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Reconditioning of Computers: Identifying Contextual and Design Barriers

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Abstract

Fast technological development and short innovation cycles has resulted in shorter life spans for certain consumer electronics. Reconditioning is proposed as one of the strategies to close the loops in the circular economy and increase the lifespan of products and components. The paper therefore examined contextual and design barriers for reconditioning of computers (laptops and desktops), and based on the barriers, design for reconditioning recommendations were made. The study was based on a single case study of a reconditioning company and the main method applied to collect information were qualitative research interviews.

The case study of the contextual barriers indicated that trust from the buyer and the seller of the used computers were important for a viable business. If trust was not in place, it could be a potential barrier. Furthermore, economy obsolescence and a lack of influence on the design of the products, as a third party reconditioner, were identified as potential barriers to reconditioning. Finally, product diversity and low product quality were identified as barriers. Design barriers were identified within the following categories: durability, the first user, BIOS Password, easy disassembly, cleaning and spare parts. These barriers were reformulated into 21 design for reconditioning recommendations.

KEYWORDS

Reconditioning, Computers, Ecodesign, Circular Economy

1. INTRODUCTION

Through the past three decades, waste electronic and electrical equipment (WEEE) has increased rapidly (Amankwah-Amoah, 2016) and reached an estimated generation of 41.8 MT WEEE in 2014 (Baldé et al., 2015). This is driven by an increasing group of consumers having access to electronic and electrical equipment (Amankwah-Amoah, 2016), but also by the fast technological development and psychological obsolescence (Prakash et al., 2016; Robinson, 2009). Fast technological development and short innovation cycles has led to shorter life spans for certain consumer electronics (Prakash et al., 2016; Robinson, 2009). As an example, the life span of processing units in computers has decreased from 4-6 yeas in 1997 to 2 years in 2007 (Robinson, 2009). Furthermore, consumer electronics are often still functioning, when they are replaced (Prakash et al., 2016). Circular economy is proposed as a framework to reduce the problems with increasing waste generation and resource scarcity (Ghisellini et al., 2016; Stahel, 2013). Various strategies can be applied to increase the circularity of products and materials such as reduction, maintenance, repair, reuse, reconditioning, remanufacturing and recycling see figure 1 (Ellen Macarthur Foundation, 2012; Stahel, 1982). However, the vast majority of consumer electronics are not designed to be maintained, repaired, reuse, reconditioned or remanufactured but are designed for a linear economy (Hatcher et al., 2011). The purpose of this paper is therefore to identify contextual and design barriers when reconditioning computers, and to provide design recommendations on how to overcome these barriers.

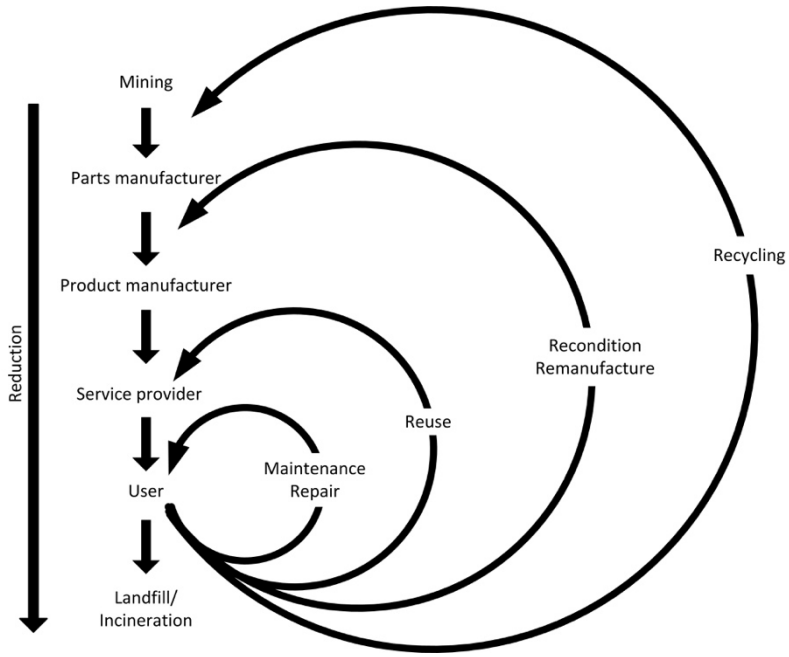

Figure 1: Strategies to close the loops in the circular economy (Bundgaard, 2016).

In this paper, the reconditioning and remanufacturing processes is assumed similar although they vary in extent and degree. Reconditioning and remanufacturing typically include the following processes: sorting, inspection, disassembly, cleaning, reprocessing and reassembly, the replacement of components, and final testing (Hatcher et al., 2011). Reconditioning is defined as the process of returning a used product to a satisfying working condition inferior to its original specifications and with a warranty that is less than a new product (Ijomah et al., 2004; King et al., 2006). All major components that have failed or are on the point of failure are rebuild or replaced (Ijomah et al., 2004; King et al., 2006). Remanufacturing, on the other hand, is the process of returning a product to at least original performance specifications and providing a warranty at least equal to that of a new product (Ijomah et al., 2004; King et al., 2006). Remanufacturing encompasses a total dismantling of the product and restoration and replacement of its components (King et al., 2006: 8)

2. RESEARCH DESIGN AND METHODS

This section introduces the research design and the main methods applied in the study. The study is a single case study of a company reconditioning computers (laptops and desktops) and the main data collection method used was qualitative research interview.

2.1 Case Study Research

Several authors have contributed to the understanding of case study research, including Yin (1984, 1994, 2014), Creswell (2014), and Flyvbjerg (2006). Yin (2014) defines a case study as '*an empirical inquiry that investigates a contemporary phenomenon (the "case") in depth and within its real-world context*' (Yin, 2014), and according to Flyvbjerg (2006) case studies enable an in-depth study of the research object or phenomenon in society on its own term.

Generalisability of a case study can depend on the case selection criteria (Bryman, 2012; Flyvbjerg, 2006). The reconditioning company (and more specifically the reconditioning of computers) was selected as an information-oriented case or more precisely as an extreme or deviant case following Flyvbjerg's (2006) terminology. The aim of an extreme or deviant case is *"to obtain information on unusual cases, which can be especially problematic or especially good in a more*

closely defined sense" (Flyvbjerg, 2006: 230). Reconditioning of computers can be considered an extreme or deviant, because computers are characterised by a high turnover of devices and short innovations cycles (Robinson, 2009). Consequently, the product group can be more difficult or problematic to recondition and resell than for example household washing machines or pumps. Therefore, it could be expected than the design and contextual barriers for reconditioning identified in this case might be more comprehensive than for a less complex product group with slower innovation cycles. However, there are limitations of the case selection. The company reconditioning computers primarily does replacement of components, data deletions and cosmetic changes. Consequently, the design and conditional barriers in relation to repair is not fully illustrated by this case.

2.2 Qualitative Research Interviews

Semi-structured qualitative research interviews were performed with key employees from the different functions in the reconditioning company (for details see table 1). Steiner Kvale's seven stages to conduct an interview was used to plan, carry out and process the interviews (Kvale and Brinkmann, 2015). An interview guide was made specifying the purpose of the interview along with themes and specific questions, but it was possible to deviate freely from the themes and questions. Subsequently, the interviews were transcribed and analysed. The knowledge obtained from the interviews was verified by the Head of Operations of the reconditioning company.

Interviewees	Purpose	Documentation
Two employees from production working with cleaning and changing components	To map their experiences with reconditioning and possible design improvements.	Recorded and transcribed
Employee responsible for the grading of the products	To map his experiences with reconditioning and possible design improvements.	Recorded and transcribed
Employee from service working with the repair of sold products	To map his experiences with reconditioning and possible design improvements.	Recorded and transcribed
Employee responsible from software	To map his experiences with reconditioning and possible design improvements.	Recorded and transcribed
Head of operations	To gain a detailed understanding of the business model and to identify success factors and barriers	Recorded and transcribed

Table 1: Overview of interviews conducted

3. RESULTS OF THE CASE STUDY

This section includes the main findings from the case study. It includes a description of the case company and an account of the contextual barriers and design barriers for reconditioning identified.

3.1 Description of the Case Company

The reconditioning company mainly reconditions used information and communication equipment including desktops, laptops, screens, servers, smartphones, tablets and printers (Head of Operations, 2014). Thus, this case study has focused on desktop and laptop computers. The company reconditions up-to 600 units a day. The company buys the used equipment from larger companies and organisations, as they have equipment of a sufficient quality and quantity (Head of Operations, 2014). The company finds it difficult to have a visible business buying from the consumer market, because the quality is often lower and because they need a certain quantity of the same brands and models to standardise the processes in their operations (Head of Operations, 2014). According to the Head of Operations (2014), they recover around 90% of the products they buy, but the recovery percentage varies depending on the product category. The reconditioning processes include: cleaning, data deletion, performance testing, grading of the equipment, re-installation of

Image and finally customisation of the equipment (see figure 2) (Head of Operations, 2014). Data deletion is part of the company's core business, and they can ensure data deletion without destroying the equipment's reuse potential (Head of Operations, 2014). They only carry out limited repair, as they in the outset only buy functioning products (Head of Operations, 2014). The company provides a 1-2-year warranty, when the product is resold (Head of Operations, 2014). The company sells the products on a broker market, and the equipment is then resold through external retailers (Head of Operations, 2014).

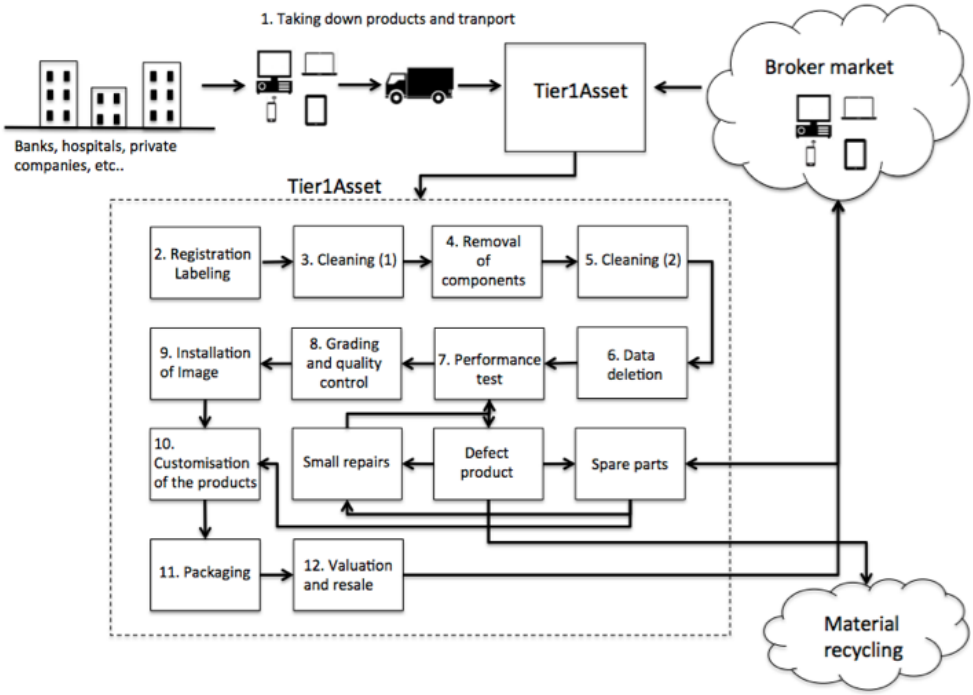

Figure 2: Overview of the processes at the reconditioning company

4.2 Contextual Barriers for Reconditioning

The case study of the reconditioning company revealed barriers for reconditioning of computers related to the system and the structural context in which the company operates. Hereafter referred to as the contextual barriers for reconditioning.

If the buyer of the reconditioned computers lacks trust in the reconditioning company and their products, it can be a barrier for reconditioning (Head of Operations, 2014). The buyer needs to believe that the reconditioned product has a satisfying quality. One of the company's strategies (to ensure customer trust) was the introduction of a grading system (Head of Operations, 2014). The grading system was introduced to ensure a standardised quality, and that the product would live up to the buyer's expectations (Head of Operations, 2014). Another strategy was to become an authorised Microsoft refurbisher (Head of Operations, 2014). If the seller of the used computers lacks trust in the reconditioning company, it can also be a barrier for reconditioning (Head of Operations, 2014). The seller of the used computers needs to trust the reconditioning company, and that they can ensure a safe and secure data deletion. To ensure data security, the reconditioning company uses a standardised and certified software that can secure and document a complete data deletion (Head of Operations, 2014).

Another potential barrier is the costs of repairs or more specifically products that are beyond economic repairs. The reconditioning company buys primarily functioning products, and they only do very limited repairs (Head of Operations, 2014). However, according to an employee from Grading and Technique (2014) the company could, with a few small repairs, get more defect products and components back into the cycle. It would however necessitate a new set-up of the company's facilities. The question is whether it would be a viable business for the company to increase repairs of computers. Economic obsolescence (where the costs of repairs are equal or higher than the costs

of purchasing a new product) is a prevalent problem for consumer electronics (Prakash et al., 2016). As an example, usual failures in laptops are the battery (33%), main board (23%), screen and fan (19%) and graphics card (13%), and the costs of exchanging main boards, processors or graphics chips represent some of the highest costs for laptops (Prakash et al., 2016). Real wages are also high in Denmark, therefore time-consuming repairs may not be viable. According to the Head of Operations, the varying prices on the broker market are also a potential barrier for the company (Head of Operations, 2014).

Another barrier is a result of the company being an independent third party reconditioning company, which implies that they have no influence on the product design. In literature, there is little evidence that reconditioning or remanufacturing is considered during the design processes (Hatcher et al., 2014). Furthermore, the reconditioning company was no control of the supply of products, which is mainly controlled by the OEMs and the seller of the used computers.

The reconditioning company needs a certain quantity and quality of the used computers they buy to have a viable business (Head of Operations, 2014). It implies that the company primarily buys high-end computers and mainly from larger companies and organisations, as they can provide a larger quantity of similar products with a sufficient quality (Head of Operations, 2014). This is a barrier for utilising the reconditioning potential of used equipment from the consumer market.

4.3 Design Barriers for Reconditioning

With outset in the interviews with employees from the different operations at the reconditioning company several design barriers for reconditioning were identified. These design barriers are then reformulated into design recommendations in table 2.

ICT equipment is typically less *durable* and less technically stable compared to other product categories such as pumps, medical equipment and office equipment (Hatcher et al. 2014), and it can be a barrier for reconditioning. Therefore, the reconditioning company primarily buys used high-end computers with a longer-projected lifespan. Another potential barrier for the reconditioning potential is the physical appearance of the computer (Employee from Cleaning, 2014). Therefore, the computers' surface should be resistant to scratches and bumps. The *first user* can also be a potential barrier for reconditioning, if the product is not treated and maintained correctly (Head of Operations, 2014). The user of the products should therefore have information on how to keep and maintain the computer.

A barrier for reconditioning of computers (especially laptops) is the increased use of *BIOS passwords* to deactivate different computer functions or the entire computer (Employee from Grading and Technique, 2014; Employees from Software, 2014). If the seller of the used computers does not provide the BIOS password and some functions are deactivated, the computer must be sold without the deactivated functions. If the entire system is locked by a BIOS password, then the computer can only be used for spare parts (Employees from Software, 2014). According to the Employee from Software (2014), 80% of the equipment they discarded are due to the use of BIOS Passwords.

Another potential barrier for reconditioning, is that it can be difficult to *disassemble* the product and thereby allowing for the different reconditioning processes to be carried out (Employee from Cleaning, 2014; Employee from Grading and Technique, 2014; Employee from Repair and Service, 2014). It is especially relevant for components, which are often changed during reconditioning such as: keyboards, RAM modules, processors, graphics cards, batteries, palm rests and covers. Screws and many different types of screws were also highlighted as a potential barrier whereas a robust click system made the disassembly easier (Employee from Cleaning, 2014; Employee from Repair and Service, 2014). Another design challenges is that it can be difficult to intuitively understand how to disassemble computers and that there is a large variation between brands and models (Employee from Cleaning, 2014). Therefore, the disassembly and removal of certain components could be made more self-explanatory and standardised.

A barrier for reconditioning is also the use of safety and security tags for anti-theft protection (Employee from Cleaning, 2014). The safety and security tags are difficult and time consuming to

remove and can also leave permanent marks on the computer decreasing the value of the computer (Employee from Cleaning, 2014). *Cleaning* of the computers can also be difficult, if there are many nooks and corners that are difficult to access (Employee from Cleaning, 2014). It is also important to ensure a product design, where it is possible to remove dust inside the computer using air pressure (Employee from Cleaning, 2014). Consequently, it is important to avoid product design that are difficult to clean, and where dirt and dust and gather and be difficult to remove. Spare part availability is not currently an issue for the reconditioning company, as they generally have access to the needed spare-parts (Head of Operations, 2014). However, it is important to ensure easy access to spare-parts. Furthermore, even though certain components are standardised there is still an improvement potential especially when it comes to power plugs (Employee from Grading and Technique, 2014; Employee from Repair and Service, 2014; Employees from Software, 2014; Head of Operations, 2014).

	Design for Reconditioning Recommendations
Durability	(1) Design products of high quality with a long lifespan.
	(2) Use materials for the casing that are resistant to scratches and bumps.
User	(3) Provide the user with information on best use and maintenance of the equipment.
BIOS Password	(4) Limit the use of BIOS passwords.
	(5) Make BIOS passwords available to the reconditioner.
	(6) Producers could provide a software that can reset the BIOS password.
Easy disassembly	(7) Make it easier to disassemble the product.
	(8) Make it easy to remove and replace components such as keyboards, RAM modules, processors, graphics cards, batteries, palm rests, screens and co-vers to ensure that it is possible to upgrade, customise and repair the product
	(9) Make disassembly intuitive; ensure self-explanatory structures or provide instructions for the repair, customisation and updating of the product.
	(10) Reduce or avoid screws and use the same types of screw.
	(11) Where possible, use robust click systems that can be separated and reassembled several times.
	(12) Use modular design.
Cleaning	(13) Where possible, avoid safety and security tags and other labels.
	(14) Use safety and security tags and other labels that can be removed without leaving a permanent mark; in particular, avoid tags that are corroded or burned into the product. Place the marks in a less visible place, e.g. on the back of the product.
	(15) Make the surfaces easy to clean.
	(16) Avoid a design where dust and dirt can gather and be difficult to remove.
	(17) Make it easy to remove dust e.g. by easy access to central parts in the desktop and laptop.
	(18) Easy disassembly of the desktop's sides.
Spare parts	(19) Have spare parts available for an extended period.
	(20) Use standardised components.
	(21) Standardise power plugs.

Table 2: Overview of design for reconditioning recommendations

4. CONCLUSIONS

The case study of the contextual and design barriers identified when reconditioning computers indicate that trust from the buyer and the seller of the used computers is important for a viable business. If this trust is not in place, it can be a potential barrier. Another potential contextual barrier for reconditioning of computers is economic obsolescence more specifically that the cost of repairing the computer can be equal or higher than the cost of buying a new. Furthermore, the fact that the

reconditioning company is an independent third party reconditioner implies they have no influence on the design of the products and often the products are not designed to be reconditioned or remanufactured. The reconditioning company also needs a certain quantity to be able to standardise their processes and have a viable business. Hence, product diversity and short innovation cycles is a barrier for utilising the computers from the consumer market. Finally, the reconditioner needs a certain quality and mainly reconditions high-end computers. Therefore, low product quality can be a barrier for reconditioning.

Design barriers were also identified for reconditioning computers within the categories: durability, user, BIOS password, easy disassembly, cleaning and spare parts and these barriers were reformulated into design for reconditioning recommendations. In total 21 design recommendations were identified. A number of these design recommendations can also be found in existing eco-design design guidelines such Ecodesign Pilot (Institute for Engineering Design, n.d.) and the ECMA Standard (ECMA, 2004). However, some of the design for reconditioning recommendations were more detailed and new compared to existing ecodesign guidelines.

The case study was selected as an extreme or deviant case, because reconditioning of computers can be considered as more difficult due to the fast innovation cycles. Therefore, the barriers identified in the case are expected to be more comprehensive compared to products that are less prone to obsolescence. Thus, the fact that the reconditioning company conducts limited repairs implies that design and contextual barriers in relation to repair is not fully elucidated by the case study.

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