

POTENTIAL AND BARRIERS FOR REUSING LOAD-BEARING BUILDING COMPONENTS IN FINLAND

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ABSTRACT

The European Waste Framework Directive, as set forth by the European Union in 2008, introduced a waste hierarchy that prioritizes reuse of waste over recycling whenever technically feasible and financially possible. In the field of construction, life cycle analyses on different materials have shown that reuse of structures possesses a remarkable carbon saving potential. This is the main asset that reuse has over virgin and recycled materials, although many other opportunities have also been recognized. Nevertheless, reuse has not gained ground in Western industrialized societies such as Finland. The barriers hindering reuse have been documented in the literature and they include cost, quality, quantity, perception and trust, among others.

In this study, a panel of experts working within construction and recycling industries, research and administration was surveyed about the reuse potential of prefabricated load-bearing components made of different materials in the Finnish context. In addition, the panellists were requested to identify the main barriers obstructing the reuse of the aforementioned components. The materials include concrete, steel and timber, which cover the majority of contemporary construction in Finland. The respondents evaluated that prefabricated steel has the highest reuse potential and concrete the lowest. The future potential of timber was seen as nearly equal to the potential of steel. In general, columns and beams were estimated to have better reuse potential than floor slabs and roof trusses. The potential of sandwich panels was evaluated to be the lowest.

The survey answers point out a number of issues that need addressing in order to enable reuse of components in large scale and in industrial construction. These results may not only have implications for recycling but for the technologies used in new construction as well. Especially prefabricated concrete was seen to be burdened by not being designed for deconstruction. However, it is the lack of an established practice that seems to be the main barrier for reusing steel and concrete. Technological constraints and physical properties may nonetheless delimit the utilization of some components. As for timber, its nature as a biodegradable material seems to form the main handicap for reuse, restraining the demand. Remarkably, cost of reuse was not seen to be among the most significant barriers, unlike other studies suggest.

Key words: reuse, recycling, waste, sustainability, resilience, survey

Introduction

The European Waste Framework Directive, as set forth by the European Union in 2008, introduced a waste hierarchy that prioritizes reuse of waste over recycling whenever technically feasible and financially possible [1]. In the field of construction, life cycle analyses on different materials have shown that reuse of structures possesses a remarkable carbon saving potential [2, 3, 4]. This is the main asset that reuse of components has over virgin and recycled materials, although economic and social opportunities have also been recognized. These include new possibilities for business and employment as well as utilization of local resources (materials, workforce) [5, 6]. Estimates of reuse potentials of components made of different materials have been presented. With regard to the environmental benefit and the viability of reuse, high potentials have been associated with structural steel framing, glued laminated timber as well as traditional timber framing, and medium potentials with precast concrete frames and steel roof trusses. [7]. Nevertheless, component reuse has not gained ground in Western industrialized societies such as Finland. The barriers hindering reuse have been documented in the literature and they include cost, inconsistent quality, inconsistent quantity, perception and trust, among others [5, 6]. Because reuse is considered to be labor-intensive, high labor costs have been seen as the decisive barrier for reuse in the EU [8].

However, the research has remained on quite general level so far. There are local issues that have not been addressed in studying reuse potentials and barriers. For example, structural systems, climate (nature and severity of weather exposure) and societal conditions vary from country to country. The purpose of this study was to survey construction and recycling industry members in Finland using material-component pairs in order to recognize which of the barriers they consider to be crucial in Finland and which are seen as less important. The research also aimed at

identifying if some of the barriers are assessed to be material-specific and if some materials or components are evaluated to have better reuse potential than others. The study focused on prefabricated load-bearing structures made of concrete, steel and timber. These materials cover the majority of contemporary structures in Finland: in 2008, 35% of load-bearing structures in the Finnish building stock were made of precast concrete, 34% of timber and 21% of steel [9]. Examples of reusing components made of all of these materials have been documented worldwide [7].

Research Material and Methods

The study is based on surveying a panel of experts (N=11) working within construction and recycling industries, research and administration in two phases. In the first phase, a futures research method called Delphi was employed [10]. The respondents were asked to evaluate which percentage of load-bearing components from demolished (or rather, dismantled) buildings will likely be reused in 2020 and in 2050. They were also asked which percentage they would prefer to be reused. Each of the three material categories included four types of prefabricated structures: two vertical (columns and wall panels) and two horizontal (beams and slabs or trusses). The examination of the data is quantitative. The median is used as the statistic because the sample is small and the data shows high standard deviation. However, the interpretation is based on a qualitative tradition. The predicted percentages are not to be considered as exact numbers: rather they represent relative reuse potentials of the materials and components as seen from the experts' perspective. In the interpretation of the results, we make the following assumptions:

- Percentages for 2020 reflect the potential with current practices and percentages for 2050 the potential with significant technological developments. Likely percentages reflect processes that are already ongoing and preferred percentages require changes that have not been initiated yet or that are only nascent. Differences between likely and preferred percentages reflect the attitudes, values and backgrounds of the respondents.
- The likely percentages for 2020 reflect the industry's current preparedness to salvage and reuse components. The preferred percentages for 2020 reflect the reuse potential with current technologies but might require some administrative or other non-technology-related changes. We assume this because significant developments to construction or recycling technologies and processes cannot be expected to take place in only six years, as these investments are capital-intensive.
- The likely percentages for 2050 reflect the potential with technological changes in demolition/deconstruction and waste management (in addition to the aforementioned behavioural and societal changes). The preferred percentages for 2050 reflect the potential with technological changes in building production, i.e., design for deconstruction (DfD). We base this on

two facts. Firstly, the current EU regulation has put high pressure for the recycling industry to develop their technologies and this development has already been initiated. Secondly, the Finnish construction industry has not taken steps towards developing deconstructable buildings. This makes the development of recycling technologies more likely than the development of DfD.

Table 1 : List of barriers.

Economic barriers	Higher price
	Lack of demand
	Lack of supply
	Difficulty of scheduling
	Attractiveness of conventional recycling
	Higher insurance fees
Social barriers	Norms
	Lack of awareness
	Bad image of salvaged components
	Bad image of the original product
	Health risks
Ecological barriers	Unclear environmental benefit
	Emissions from transport and reconditioning
Technological barriers	Components not designed for deconstruction
	Inadequate material properties or damage
	Lack of applications and examples

In the second phase, the panelists were requested to identify the main barriers obstructing reuse of the aforementioned components. Three most important barriers could be selected from a list of 16 issues organized under four topics as shown in Table 1. These were derived from the literature [5, 6]. The respondents were also encouraged to list new barriers if they did not find the list comprehensive. Open fields were provided for arguments and comments under each material category.

Reuse Potential of Different Materials and Components

Table 2 summarizes the results of the first survey. In the table, the highest and second highest values in each year category are indicated with two shades of green, the lowest and second lowest values with two shades of red.

Looking at the likely reuse percentages for 2020, the respondents consider steel and concrete beams and columns to have the best reuse potential with current technologies and business models. With the current practice, there is potential for increasing reuse of steel and timber (glulam) beams and columns (highest preferred percentages for

2020), if behavioural and societal barriers (i.e. barriers not related to technology) are mitigated. Looking at the likely reuse percentages 2050, steel beams, columns and trusses as well as timber beams, columns and CLT have the highest reuse potential in future. The respondents would prefer especially timber to be reused in future (highest preferred percentages for 2050).

Table 2 : Likely and preferred reuse percentages in 2020 and in 2050 (medians of answers).

Material component	Likely in 2020	Preferred in 2020	Likely in 2050	Preferred in 2050
Concrete				
beams		15	15	
columns				
slabs				
sandwich panels				
Steel				
beams				
columns		20		30
trusses		15		35
sandwich panels		17,5	15	35
Timber				
beams		20		
columns		20		
trusses				40
CLT slabs and panels				

Potential of Concrete Components

Currently, concrete beams and columns have the highest reuse potential together with steel components of the same type. However, concrete as a material is estimated to have the lowest reuse potential in future. Of the listed concrete components, the respondents evaluate that concrete beams are most potential with regard to reuse. The potentials of concrete columns and slabs are nearly equal. Sandwich panels have the lowest potential for reuse.

Potential of Steel Components

Currently, steel beams and columns have the highest reuse potential together with concrete components of the same type. Unlike concrete, steel is evaluated to have a remarkable future potential, too. Of the listed steel components, steel beams have the best reuse potential, but the potential of columns is nearly as good. Steel trusses are less potential regarding reuse, and sandwich panels have the lowest potential. However, their potential is nonetheless higher than that of any concrete components. Steel trusses have better reuse potential than timber trusses.

Potential of Timber Components

Although timber as a material currently has the lowest reuse potential, respondents evaluate that timber has a remarkable future potential for salvage. The future potential was seen as nearly equal to the potential of steel. Timber beams and columns have practically as good a potential for reuse as steel beams and columns. The future potential of CLT slabs and panels is not seen to be remarkably lower, either. It is higher than with steel sandwich panels or concrete slabs and sandwich panels.

Barriers for Reuse of Components

Main Barriers for Concrete Components

Not being designed for deconstruction was seen as the main barrier for reusing concrete panels and slabs, but this factor was not evaluated to have significance for beams and columns. Primary barriers for beams and columns as well as secondary barriers for panels and slabs consisted of a variety of market-related issues (lack of demand and supply, lack of awareness, applications and examples as well as difficulty of scheduling and costs). Inadequate material properties or damage were seen as a tertiary barrier for all the component types. The answers showed only little dispersion.

The respondents provided plenty of comments for concrete. One respondent considered that only non-weather-exposed concrete structures should be reused; another called for standardization for reused components. A third one pointed out that the structural designer would need information about the capacity of the structures, which is not available with reused components; and a fourth one evaluated that designing new buildings with old spans is difficult. In addition, the respondent mentioned that the norm for the minimum room height has increased and old wall panels are lower than what is required today. As for the deconstruction work, one panellist pointed out that the elements should be transported directly from the deconstruction site to the construction site to minimize the risk for damage; in addition, the schedule for deconstruction should be planned as loose enough and the client should be willing to pay for the extra time.

To sum up, concrete beams and columns have good technical prerequisites for reuse per se, although their condition may be a problem. The main barrier preventing their reuse seems to be the lack of an established practice, which would consist of supply and demand, quality control as well as applications and examples. On the other hand, the difficulty of deconstructing panels and slabs was seen as the main barrier for their reuse. If this issue could be solved, the rest of the barriers would be practice- and condition-related similarly as for beams and columns.

Main Barriers for Steel Components

The main barriers for reusing steel beams and columns were the attractiveness of conventional recycling and unawareness about reuse possibilities (including lack of applications and examples). Norms were also seen to prevent reuse. Other significant barriers were market-related (lack of supply and demand, difficulty of scheduling). The barriers for reusing steel trusses were similar. The main barriers were, however, lack of demand and inadequate material properties or damage. The latter was also the primary barrier for reusing steel sandwich panels. The answers showed quite a lot of dispersion.

In addition to the readily given options, the respondents brought up the difficulty of dimensioning the structures for stresses when the quality of the steel is unknown. As for norms, one respondent mentioned that avoiding the status of waste would be crucial. Another respondent pointed out that due to changes in fire and stress norms, old parts need modification, which increases costs.

In all, construction technology does not seem to hinder reusing steel components remarkably. Instead, it arises that the lack of an established practice is currently the main barrier for steel reuse. This consists of factors such as attractiveness of conventional recycling, unawareness of reuse, norms and design practices and the vicious circle of no supply and no demand. Physical properties or damage may, however, delimit the reuse of steel trusses and sandwich panels.

Main Barriers for Timber Components

All timber components share the main barrier for reuse and that is inadequate material properties or damage. Unawareness, lack of demand for salvaged timber and difficulty of scheduling were seen as other major barriers. In addition, respondents consider norms to prevent timber reuse. Although salvaged timber beams and columns were seen to suffer from a bad image, health risks were not seen as a barrier unlike for CLT slabs and panels and timber trusses. The answers were very widely dispersed over several factors. In addition, the respondents brought up the need for stress grading, which was not included in the questionnaire.

In conclusion, the nature of timber as a biodegradable material seems to form the main handicap for reusing timber. This is a combination of inadequate material properties or possible damage as well as associated health risks and the bad image that follows. Other significant barriers were unawareness and lack of demand as well as norms. Unlike for other materials, supply of salvaged components was not seen as a challenge.

Shared Barriers for Components

Nearly all materials and component types (wall panels excluded) shared one common major barrier: demand. Awareness was another factor with shared significance for columns, trusses and slabs regardless of the material. Scheduling is a challenge that wall panels share, while both timber and steel trusses are challenged by material properties or damage and norms.

Barriers of Low or No Importance

Costs were not listed among the most significant barriers for reuse, unlike other studies suggest. Only timber reuse was seen to be significantly challenged by bad perception associated with salvaged components as well as health risks. Emissions from transportation were only seen as a barrier for reusing steel. None of the respondents listed possibly higher insurance fees, bad perception of the original products or questionability of environmental benefits as barriers for reusing any materials or components.

Conclusions

This study points out a number of issues that need addressing in order to enable reuse of components in large scale and in industrial construction. These results may not only have implications for recycling but for the technologies used in new construction as well. The survey answers demonstrate that industry members begin to reflect the financial and social aspects of reuse only after the technical feasibility has been shown.

The respondents evaluated that prefabricated steel has the highest reuse potential and concrete the lowest. The potential of timber is nearly equal to the potential of steel. In general, columns and beams were estimated to have better reuse potential than floor slabs and roof trusses. The potential of sandwich panels was evaluated to be the lowest.

The lack of established practices seems to be the main barrier for reusing steel and concrete, although technological constraints and physical properties may delimit the utilization of some components. Especially prefabricated concrete was seen to be burdened by not being designed for deconstruction. As for timber, its nature as a biodegradable material seems to form the main handicap for reuse, restraining the demand. Remarkably, cost of reuse was not listed among the most significant barriers, unlike other studies suggest. In addition, the respondents took the environmental friendliness of reuse as a given fact, as none of them declared the controversy of it as a barrier for reuse.

Limitations of the Study

A limitation of the study is that the answers represent the opinions of the respondents, not necessarily the objective truth. The number of respondents was small and the opinions showed a lot of diversity. In conclusion, the results are only as valid as the expertise of the surveyed panel.

Policy Recommendations

The waste hierarchy that prioritizes reuse over recycling was added to Finnish Waste Act in 2011. Other than that, no policies for establishing reuse practices have been initiated in Finland so far. This study gives an indication where policy-makers could start off. As steel, timber and concrete beams and columns were evaluated to have the best reuse potential per se, these components could act as trailblazers for new reuse practices if barriers preventing their utilization would be removed.

In brief, policy-makers should act upon the main barrier recognized in this study: the lack of established practices. Policies could aim at creating preconditions for more widespread experimental construction. A nationwide trial for more lenient salvage and reuse could consist of flexible and coherent interpretation of norms, raising awareness, bringing together demolishers and builders and, possibly, some economic incentives. In addition, procedures for evaluating the physical properties of salvaged structures should be established and structural design guidance created.

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