature of this research means that further case studies can increase the generalizability of the findings and consolidate solutions that promote circularity in Swedish building sector.

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