Methodology to Assess the Circularity of Product Design for Mobile Electronics

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Abstract

Circular product design refers to different design measures which aim to extend the use time of products and components for as long as possible, thereby preserving materials and minimising environmental impacts over the whole product life cycle.

The objective of this research was to develop method to assess the circularity of product designs of mobile electronic products (such as smartphones, tablets, etc.) and will guide the user towards a circular product. This method was integrated into a web-tool that is simple in its application, is widely applicable to assess and evaluate mobile electronic products, and determines strengths and weaknesses of the product design.

1. Introduction

The main objective of this work is to develop an assessment method that is able to assess the suitability of electronic products for a circular economy (CE) model. This method serves as the basis for a web tool D4R pilot (Quelle, URL) similar to the well-known Ecodesign Pilot (Quelle, URL). The focus in this work is on electronic devices like smartphones and tablets. The "D4" from the acronym D4R-Pilot, stands for "Designed for". The "R" has several meanings and stands for the basic End-of-Life strategies, which among other things form the basis for a CE model. These basic strategies are "Repair", "Reuse", "Remanufacturing" and "Recycling". The fulfilment of these strategies are the foundations for the suitability of a CE-compatible product.

2. Method

In order to assess product designs first of all it was necessary to distinctly define the so-called “D4R strategies” (Repair, Reuse, Remanufacturing and Recycling) based on academic literature and standards [1], [2]. Although there is a long history of D4R strategies, there is significant change in the product technologies, which needs to be considered, but also some innovative developments in 4R processes, such as robotics for disassembly. Secondly, a criteria catalogue, with a set of specific design measures related to the 4Rs and specifically relevant for mobile electronics was defined (e.g. the housing can be easily removed in order to access the internal components). This catalogue, in combination with a specific assessment scale & key, is the basis for the assessment method. Further the developed method was tested on several devices (smartphone, digital voice recorder…), to adjust the assessment scale and test the method with its underlying criteria according its usability.

2.1. Definition D4R strategies

2.1.1. Product Repair

If a product is easy to repair, its life time and therefore the use time of the device can be extended. This can prevent a new product from being used immediately because of damage of the old product, but instead repairing or replacing defective components. Properties that have an impact on whether a product is easy to repair are for example: ◆detachability of connections, ◆use of common fasteners, ◆number and variety of fasteners, ◆possibility to exchange individual components, ◆availability of repair instructions and tech. documents, ◆good accessibility, easy opening of the housing, ◆non-destructive removal of parts, ◆good identifiability of the components, ◆simple method of failure analysis, ◆little expertise required, ◆large availability of spare parts, ◆low spare parts prices, ◆short repair time, ◆low product complexity, ◆low risk of injury, ◆etc…

2.1.2. Product Reuse

If a product is no longer used by its user for its intended purpose, it would be best from the perspective of the Circular Economy to continue using the device itself, or at least as many components as possible, in their original state and for their original purpose. Properties: ◆detachability of the connections, ◆good accessibility, easy opening of the housing, ◆longevity of the components, ◆aging-resistant materials, ◆modular design, ◆ non-destructive removal of parts, ◆independence of individual components, ◆similarity of the components to previous and subsequent models, ◆uniform, product-independent components (e.g. the same charging system

for smartphones and MP3 players), ◆test procedures for functionality checks to assure faultless products, ◆possibility to check the functionality of single components, ◆possibility of data erasure, ◆etc…

2.1.3. Product/Part Remanufacturing

The possibility of extending the use time of products, components or single parts in the case of obsolete devices, by refurbishing and/or updating the hardware and software components, represents a further variant for realizing a CE-strategy. Mainly relevant properties are: ◆detachability of the connections, ◆good accessibility, easy opening of the housing, ◆modular design, ◆aging-resistant materials, ◆product design that enables future product updates or improvements, ◆etc…

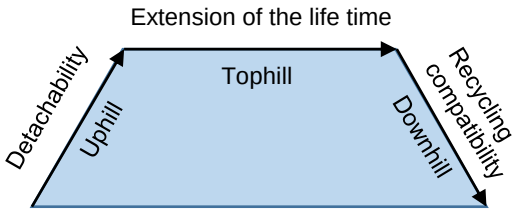
2.1.4. Product Recycling

If a product and its components cannot be reused in any other way, it is most appropriate in this case to recycle as much of the materials used as possible so that they can be used for the production of other products. Properties are: ◆use of recyclable materials, ◆good separability of the materials, ◆good identifiability of the materials used, ◆avoidance of hazardous substances, ◆low variety of materials used, ◆good accessibility, easy opening of the housing, ◆etc…

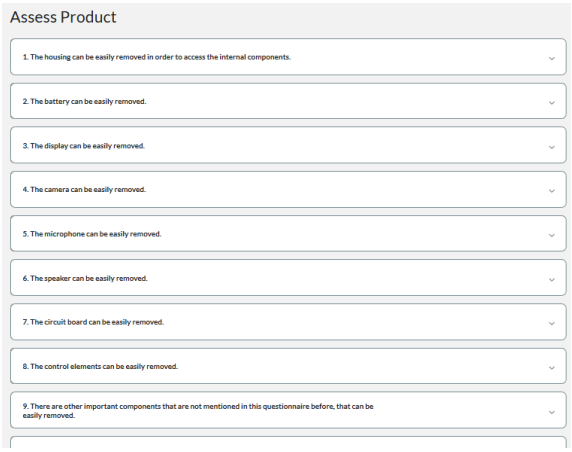
2.2. Catalogue, Assessment Questions, Assessment Scale & Keys

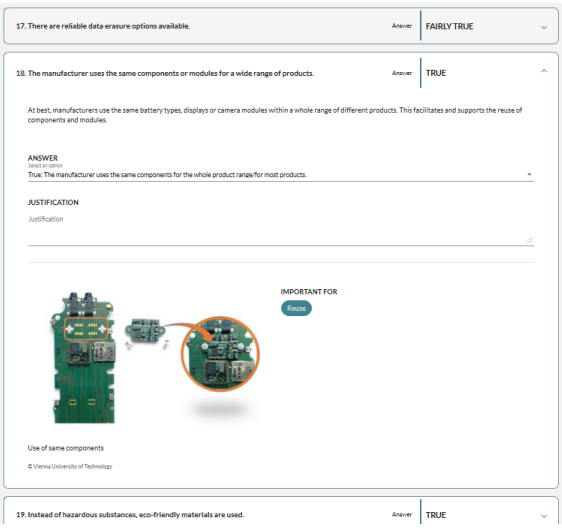
2.2.1. Catalogue and Assessment Questions

In the course of selecting the relevant design criteria for the criteria catalogue, it was shown that some of the product properties listed above have an impact on several of the four areas, "Repair", "Reuse", Remanufacturing" or "Recycling". The similarities and possible contradictions of the criteria between the individual CE-strategies had to be clarified first. Meaning, it is for example important, to recognize that none of the product properties listed are in direct contradiction to one another, since repair, reuse and remanufacturing criteria generally have the same design requirements [3]. So if a single property is improved, there is no need to fear that other areas of CE suitability will automatically deteriorate. In order to avoid multiple assessments for the same design criteria, but still allow clear design, 24 assessment questions for the tool were broken down differently based on three basic functions among the value hill (Quelle?):



Apart from the structure of the questions, the so called "main components" of the mobile electronic products were also defined in order to enable a more precise, but also easier evaluation. These components represent the most important components of common mobile electronic products. The idea behind this definition is to create a subdivision between important and less important elements and thus to enable partial points if at least the main components (and not all components) achieve a positive result becomes. Different mobile electronic products were examined and the following main components were derived: ◆ housing, ◆energy source (battery), ◆display, ◆PCB, ◆controls elements, ◆speaker, ◆microphone, ◆display, ◆cameras





If a product to be assessed does not have one or more of these main components, the related assessment questions are not part of the evaluation to achieve a correct result.

2.2.2. Assessment Scale

The assessment questions were formulated specifically as a decision question. In addition to the classic answer options "yes" and "no", there are also the options "rather yes" and "rather no" to allow gradation and thus partial points if a criterion is not completely fulfilled. A question answered positively always represents a positive assessment of the corresponding product characteristic. The degree of fulfilment corresponds to 100% for "yes", 60% for "rather yes", 30% for "rather no" and 0% for "no".

2.2.3. Keys

Each answered question is weighted with a relative importance key, so that particularly important product design criteria can be more strongly enter the evaluation, for example: Assessment Question: Is the camera easy to remove? Defined relative importance key for each CE-strategy: (RP-5%, RU-5%, RM-10%, RC-0%)
Now the product suitability regarding the four CE-strategies ("4R's") can be determined. The assessment result is given as a percentage between 0-100% and results as follows (example CE-strategy repair):

$$Strategy\ performance = \sum Fulfilment\ of\ questions\ x\ \text{Relative importance key}(RP)$$

The Overall D4R-Score of the product results from:

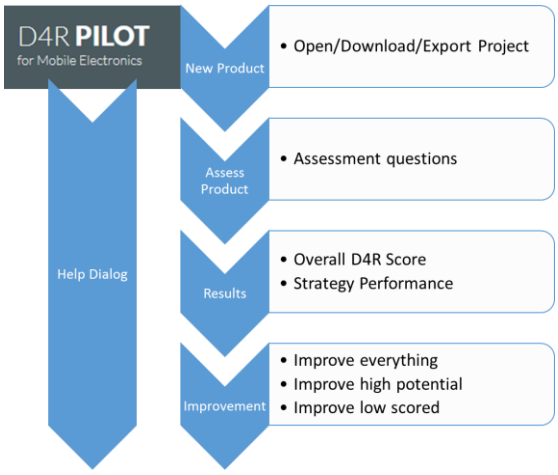
$$Overall\ D4R\ Score = \sum Strategy\ performance\ (RP, RU, RM, RC)\ x\ Absolute\ importance\ key$$

From an environmental point of view, it makes more sense to keep the actual product (repair) or at least its components (reuse, remanufacturing) longer in the usage phase than to recycle the materials from it in order to manufacture new products. Therefore the absolute importance key is defined as:

Repair (RP) 40% *Reuse (RU) 25%* *Remanufacturing (RM) 25%* *Recycling (RC) 10%*

2.3. Tool Workflow

For an objective evaluation, it is assumed that a certain level of specialist knowledge about the products to assess is available, since otherwise partial areas cannot be evaluated accordingly. However, the tools workflow is designed to be easy and flexible to use.



For every new product assessment as a first step a new project must be created. The tool is designed in a way that it is possible to save one's projects and edited them again later. The assessment is carried out by selecting the most appropriate answer option of the 24 assessment questions. The next step shows already the results (Querverweis Bild). The "Overall D4R Score" gives rough summary, while the "Strategy Performance" shows a detailed in depth view related to the single CE-strategies. In a third step a new product version to be improved can be created (as a new project), and the tool gives different filter options to highlight improvement potentials.

3. Results

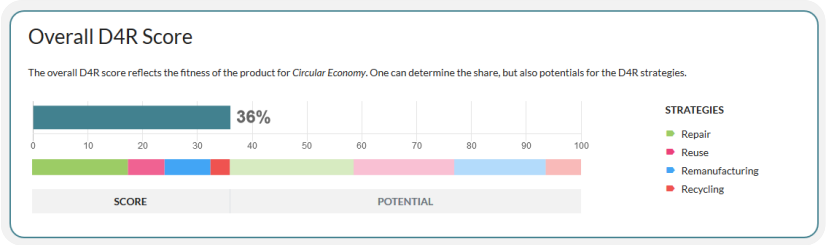
The proofed assessment method was translated into a free available web-tool, the D4R Pilot: https://d4r-pilot.ecodesign.at. In summary, the following was achieved:

1) The questionnaire of the Pilot is based on the defined criteria catalogue of relevant product design measures.

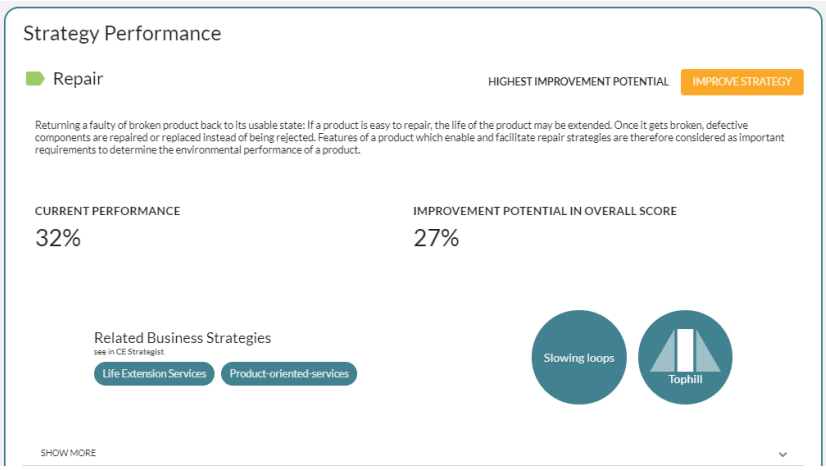
2) Per assessment scale the degree of fulfilment for each design criterion can be evaluated, from "True" up to "False" or "Not Relevant".

3) In the tool's background a defined key for every single criterion weights each criterion in terms of its importance related to the particular CE-strategy (Repair, Reuse, Remanufacturing and Recycling).

4) As result of the questionnaire, the overall CE-performance as well as the detailed performance regarding the D4R-strategies are displayed.



5) The tool highlights also the improvement potential and gives different possibilities to improve the product. The intended improvements are saved as an improved product version, the new CE-performance are shown immediately.



4. Conclusions

With the help of the D4R pilot, it is possible to assess the Circular Economy suitability of mobile electronic products in order to determine a quick potential for improvement. Appropriate measures can be taken during the product development process to improve the identified weaknesses. Similar products can also be compared with each other, which means that this method also shows advantages and disadvantages and the result can also serve to make transparent decisions.

When it comes to dismantling, a fairly precise answer to the questionnaire is possible, even if only the product itself is available without further knowledge. For the other areas, a certain amount of detailed knowledge or more detailed information about the assessed product must be available in order to get an accurate result.

5. References

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