EVALUATING REUSE CONDITIONS DURING A CIRCULAR DEMOLITION PROJECT: AN ETHNOGRAPHIC STUDY

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Reuse of building elements is necessary to achieve a circular construction industry. This means that demolition contractors get another role: these firms should recover elements instead of destructing them. Previous research revealed a proposition with three conditions which must be all satisfied for a demolition contractor to recover elements for reuse: identify economic demand, distinguish disassembly routines, and control future performance. This research extends that work by evaluating whether it accurately predicts reuse decisions in another context. An ethnographic research method was adopted in which 300 hours of active participant observations were conducted during a circular demolition project. It appears that the proposition could account for the recovery of most building elements: some elements were destructed due to poor project preparation and time constraints. A new 'auction company' mechanism was used for identifying an economic demand. These insights sharpen the previous proposition and offer new opportunities for closed-loop material flows.

Keywords: circular economy; demolition; ethnography; recovery; reuse

INTRODUCTION

The construction sector has a poor track record for its material usage. The sector is responsible for about 46% of the total waste production in Europe. Construction and demolition waste (CDW) is often not processed properly as a big part is still disposed to landfill, which leads to negative environmental impacts such as soil and groundwater pollution (Gálvez-Martos \textit{et al}., 2018; Llatas, 2011). Moreover, the construction sector consumes worldwide about 40% of the materials and continuing this consumption will lead to natural resource depletion (Yilmaz \textit{et al}., 2019). These problems are caused by a linear (take-make-use-dispose) economic model in which materials are discarded at the end of a life cycle. Researchers and policymakers therefore increasingly call for an alternative, cyclical economic model focused on reduce, reuse, and recycle activities. A circular economy is a regenerative system which aims to design out waste and to close material loops (Ellen MacArthur Foundation, 2013). A change towards a circular economy is needed to protect the environment and to provide new business opportunities simultaneously. This means that demolition contractors need to move towards reuse-oriented deconstruction practices in which construction steps are reversed (Kibert, 2016). Little is known about this imperative change in working practices.

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LITERATURE REVIEW

Most previous research into this area revealed reuse barriers through literature studies at some distance of daily deconstruction practice (see e.g., Durmisevic and Binnemars, 2014; Hosseini et al., 2015; Iacovidou and Purnell, 2016; Storey and Pedersen, 2003). Van den Berg et al., (2020), however, conducted participant observations during the deconstruction of a temporary building to inductively develop a proposition for predicting the recovery of building elements. Their - theory building research revealed three conditions which must be satisfied before demolition contractors will recover any element for reuse. First, an economic demand for the element must be identified by the demolition contractor, for example through contractual documents, indirect sale channels or on-site meetings. Second, the demolition contractor must be able to distinguish disassembly routines which is dependent on the skills of the demolition contractor and the type, amount, and accessibility of the connections. Third, the demolition contractor should be able to control the future performance of the building element until it is used in the new building or structure, for example by storage on- and off-site, packaging and reparations. According to this proposition, all three conditions must be satisfied should recovery for reuse of a certain building element occur; otherwise, that element will be treated as waste (i.e., destructed). Given its inductive nature, the generalizability of this proposition has remained unclear.

This research therefore aims to test whether the proposition of Van den Berg et al., (2020) can accurately explain whether building elements in different contexts are recovered for reuse or not. The paper starts with an elaboration of the ethnographic research methodology adopted. Subsequently, contextually rich evidence is provided for reuse conditions that are either satisfied or not. After that, it is discussed whether resulting end-of-life options (i.e., recovery or destruction) match with the focal recovery proposition. Limitations of our research and suggestions for future research are provided before the paper ends with a sharpening of the proposition.

METHOD

This research adopted an ethnographic research methodology for testing the focal recovery proposition. Specific attention was thereby paid to identifying any possible other mechanisms to satisfy the conditions and whether there are other conditions which influence the recovery of building elements for reuse.

To conduct this research, a deductive reasoning approach was used. Deductive reasoning is about testing whether a certain theory that was developed in one context can also be applied to other specific contexts (Hyde, 2000) like, here, other types of demolition projects. This implies that both the three recovery conditions and the resulting outcome must be studied up closely. Participant observations, based on the ethnographic research methodology, were therefore selected as the primary research method. Ethnography is a qualitative research methodology concerned with the study of social environments (Pink et al., 2010). Participant observations can be used to observe and engage in activities, people, and other aspects in a situation (Spradley, 1980). A participant observer is not only observing people but is also actively involved during their daily activities (DeWalt and DeWalt, 2011). Participant observations thus provide unique opportunities to closely observe and participate in real-world selective demolition practices.
In this research, the first mentioned author conducted observations as an active participant during a selective demolition project. During the project, the researcher was involved in assigning tasks to the demolition workers, executed the daily demolition activities, and sold building elements at the site. The data collection during the participant observation of approximately 300 hours was done by noting down the observations in a field diary and by taking about 350 pictures. Interviews were conducted with people who worked on the project (i.e., demolition workers and one project manager), people who bought building elements (e.g., traders) and people who passed-by the project (e.g., residents). These interviews were unstructured, which means that the researcher did not predefine a framework or questions (Zhang and Wildemuth, 2009). This should lead to reasons why the observed people take decisions and do their activities as they do. Information received during these interviews was noted down in the field diary. Project documents were also collected from the demolition contractor. These documents were for instance material inventories, demolition specifications, action plans and a health and safety plan. The data collected from these interviews and documents could be used to complement and check the validity of the data gathered during the participant observation, as other data sources are used.

The proposition was tested by first creating a list of all building elements present in the to-be-demolished buildings. Thereafter, it was systematically checked for each element separately if all three different conditions could be satisfied. When this was the case, the element was added in the list of building elements which should theoretically be recovered for reuse. During the execution of the demolition, it was then checked whether these elements were also actually be recovered for reuse. Moreover, it was observed which mechanisms were used in practice to satisfy the three conditions. This ultimately led to a sharpening of the proposition.

Project: Circular Demolition of 96 Duplex Houses

The research was executed at a selective demolition project with explicit circularity goals. It concerned 96 duplex (terraced) buildings located in the Netherlands. The leading researcher was present during the demolition of the first 48 houses. The houses were built in the sixties for permanent use. This differed from the demolition project used as case project for the theory development (temporary - permanent and utility - housing). The researcher chose this project as the demolition contractor had to recover elements for reuse, to satisfy with the targets of the client. The demolition project started with the site preparation, where facilities were installed, and greenery was removed. The next step was the asbestos remediation, followed by the strip-out to separate waste streams and to recover valuable building elements. After all houses were stripped, the demolition of the superstructure started. During the demolition of the superstructure, building elements were still harvested. After that, the substructure was demolished, whereby all debris and other waste streams were removed and transported. The final stage was the project delivery towards the client.

FINDINGS

An overview of the building elements which were - or were not - recovered for reuse during the demolition of the houses is given in Table 1, divided in the six shearing layers of Brand (1995). From this table, it can be seen that the kitchens, sockets and switches, and structural beams were destructed, which was in contrast with the proposition. This means that all three conditions were satisfied for these specific elements, what should indicate that these should theoretically be recovered for reuse.
For each of the three conditions, it will be outlined how these were satisfied for the different building elements (i.e., what mechanisms were used) and why conditions were not satisfied for some building elements.

Table 1: List of elements which were (not) recovered for reuse

<table>
<thead>
<tr>
<th>Layer</th>
<th>Recovered for reuse</th>
<th>Not recovered for reuse</th>
<th>Matches proposition?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stuff</td>
<td>-</td>
<td>Lamps, curtains, mirrors</td>
<td>Yes</td>
</tr>
<tr>
<td>Space plan</td>
<td>Kitchens, HPL plates, glass wool, kitchens</td>
<td>Kitchens, laminate, stairs</td>
<td>Yes, except some kitchens</td>
</tr>
<tr>
<td>Services</td>
<td>Boilers, ventilation boxes, fuse boxes</td>
<td>Radiators, sockets and switches, gutter brackets, toilets, sinks</td>
<td>Yes, except some sockets and switches</td>
</tr>
<tr>
<td>Skin</td>
<td>Bricks (outer wall), plastic frames, back doors, roof decking (wood)</td>
<td>Front doors, windows, wooden frames, plastic dormers</td>
<td>Yes</td>
</tr>
<tr>
<td>Structure</td>
<td>Wooden beams and planks</td>
<td>Foundation, bricks (inside walls), structural beams</td>
<td>Yes, except some structural beams</td>
</tr>
<tr>
<td>Site</td>
<td>-</td>
<td>Pavement</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Condition 1: Identify Economic Demand

The first necessary condition for reuse to occur concerns identifying an economic demand. It was found that this condition was satisfied for most building elements (except for instance the radiators, toilets and sinks, structural beams, front doors and plastic dormers). Most elements that satisfied this condition were recovered, which is in line with the proposition. All elements for which this condition was not satisfied were destructed, which also matches the proposition.

During the site preparation, the project manager had already contact with a trader for all the plastic frames and wooden back doors. This trader showed also interest in the ventilation and fuse boxes during the strip work. Moreover, the project manager knew during the preparation that a second-hand building material company had interest in all roof tiles and that another trader had interest in all wooden beams and planks. So, the demolition contractor identified for some building elements an economic demand during the site preparation.

Regarding the kitchens, no economic demand was identified till the start of the strip-out. The demolition workers were instructed how to strip the houses. Then the project manager asked them whether they knew a buyer for the kitchens. One of the demolition workers joked: "yes, I know someone: the wood container of the local waste processing firm." They were discussing and arguing that nobody wants these kinds of kitchens and that new ones are only a few hundred euros more expensive. So, the workers started the strip work and demolished the kitchens. After one week of strip work, an economic demand was identified for the kitchens. An auction company was interested in the second-hand kitchens. This company was specialized in (dis)assembling kitchens. It buys the second-hand kitchens and sells these again through online auctions at their own website. From that moment, the demolition workers were instructed to keep the kitchens in the houses. This indicates that it is essential to identify an economic demand before the strip works starts. During the strip-out work, also economic demands were identified. An interest in boilers and glass wool plates was identified by using an online marketplace. The boilers were almost sold directly, as these were of good quality and were relatively new. This was
not the case for the glass wool plates and the project manager did not see an economic demand. However, the researcher offered these for free and there was a buyer directly. This can be seen as an indirect economic demand, as less glass wool plates had to be disposed, which resulted in less disposal costs.

The bricks were bought by a partner of the demolition contractor. This was no contractual relation. The project manager argued "it is hard to do this with contracts, as it is not known during the strip-out whether the bricks are easy to clean". The buyer explained "we take the bricks and put a new certificate on these bricks by testing them in the lab. After that, we can sell them to a contractor again. However, we need bulk to meet the contractor's demand". During the demolition of the superstructure also an economic demand was identified. Passers-by and residents showed their interest in wooden beams and High-Pressure Laminate (HPL) plates. These people had also an interest in the modern switches and sockets.

There was no economic demand identified for all radiators, toilets and sink, structural beams, front doors, and plastic dormers. A trader who was disassembling the plastic frames during the strip work argued that people do not want to have these doors, radiators, or toilets in their new house, as these are aesthetically not modern. The structural beams had a length of only two meters and the project manager said that there was no time to wait for a trader which has interest for these dimensions. Summarizing, most elements that satisfied this condition were also recovered for reuse, except the modern sockets and switches. Moreover, all elements that did not satisfy this condition were destructed. So, this was in line with the proposition for all elements except the modern sockets and switches. Mechanisms observed for identifying an economic demand were traders, online marketplaces, passers-by, and an auction company.

**Condition 2: Distinguish Disassembly Routines**

The second condition for reuse to occur concerns distinguishing disassembly routines. This condition was satisfied for all elements for which an economic demand was identified as well. Indeed, all elements that satisfied this condition were also recovered for reuse. Contrarily, all elements that were destructed did not satisfy this condition. Both situations indicate that this is in line with the proposition. There were building elements which were easy to disassemble as these related to reversible connections (i.e., screws and bolts). These were the plastic frames, kitchens, ventilation boxes, back doors, boilers and HPL plates. Moreover, the roof tiles and glass wool plates had loose connections, which made it easy to disassemble these. These elements were all recovered during the strip-out, as these elements were at that moment still of good quality. As an example, the ceiling made of gypsum plates was removed with a crowbar. All gypsum was discharged with wheelbarrows from the houses in separate containers. After that, the glass wool plates could be picked out and was stapled in the houses till it was picked up by a buyer. The demolition contractor hired a specialized company with a big telehandler to disassemble the roof tiles, while guaranteeing safety and speed (Figure 1a).

The bricks of the outer wall were attached to each other with mortar, which means that these seemed to have an irreversible connection. During the demolition of the superstructure, the inside and outside walls were destructed by crane and fell onto the ground. From that moment, a brick cleaning company arrived which was hired by a partnering firm who bought the bricks. This company was removing the mortar from the bricks (Figure 1b). However, more bricks could have been reused when these
were not mixed with the rubble, as the brick cleaning company did not want to separate the bricks from the rubble as that was too time consuming. The crane operators also showed disassembly routines during the demolition of the superstructure, as they used their skills to recover difficult accessible elements. An experienced machinist lifted the wooden floors including the wooden beams as a whole out of the building and put it upside down in order to separate the beams from the planks (Figure 1c). The demolition contractor did not disassemble the modern switches and sockets, although these consisted out of reversible connections. These were easy to disassemble, but it took the contractor too much time which would hinder the time planning. They were in the garages, which had to be demolished before the houses could be demolished. Due to that, these were destructed and thus treated as waste.

Summarizing, most elements that satisfied this condition were recovered for reuse. The modern sockets and switches were not recovered; however, these could easily be disassembled due to the reversible connections. The reason that these were not recovered was that there was no time left regarding the project planning. Besides that, all elements that did not satisfy this condition were destructed. So, this was in line with the proposition for almost all elements. The mechanisms observed for distinguishing disassembly routines were specialized companies, reversible and loose connections, and skills of the operators.

Figure 1: (a) a specialized company recovering roof tiles, (b) workers who clean the bricks, and (c) a complete wooden floor of beams and planks lifted out of the building

Condition 3: Control Future Performance

The third and last condition for reuse to occur is about controlling the future performance of the elements. This condition was satisfied for all building elements which were recovered. Moreover, it was found that this condition was not satisfied for all elements which were destructed. Both situations indicate that it is in line with the proposition.

During the strip-out, elements were disassembled and directly transported to their new destinations. This ensured that elements could not be damaged during other demolition activities at the project site. A trader had his own truck which he used to transport all doors, plastic frames, and ventilation and fuse boxes safely. Workers of the auction company disassembled the kitchens and packed them on pallets. Kitchens were disassembled in the houses and were laid down in parts outside. When all parts were outside, the company packed them safely on pallets and stored them in the truck. These were also directly transported towards the warehouse of the auction company (Figure 2a). The roof tiles were first stored during the strip work; they were packed into crates to store and transport these without having damage (Figure 2b). However, they could not be stored for a long period, as space was needed at the demolition site to start with the demolition of the superstructure. Elements like glass wool plates and
boilers had to be stored on dry and safe places. The houses which were not demolished yet were used to store these elements until the buyer picked them up. During the demolition of the superstructure, bricks were cleaned and directly packed on pallets by using plastic foil (Figure 2c). These pallets were stored on site for a longer period, as there was enough space since the superstructure was demolished. These pallets were transported when the amount was enough to fill a truck. The structural elements like the wooden beams and planks were stored in containers on site and were changed when these were full. The HPL plates were stored on site until the interested passers-by picked them up.

Summarizing, the future performance was controlled for all elements that also satisfied the first two conditions. All elements that satisfied this last condition were recovered for reuse. Indeed, all elements that did not satisfy this condition were destructed. This is in line with the proposition. Mechanisms used to control the future performance were packaging, storage on-site and directly transporting elements to the new destination.

Figure 2: (a) packed kitchens which are directly transported, (b) storage of roof tiles in crates, (c) storage of the bricks packed on pallets

DISCUSSION

This study evaluated reuse conditions during a circular demolition project. Through systematically collecting and analysing ethnographic data, a proposition developed by Van den Berg et al., (2020) was tested in a new context. The proposition linked three conditions together to predict whether a demolition contractor would recover any building element for reuse (or not).

This research identified that the previously developed conditions can accurately account for recovery (for subsequent reuse) of almost all building elements. During this circular demolition project, many building elements were recovered; bricks (outer wall), wooden beams and planks, rooftiles, kitchens, glass wool plates, boilers, HPL plates, doors, ventilation and fuse boxes, and plastic frames. The three conditions were satisfied for all these elements. There were also a lot of elements which were destructed as these did not satisfy one or more of the three conditions. For instance, the demolition contractor did not see an economic demand for the radiators, front doors and plastic dormers. These building elements were destructed. Both situations are in line with the proposition. However, there were some exceptions which indicated that it can be different in practice. These exceptions were found for the modern sockets and switches, and structural beams. Regarding the modern sockets and switches, an economic demand was identified, and these elements were easy to disassemble. Yet these elements were destructed as it took the demolition contractor too much time: otherwise, the demolition of the superstructure would be delayed. The
time needed for disassembly is incorporated in the second condition. However, the demolition contractor could better prepare this and disassemble these elements directly at the start of the strip out. The structural beams were not recovered for reuse as there was no time to wait for a buyer, although they knew that there is someone who has an interest. This example also indicates that an economic demand could be identified when the demolition contractor searches already for an economic demand during the preparation of the project. Both exceptions indicate that a good preparation is needed to reuse elements. This is somewhat overlooked in the original proposition. Although these exceptions, it can be said in general that the previously developed proposition holds for almost all building elements.

Contributions: Reinforced Proposition and New Mechanisms

Our in-depth insights show that the recovery mechanisms (through which the conditions are being satisfied) partly correspond with the earlier identified ones. Regarding the economic demand, mechanisms that were observed in both studies were on-site meetings with passers-by and the use of indirect sale channels (i.e., online marketplaces and traders). In this project, there was no use of contractual documents though. A new mechanism was identified as well: the demolition contractor identified an economic demand for some of the kitchens using an auction company. That company was specialized in disassembling, transporting, and re-assembling second hand kitchens. It sells recovered kitchens by organizing (online) auctions. By using this mechanism, it was possible to find an economic demand for these kitchens and thus the kitchens could be recovered for reuse. Whereas Veleva and Bodkin (2017) argued that online auction providers are main players within biotech industry, this mechanism was not yet described for reuse of building elements.

Regarding the disassembly routines, mechanisms that were observed in both studies were the skilled operators, accessibility, and reversible connections. However, regarding the bricks of the outer wall, these were normally seen as irreversibly connected with mortar. However, it was observed that these can be disassembled and cleaned. This indicated that such mortar-based connections do not necessarily pose a barrier for the recovery for reuse. It was observed in this project that separating building elements during demolition is important and can prevent destruction of elements. Van den Berg et al., (2020), for example, suggested that designers could separate elements in building layers with different service lives. We add that separating the different layers during the demolition can stimulate recovery for reuse. This was important during this focal project, as the bricks were mixed with the rubble which took the brick cleaners too much time to sort all bricks. The mechanisms to control the future performance that are observed in both studies were: packaging, storage on-site and directly transporting elements - but there was no storage facility where reparations could be executed.

It was also found that there can be other reasons for the destruction of some building elements. First, timing issues led to the destruction of some building elements (i.e., the kitchens, the modern sockets and switches, and structural beams). For example, the auction company wanted to recover all kitchens, but they were contacted too late and therefore had insufficient time to recover all of them. Timing appeared an important factor for the recovery of elements during this project. The time factor had only been addressed implicitly in the second condition (of distinguishing disassembly routines). We argue that this factor is essential and warrants more research to determine whether such constraints related to the project (rather than the element)
influence recovery for reuse. Polina (2018), for example, argued that the planning phase becomes more important for circular demolition projects as more decisions must be made regarding demolition techniques, scheduling and the waste and material handling. Other reasons found for the destruction of building elements were that the building elements did not meet with the current Building Decree or did not have performance specifications. This barrier was also discussed in literature (see e.g., Hosseini et al., 2015; Storey and Pedersen, 2003). Surprisingly, this was not a problem for the recovered bricks as these got new certificates after tests were executed in the lab. This indicates that this barrier was solved for this specific element. It is recommended that demolition contractors put more effort in the preparation for material recovery and determine for which elements there is an economic demand. Moreover, it is important to separate elements of the different building layers during the demolition works. It is expected that these recommendations lead to higher rates of reuse, which is needed to shift to a circular construction industry.

Limitations and Future Research
This research was limited to one project of one specific demolition contractor. This could influence the results since every project is unique and that every demolition contractor has other working procedures. During the research, it was sometimes difficult to switch between the observer and worker perspective. This was also described by Löwstedt (2014) as a difficulty when doing an ethnographic study in the construction sector. Future research should be done to further evaluate whether the conclusions hold for other demolition projects. Besides that, research can elaborate project-related recovery conditions regarding timing and preparation constraints. It is, finally, interesting to explore or develop any other (new) mechanisms to satisfy the necessary conditions.

CONCLUSION
This study used deductive reasoning to test a proposition of Van den Berg et al., (2020) that can be used to predict recovery of building elements for reuse. We thereby sought to identify possible other reasons or conditions which could determine whether building elements will be recovered for reuse or not. Based on ethnographic data collected during a selective demolition project, it can be concluded that the proposition holds for most - but not all - recoverable building elements. For some elements (i.e., kitchens, modern sockets and switches, and structural beams), all three conditions for the recovery for reuse were satisfied, but they were still destructed. All elements that were recovered for reuse did satisfy all three conditions, which is in line with the proposition. The demolition contractor had issues with timing and did not know for all elements beforehand what could be recovered and for which there was an economic demand. Thus, while it appears that project-related constraints influence the recovery of building elements as well, the recovery proposition tested here has wider applicability and can be used to predict which building elements will be recovered for reuse during a demolition project - and which ones not.

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