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Repair of electr(on)ic products: current practices in Barcelona

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Abstract

In the past years, the need for more durable and repairable products has progressively increased. The 2020 Circular Economy Action Plan includes some actions to develop legislative and non-legislative measures for the "right to repair". Implementing measures to favour repair are limited and not uniformly included in EU ecodesign regulations which denotes the need to advance in a more systematic analysis of repair and repairability of electr(on)ics. This paper revises methods for assessing repair and reparability of electr(on)ics. The analysis has allowed to identify opportunities to investigate further the feasibility to use the EN 45554, and the eDIM methods. The results obtained from the analysis of tertiary coffee machines has help identify design features to facilitate their repair and remanufacturing. Regular maintenance and material selection resulted to be potential key aspects to maximize the durability of some of their priority parts. The analysis of small household electr(on)ics shows that in general about 50% of the products taken to repair events were successfully repaired. One third of the products were hard or impossible to disassembly due to the use of connectors such as glue and single snap fits, while the remaining products were sent to recycling. Previous information and knowledge about the electr(on)ic was crucial to facilitate the repair, and also to assess repairability. Few suggestions to improve the quality of data collected during the events were proposed and successfully implemented in an on-line survey. Despite the efforts done on standardisation, the results show some still existing limitations to apply the proposed methods to electr(on)ics.

Keywords: circular economy; repairability; electronics, e-waste prevention; design for disassembly; ecodesign

1. Introduction

Repair is one of the proposed strategies, together with reuse, remanufacture and refurbishment to reduce the amount of electronic waste, a waste stream increasing at an annual rate of 2% worldwide [1, 2]. The 2020 EU Circular Economy Action Plan (CEAP) proposes several actions oriented to manufacturers as well as to consumers to improve the current environmental performance of electr(on)ics commercialised in Europe. In fact, electronics and Information, Communication and Technology (ICT) products are presented as key sector to improve towards a circular economy [3]. Some of the actions targeting manufacturers include the circular electronics initiative, the common charger solution, and the development of a reward system to return old electronic devices. It also includes a review of the directive on the restriction of the use certain hazardous substances in electrical and electronic equipment (2011/65/EU), and guidance to improve coherence of relevant legislation with the REACH regulation (EC/1907/2006) and ecodesign regulations. From the consumer's perspective, it comprises the development of legislative and non-legislative measures establishing a new "right to repair" and a legislative proposal empowering consumer in the green transition [3]. Aligned to these measures, some EU Member States are working to provide repairability

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information to consumers. For instance, the French government has recently published a national repairability score for five electr(on)ic products: smartphones, laptops, televisions, washing machines and lawnmowers [4]. The Spanish government also announced that EEE will be labelled depending on their repairability in the future [5].

The 'Right to repair' movement has gained momentum since the first Repair Café in Amsterdam in 2009. More and more repair community workshop addressed to citizens to support the repair of electronic devices they own without any manufacturer or technical restrictions. The outcomes of some of these workshops show that the main limitations to repair in such contexts are the use of design features impeding accessibility, a higher economic cost of spare parts compared to the cost of purchasing a new brand equipment and the unavailability of spare parts [6, 7, 8, 9]. Some 'Right to Repair' organizations are providing their expertise to governments to include in legislation more repairable measures in future products [8]. A study showed also that many consumers would be willing to pay a 10% more for products with better durability and repairability [10].

Although repair and repairability are used indifferently many times, they have different meanings. Repair is defined as "*the process of returning a faulty product to a condition where it can fulfill its intended use"* [11] while repairability is "*the measure of the ease of performing the actions to restore the failure items*" [12]. To monitor repairability along with other material efficiency aspects, the EU standard organizations CEN and CENELEC developed eight new standards that include methods for evaluation.

This paper focuses on the analysis of repair and repairability of two typologies of products: business-to-business (B2B) products and business-to-consumer (B2C) products. The first objective is to understand the type of data related to repair generated for both typologies of products. The second objective is to assess the repairability of the electronics using as a guideline the EN45554 standard 'General Methods for the Assessment of the Ability to Repair, Reuse and Upgrade Energy-related Products' [13]. The second section of this paper includes the methodology used to analyse the two typologies of products and illustrates how repair and repairability can be assessed. The results include some relevant information obtained from the analysis of repair data available as well as some indications of potential design improvement opportunities determined from the repairability assessment. The paper concludes with a general overview of the importance of having in place standards such as EN 45554, a short discussion about its applicability to B2B and B2C products, and the possible steps to promote more circular products.

Nomenclature

B2B	Business-to-business
B2C	Business-to-consumer el
CEAP	Circular Economy Action Plan
CEN	Comité Européen de Normalisation
CENELEC	Comité Européen de Normalisation Electrotechnique
HORECA	Hotels, restaurants, and catering sector
ICT	Information, Communication and Technology
NGO	non-government organization
SME	small and medium enterprise
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals

2. Methodology

The methodology for the analysis included three main steps as shown in Figure 1: the definition of the case study, the analysis of current repair data and the assessment of the repairability of two typologies of products. In the first step, the definition of the case study included the selection of two organizations involved in the repair process of elect(on)ics. In this paper, one organization per typology of product was selected. For the B2B case study, a tertiary coffee machine manufacturer addressed to hotels, restaurants, and catering sector (HORECA) was selected. This company offers an official after-sales repair service, which is carried out by specialized industrial repair technicians. For the B2C case study, the voluntary organization 'Restarters Barcelona', part of the international The Restart project was approached. This organisation promotes repair events called Restart Parties, where a team of multi- skilled volunteers share their expertise and knowledge in repairing unfunctional electronic devices.

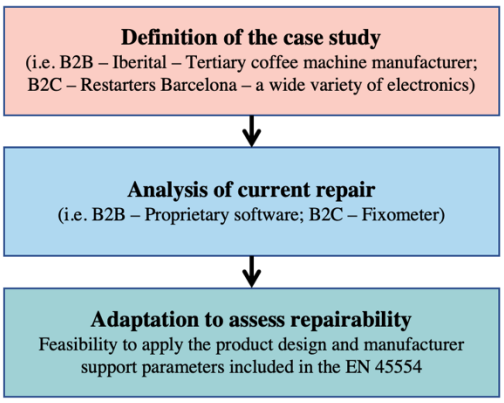

Fig.1. Methodology to analyse the repair and repairability of electr(on)ics.

In the second step, the repair process and the available repair data were analysed for each case study separately. For the B2B case study, an internal technical service management software was used to register all the repair operations, including the most frequently replaced parts of each tertiary coffee machine. Such information has been proved useful to help determine the priority parts of tertiary coffee machines. For the B2C case study, Restarters Barcelona collects all the repair data in an online database called Fixometer created and managed by The Restarters Project. Data, available from 2015 onwards, were useful to identify the most frequent devices in repair events and their status after the repair party: repaired, repairable, and end-of-life products.

In the third step, the EN 45554 standard 'General Methods for the Assessment of the Ability to Repair, Reuse and Upgrade Energy-related Products' published by

CEN/CENELEC [13] was adapted and applied to assess repairability in both case studies. According to EN 45554, products are assessed based on the priority parts, the identification of relevant criteria (divided in product design parameters and manufacturer's support parameters) and finally, a classification score for each category and priority part. A priority part is determined considering their functional importance as well as the frequency of failure [13]. This study focused on product design parameters to identify barriers and opportunities to improve the repairability of products. The following table (Table 1) presents the different parameters included in the EN 45554 that were taken into consideration in our study, and their relevance according to Cordella et al. (2019).

Table 1. Parameters included in the EN 45554 'General Methods for the Assessment of the Ability to Repair, Reuse and Upgrade Energy-related Products' and their relevance according to Cordella et al. (2019).

Parameters included in the EN 45554 standard	Parameters and their relevance (red= high, orange=medium, green=low)
Product related parameters	Time for disassembly
	Disassembly sequence/depth
	Fasteners and connectors
	Tools
	Skill level
	Working environment
Support related parameters	Diagnostic support and interfaces
	Type and availability of information (manuals, schemes)
	Availability of spare parts

3. Results

3.1. Analysis of the B2B product: the case of tertiary coffee machines

The analysis of the B2B product was performed in collaboration with Iberital, a European small and medium enterprise (SME) specialized in the manufacturing of professional coffee machines, categorized in the tertiary coffee machines group. Generally, coffee roasters (coffee suppliers) purchase and distribute coffee machines to the HORECA businesses. In general, the internal design of the two professional coffee machines models analysed was highly standardized being their disassembly possible with standard tools. Thus, repair and remanufacture were common practices in professional coffee machines. This is also because coffee roasters aim to maximize their useful lifetime to pay off the cost of purchase. When failure occurs, coffee roasters generally contact the official manufacturer's after-sales service. Then, information is systematically registered in the SAT management software, including the most frequently replaced parts. Such information together with the expertise of an official repairer helped determine the list of priority parts, the first step of EN 45554 standard to assess repairability.

Table 2 shows the priority parts identified, classified as functional and worn parts. They are displayed from higher to lower replacement rate and with a short description of the disassembly depth. Regarding the functional parts, there were four out of the nine priority parts with high replacement rate. These parts are the pressure switch, the group solenoid valve, the tubular filter of the coffee group and the pump, all highlighted in orange in Table 2. There was only one priority worn part with very high replacement rate. Another parameter to include in EN 45554 to assess repairability is the disassembly depth, thus the number of steps necessary to remove a priority part. This can be estimated following the procedure established in the eDIM method [14]. According to eDIM, a step finishes with the removal of a part, and/or with the change of tool. All the priority functional parts with high replacement rate needed a maximum of 8 to 10 steps for their disassembly.Of all the worn parts, the steam/water knobs level needed double the steps that the other three priority parts.

Table 2. Priority parts identified of tertiary coffee machines.

	Priority parts	Replacement rate	Disassembly depth
Functional parts	Pressure switch	High	8-10
	Group solenoid valve	High	8
	Tubular filter (group)	High	4-8
	Pump	High	7-9
	Vacuum valve	Medium	6
	Charge solenoid valve	Medium	7-9
	Motherboard	Low	6
	Resistance	Low	6
	Boiler	Low	N/A
Worn parts	Portafilter joint	Very high	1-2
	Steam/water knobs/lever	Medium	7-9
	Float cap (water tap)	Medium	3
	Touch pad	Medium	N/A

*Parts specially affected by unfiltered hard water (greater than 121 ppm mineral concentration). It reduces the durability of parts, and therefore, replacement frequency increases.

From the repairability assessment, two possible design improvement opportunities were identified. For the disassembly of one model of coffee machine, the frontal cover required two additional steps to reach the group solenoid valve. Similarly, for the second model of the coffee machine, an extra step was needed to access the pressure switch or the vacuum valve. The redesign of the external cover could minimise the numberof steps for disassembly and facilitate repair. Additionally, according to one of the repair experts consulted, the use of a water filter will potentially reduce the replacement rate of parts in contact with water during the use phase as for example the boiler or the resistance. In addition, the selection of materials also affects the lifespan of the coffee machines and the feasibility of maintenance and refurbish them. For instance, boilers made of copper are more easily corroded and thus discarded, compared to stainless steel boilers. Figure 1 illustrates the effect of hard water in the copper boiler of a coffee machine after nine years of use.

Fig. 2. Copper boiler and the effect of corrosion due to hard water

This case study was also useful to investigate the adaptation of the method presented in EN 45554 standard to assess the repairability of coffee machines. The product-specific assessment method presented was mostly possible to follow as the access to the manufacturer's information was granted. The information about the product allows evaluating all the product design related parameters, including the disassembly depth. On the other hand, the eDIM method also in the standard was proved to be helpful at defining the number of steps. One existing limitation was that the operation descriptions and time for disassembly are not appropriate for the assessment of professional coffee machines and other large appliances [14]. Overall, the EN 45554 resulted to be a useful guide to assess the repairability as well as to identify design improvement opportunities. Additionally, the importance of manufacturers and other product stakeholders to generate and share information about their products such as priority parts is highlighted.

3.2. *Analysis of the B2C product: the case of small electr(on)ic equipment*

The analysis of B2C products was developed in collaboration with Restarters Barcelona, a local entity promoting the repair of electronics in different neighbourhoods of Barcelona. Since 2015, Restarters Barcelona has organized more than 60 repair events (Restarts Parties), with an attendance of more than 420 citizens. According to their internal results, they have contributed to the prevention of 547 kg of e-waste and avoided6,768 kg of carbon dioxide emissions [15]. During the Restart Parties, a team of skilled volunteers help participants to identifythe failure of their products and fix them whenever possible. Also, volunteer organizers collect information about theproduct and its repair in a physical whiteboard. This information is later updated in the online database called Fixometer, which include the following descriptors: the product category (36 categories are defined), brand, model, and age, three repair status (fixed, repairable and end-of-life) and the description of the problem/solution (optionally added in free text format). Recently, the Open Repair Alliance, an international group of community repair organizations such as The Restart Project, proposed also to include other additional descriptiors for products classified as at end-of-life status. These include spare parts too expensive, no way to open the product, repair information not available and lack of tools. The objective is to generate knowledge about the repair barriers repair events face.

Restarters Barcelona provided the available data collected since 2015 about 430 different small household products. These data were examined to get an idea of the typology of products in repair events as well as those with higher/lower repair success. The principal product categories, representing more than half of the products and represented in Figure 3 were miscellaneous (15%), followed by small kitchen items (14%), laptops (9%), mobile phones (8%) and portable radios (6%). In addition, from the 430 products, 50% were successfully repaired, of which just a 7% required a spare part. A 32% were considered repairable and the remaining 18% end-of-life. From the categories presented, portable radios represented the category with higher repair success (67% fixed), while mobile phones have the lowest repair success (28%).

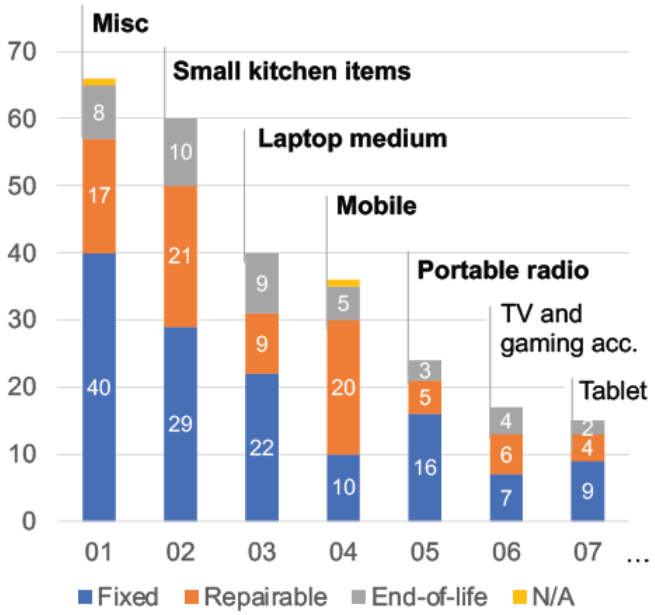

Fig. 3. Example of the quantity of electronics fixed, repairable and sent to recycling (end-of-life) in restart parties organised by Restarters Barcelona from 2015-2020.

This preliminary analysis together with the participation in some repair events allowed to identify some potential improvements in data collection. One of them is the collection of data in a digital form during the repair events. Another potential improvement is adding specific information about repairability as for example the accessibility to damaged parts. Some of the parameters included in the standard EN 45554 were adapted in a new on-line questionnaire that was tested in several Restart Parties and a total of 19 household appliances.

The previous knowledge of the products assessed is more limited compared to the coffee machines case study and other B2B products. As result, the repairability parameters are defined in a more general manner for all product categories as specifications for each product group was almost impossible. Special consideration was made to parameters related to product design, as information from manufacturers

such as the availability of spare parts or information about repair is rarely available in repair events.

Table 3 shows the parameters included for the repairability assessment and results obtained. The results are representative for the following product shares: 58% kitchen and small household items, 21% home entertainment products, 16% electronic gadgets and 5% computers and home office devices.

Regarding the outcomes related with design, almost 60% of the products use reusable fasteners while 28% of them had snap fits, adhesives or glues to fasten parts and components, which made disassembly more difficult and increase the risk of damaging the product. For the remaining 14%, accessing the damaged part was not possible. Over 80% of the products were disassembled using standard tools. The remaining 20% required specialised tools or were not possible to disassemble. For example, a snake eye screwdriver was needed to open a domestic coffee machine. Regarding the disassembly depth, half of products require a proportional number of steps, about 30% needed more steps than expected and 20% could not be disassembled. In relation to the time spent to repair, only 11% of the products was performed in a maximum of 15 minutes.

Table 3. Product design parameters adapted from EN 45554 and included in the on-line questionnaire.

Product design parameters adapted from EN 45554	Description	Results
Fasteners and connectors	Reusable (metallic screws)	58%
	Removable (single snap-fits, adhesives, glue)	28%
	Neither reusable nor removable	14%
Necessary tools	Basic/standard	81%
	Specialized tool	7%
	Proprietary tool	0%
	Not feasible with any tool	11%
Disassembly depth	Proportional nº of steps	51%
	More nº of steps than expected	15%
	Much more steps than expected	14%
	Impossible to access to damaged part	20%
Time spent	15min max.	11%
	15-30 min	50%
	30 min	22%
	More than 30 min	17%

In total, 50% of the products were successfully fixed, 40% repairable and only 10% sent to recycling. The on-line questionnaire resulted a useful mechanism to obtain more detailed data from the repair events, and will be further used in future repair events. Also, it is an interesting place to generate knowledge about the design practices adopted by manufacturers and to identify design opportunities to make more repairable products. One interesting outcome is the feasibility of adopting product related parameters of the EN 45554 for the repairability assessment performed by a community repair organization.

4. Conclusions

When assessing new circular business models, it is important to differentiate between repair and repairability. While repair focuses on failure and the procedures needed to fix the product and give back its functionalities, repairability refers to a more in-depth study where the productsis assessed from a broader perspective, and not only considering the most critical parts. Repairability assessments, as seen in this study, allow identify key design aspects to improve the ability of products to be repaired. It can also be considered a preventive strategy that can contribute to the reduction of e-waste generation by extending the lifetime ofproducts.

The development of standards such as the EN 45554 and their applicability to B2B and B2C products are necessary to define indicators and promote more repairable products. This will contribute to engage manufacturers and citizens in the debate towards more circular products. Nevertheless, as illustrated in this paper, an effort to further adapt these methods to a wider range of products is still in order. In addition to the availability of standards, defining new repairability scoring systems in products could be an effective mechanism to promote a repair culture and raise awareness to consumers about the efforts currently done to improve the environmental performance of electr(on)ics.

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