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Developing Repairability Criteria for Energy Related Products

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Abstract: Repairing modern electrical and electronic equipment is becoming increasingly difficult. The encountered challenges significantly contribute to the costs associated with repair, making direct replacement of a product often the most straightforward option for the consumer. Therefore, the Benelux Union has requested a study to investigate extending product life time by exploring repairability criteria for products. The overall aim of the proposed repairability criteria is to evaluate and, if possible, quantify the ease of repair for energy-related products (ErPs) considering the economic impact from a consumer perspective.

Introduction

As a consequence of our current throw-away society and the current lack of incentives for manufacturers to apply eco-design to their products, consumer goods are nowadays less durable and repairable than in the past. Research has shown that the average product lifetime of many products is decreasing (Bakker et al, 2014). Repairing modern electrical and electronic equipment is becoming increasingly difficult. There is a lack of appropriate repair information available and there is limited access to affordable spare parts for consumers. Additionally, rapid change of product design makes it more difficult to repair. Finally, the difficulty to non-destructively disassemble products for repair is increasing due to the more intensive application of snap-fits and adhesives.
These encountered challenges significantly contribute to the costs associated with repair, making direct replacement of a product often the most straightforward option for the consumer. Therefore, the Benelux Union has requested a study to investigate extending product life time by exploring repairability criteria for products. This research supports ongoing European standardization processes at CEN-CENELEC and research on repairability of products performed at the European Joint Research Centre (JRC).
The overall aim of this study is to evaluate and, if possible, quantify the ease of repair for energy-related products (ErPs) considering the economic impact from a consumer perspective.

In order to meet this objective, repairability criteria for ErPs are proposed. The focus of current study is repair and reuse from a consumer perspective. Many manufacturers are considering shifting their business model from selling product to selling services. In the case of product service systems, repairs usually take place in an industrial environment and are called remanufacture. In this case, the developed repairability criteria may still be useful to identify potential improvement opportunities to increase the ease of repair.
Repair activities are conducted in different ways. It can be done by the manufacturer's or retailer's after sales service (in house), it can be done by professional repairs under contract with manufacturers (outsourced), it can be done by a repair company (independent professional repair) or it can be done by the customer (self-repair). Depending on the repair route, different challenges will arise and this must be taken into account when assessing the repairability of products.

Background study

A background study has been carried out to identify existing initiatives or standards that already include a number of repairability criteria. The research focuses on scoring schemes applied in Europe and publically available information.
Qualitative evaluation methods generally consist of a number of criteria that need to be

Figure 1. Overview of existing initiative that include repairability criteria.

fulfilled in order to obtain a label, such as Blue Angel (https://www.blauer-engel.de/en), Nordic Label (http://www.nordic-ecolabel.org/) or European eco-label (http://ec.europa.eu/-environment/ecolabel/index_en.htm). These existing initiatives aim to evaluate the environmental performance of products. A number of qualitative criteria related to repair were identified such as the provision of disassembly instructions, ease of disassembly, required tools, use of standardized connections and supply of spare parts.

Semi-quantitative evaluation methods assign a weight to each criteria and sum up these weighted criteria which results in a "repairability score" for the product. The iFIXIT score card is such a semi-quantitative method that has been developed to evaluate the ease of repair for ICT products (https://www.ifixit.com/). Another example is the Austrian Technical Rules ONR 192 102:2014 that can be applied to both large household equipment (white goods) and small electric and electronic equipment (brown goods) (ONR, 2014).

Quantitative methods use measurable data to calculate a reusability index or metric. For example, the Ease of Disassembly method (eDIM) calculates the required disassembly and reassembly time (Vanegas et al, 2016), which can also be used to assess the repairability since disassembly and reassembly activities are an important part of the repair process.

Existing criteria review

In this section, the different identified reparability criteria are discussed per topic: information provision, product design and service delivery.

Information provision

The provision of adequate maintenance or servicing guidance can avoid premature failure and contribute to a longer product or component life time. Therefore some scoring and labelling scheme, such as the Austrian ONR 192 102:2014 and the Nordic Swan label, include requirements related to regular maintenance guidance.

Manufacturers usually only provide detailed information and access to relevant fault diagnosis software to selected repair service providers under contract. In order to enhance product reparability, fault diagnosis software and/or hardware should also be publically available where relevant. Unfortunately, only the Austrian ONR 192 102:2014 includes aspect related to failure/fault identification.

To effectively extend the life time of products, access to repair service information for all independent reuse and repair centers of the after-sales service is considered to be crucial. Some scoring or labelling schemes even specify that this information should be free-of-charge and available to all repair services (including those not under manufacturer's contract). However, the (minimal) content of 'repair and disassembly' instruction/information is generally not provided.

Product design requirements

Many reparability criteria are related to the product design and most of them highlight the importance of design for disassembly. Some other items such as upgradability of software driven parts and the prioritization of specific parts for partial disassembly are also discussed below. Criteria related to durability tests are important to further extend product's lifetime but they are not further discussed here because their overall goal is to avoid the need for repair activities.

Upgradability

All reviewed qualitative checklist based initiatives include requirements related to upgradability, typically for software driven

devices such as computers. The iFixit reparability score card includes a criteria for upgradable RAM and storage drives for laptops.

Ease of disassembly evaluation

The ease of disassembly to facilitate repair of priority parts is key to enhance 'reparability' of products. Different sources of difficulty in performing dismantling tasks have been identified and reparability criteria have been developed to address those difficulties.The eDIM method takes most of these into consideration including: tool type, number and type of connection and accessibility. The amount of force required is considered for connection based on adhesive and modularity is partially included in the eDIM method as this can reduce the number of disassembly steps required for partial disassembly targeting a specific component. However, the requirement to use standardized design or limitation on the required skills are not included in the eDIM method.

Prioritization of specific parts

Critical parts are identified for specific product groups such as screen and battery for phones or HHD/SSD, RAM, screen, keyboard and cooling fan for computers. However no systematic method is proposed to identify the priority parts.

Service delivery

Availability of spare parts

The reparability of products is often constrained by the unavailability of spare parts for critical components. Therefore the availability of replacement parts is required for a certain period of time after the last component batch production. The length included in the different criteria vary and depend on the product group. Typically 5 years is proposed for brown goods and 10 years for white goods. Unfortunately none of the reviewed criteria include specification on the cost of spare part.

Extension of warranty period

Currently, under the Consumer Rights Directive (2011/83/EC), the final seller is liable for a product during a period of 2 years. However, the burden of proof that there was a defect at the time of the purchase lies with the consumer after the first 6 months. The Nordic Swan and EU ecolabel require an additional year of warranty without additional cost for the consumer.

New criteria development

In this section repairability criteria are proposed. The developed method is a semi-quantitative method. A general framework has been developed that provides a clear and meaningful structure for each repairability criteria according to the criteria type and the related repair step.

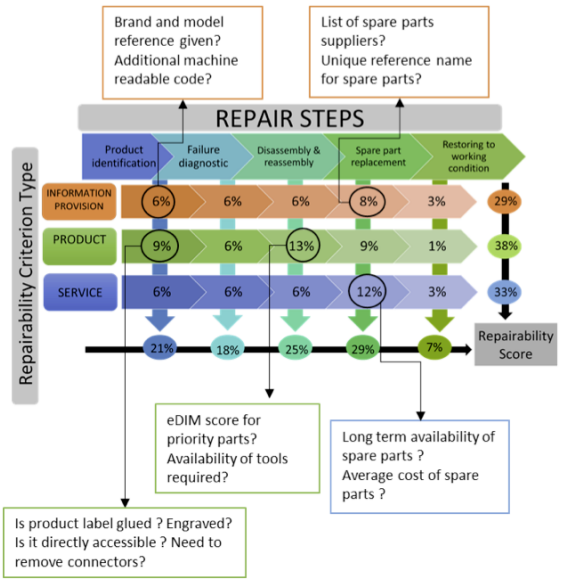


Figure 2. Repairability assessment methodology.

In total 24 criteria are proposed and each of them receive a score depending on the selected option. The different options for each criterium are described in detail and, where possible, measurable data is used. Criteria have been defined related to information provision, such as explanation of error codes, disassembly instructions or spare parts references. Other criteria assess the product design for repair, such as ease of disassembly or individual replacement of priority parts. One of the criteria, related to ease of disassembly, is based on the quantitative eDIM evaluation. Finally, there are also criteria that assess the offered repair services of the manufacturer during the use phase of the product. Although the developed criteria focus on the technical feasibility of repair, for some criteria, such as access to spare parts and repair services, the related cost has been taken into account.

Overall the weights for the generic assessment tool are quite evenly distributed, with some more emphasis on product design. Depending on the product type, the weights of the criteria can be adapted. A number of parameters has to be defined at product group level such as:

- Reference value for the disassembly metric (eDIM)
- Common failure modes
- Level of detail of provided information
- Average expected product lifetime
- Relative cost and availability of spare parts

Some criteria are dependent of the targeted priority parts. Before the start of the repairability assessment a list of priority parts should be compiled, if not already available for the relevant product group. Priority parts are independent of current difficulties to be replaced or repaired, hence the priority parts should be identified taking into account functional criticality and most frequent failure modes or misuses of products.

Application of the developed method

The developed criteria are applied in specific case studies for washing machines and vacuum cleaners. For each case study, first the selected product group is defined and characterized, the assessed product model is briefly described and, finally, the repairability criteria are applied and the selected options are justified. The main results of the case studies are summarized in Table 1.

In all cases the repairability score for a professional repairer is higher than for a consumer, partly because of the limited information that is available for consumers. For the vacuum cleaners, the accessibility of spare parts is also better for professional repairers compared to consumers.

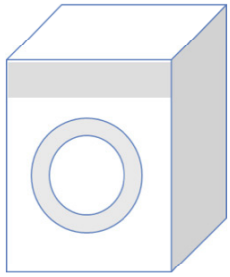
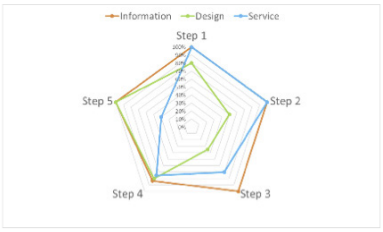
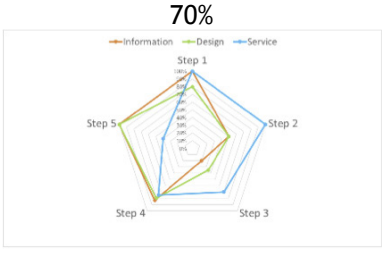
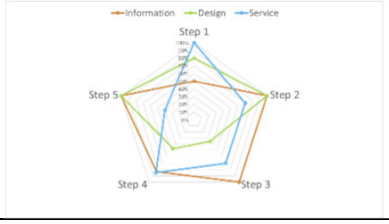
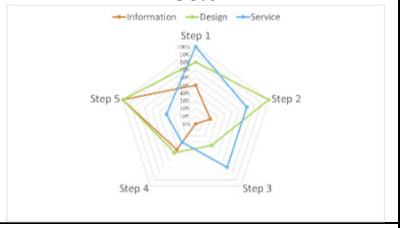
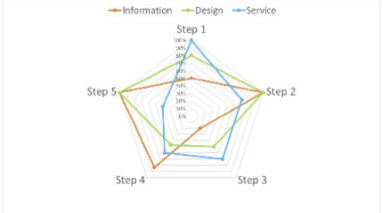
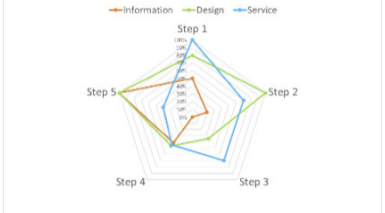
Product model	Repairability score for professional repairers	Repairability score for consumers
	77% 	70% 
	74% 	53% 
	68% 	55% 

Table 1. Case study results for applying the development repairability method.

Challenges and next steps

Some challenges have been identified when applying the developed method. These challenges need to be further explored to refine and improve the current proposed repairability criteria.

An important challenge is the identification of priority parts and failure modes. The focus of the evaluation should remain limited to the priority parts because most common product failures can be traced back to a number of specific parts. However, because all components can fail, a cut off rule needs to be

defined. The cut-off can be defined as minimum number of parts (e.g. top 5 most likely to fail components) or it could be set to cover a minimum percentage of likely failures (e.g. 75% of failures). Furthermore, within a specific product group, an identified priority part may not be relevant to all product models, such as carbon brushes for washing machines. As products are continuously developed, the number and type of priority parts may change over time.

The availability of spare parts from third parties is not straightforward to take into account. First, manufacturers are not responsible and cannot control further distribution downstream of (original) spare parts. Second, the compatibility and quality of the spare parts are difficult to verify. Another difficulty is to deal with priority parts that are covered by an extended warranty.

Another challenge that was faced during the case studies is the distinction between maintenance, repair and upgrade. At the start of the project, the aim was to clearly separate between these different actions as maintenance aims to avoid repair and because upgrading provides a product with a slightly different function or capacity. In practice however maintenance instruction provided to users may also serve for repair (e.g. cleaning of a filter). Also in consumer surveys, filters were often regarded as failure requiring repair while this is considered to be part of regular maintenance by manufacturers.

In general, devices are becoming increasingly complex as they include more electronic components. The fact that there are more (electronic) components in a product will increase the likelihood of a failure occurring during the lifetime of the product. In order to achieve increased material efficiency through extended product lifetime with repair, it will not be sufficient to request more repairable products from manufacturers, also consumers should be aware that less complex products will typically be more robust. The consumer should only choose products with specific features if this is relevant for his intended use.

Further research is needed to confirm the correlation between the single score obtained with the proposed repairability method and the ease of repair in real life. In the meanwhile, a number of specific items could be selected to better inform consumers. For example the possibility to replace or upgrade priority parts, the ease of disassembly expressed in time with the eDIM metric or the maintenance and repair service offered during the use of the product.

To reduce subjectivity of the results, the repair evaluation should include as much as possible measurable parameters. Sub-aggregated results that take the interdependencies of criteria into account are useful to facilitate the interpretation of the final repairability score. Finally, the repair evaluation method should be tailored to specific product categories and weights should be assigned that reflect the relative importance of each criteria.

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