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DOI
10.3233/978-1-61499-820-4-102

Publication date
2017

Document Version
Final published version

Published in
Plate Product Lifetimes And The Environment 2017

Product Lifetimes And The Environment 2017 - Conference Proceedings
C. Bakker and R. Mugge (Eds.)

DOI: 10.3233/978-1-61499-820-4-102

PLATE conference
Delft University of Technology
8-10 November 2017

PLATE
Product Lifetimes And The Environment

The circular pathfinder: development and evaluation of a practice-based tool for selecting circular design strategies

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Keywords
Circular product design
Circular design strategies

Abstract
The Circular Pathfinder tool, which provides guidance to companies looking for appropriate circular design strategies, was developed based on OEM (original equipment manufacturer) case studies. Ease of use was one of the main requirements during development of the tool, resulting in a software-based guide that asks a maximum of ten product-related questions, after which it gives a recommendation for one or more specific circular design strategies. The advantage of a practice-based tool is that the practical relevance is, in all likelihood, high. The disadvantage, however, is the lack of scientific validation. This paper presents a literature review of the decision variables and heuristics of the Circular Pathfinder, with the aim to uncover any discrepancies between practice and literature. The main finding is that the focus on practical usefulness of the tool has led to excessive reduction of the complexity inherent in strategic circular design decisions. Recommendations for improving the Circular Pathfinder tool are given.

Introduction

In this paper, we analyse the Circular Pathfinder tool, which provides guidance to companies looking for appropriate circular design strategies. This software tool guides its users through a maximum of ten product-related questions and, depending on the answers, provides recommendations for specific circular design strategies (e.g. refurbishment or recycling), product examples for each of the strategies and appropriate design tools (see Figure 1 for a screenshot of the tool).

Current tool development in the field of circular and sustainable design is usually research-driven: a tool is developed based on a literature review and validated with industry or with a hypothetical case (for instance de Aguiar et al. (2017). Subsequent adoption of methods and tools in practice is acknowledged as being problematic (Daalhuizen and Schaub (2011). One of main the reasons mentioned in the literature is the misalignment between the tools and the designers' requirements for tools (Lofthouse, 2006). In contrast, the development of the Circular Pathfinder tool was industry-driven. The advantage of this approach is that the practical relevance of such a tool is likely higher. The disadvantage, however, is the lack of scientific validation – which this paper aims to address.

The purpose of this paper is therefore to do a post-evaluation and scientific validation of the tool's underlying decision variables and practical heuristics. This is done by comparing these variables and heuristics against the literature, in order to uncover conformities and discrepancies, leading to recommendations for improving the Circular Pathfinder from a scientific perspective.

Background: development of the Pathfinder Tool

The Circular Pathfinder was developed for the European FP7 ResCoM project, which is aimed at developing industry pilots and support tools to assist the transition to circular business models and product designs. The tool was developed by a product design and research agency (IDEAL&CO) as an easy-to-use 'meta-tool' for the design, R&D and innovation departments of OEMs (Original Equipment Manufacturers).

A practice-based approach was taken in the design of the tool, tracing the pathways taken by a range of OEM companies (including the ResCoM partners Bugaboo, Tedrive, Gorenje and Loewe) in their implementation of circular business and design strategies (IDEAL&CO Explore & DUT, 2016). For all cases, the retrospective question was asked which contextual, product-related factors could be used to discern the different circular pathways implemented by the OEMs.

Six key product decision variables were identified that appeared to influence the chosen circular pathways in these cases:

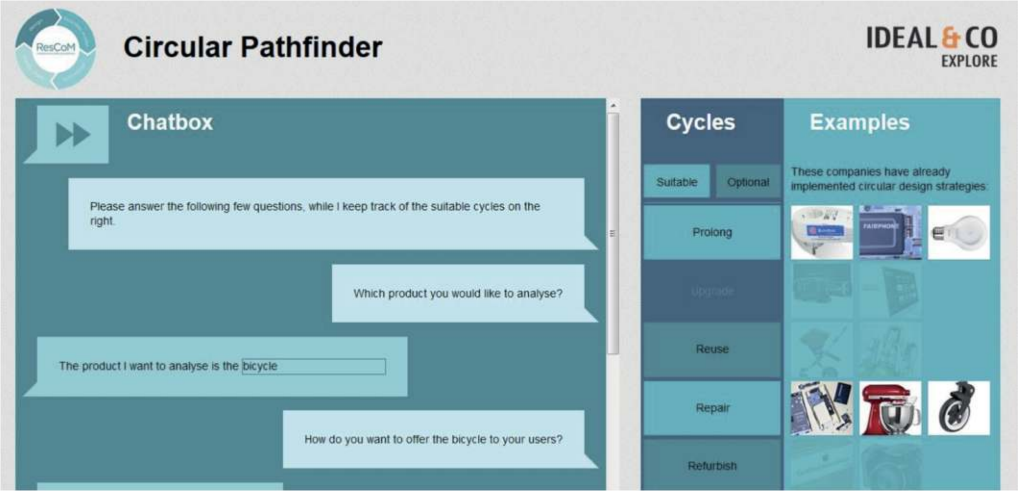

Figure 1. Screenshot of the Circular Pathfinder tool.

1. Whether the parts or materials of the product could -in principle- be collected.
2. The reason for discarding the product.
3. Whether the product could be used again after the first use cycle (as a whole).
4. Whether parts of the product are still useful to the company when the product is replaced or discarded.
5. Whether users are interested to acquire the used product (in good condition).
6. Whether users demand a warranty to assure that the used product works well.

These variables were transformed into a concise set of practical heuristics, e.g.: "Upgrade IF discarded because outdated" (figure 2), and accompanying questions, e.g.: "How long do people use the product and why do they stop using it?" (see figure 2). Based on the answers, the tool suggests one or more suitable and/or optional circular design strategies by, for example, saying "Design for upgrading is a relevant design strategy when the product becomes outdated and is discarded while it is still functional". In total, there are eight recommendable strategies: design for durability, upgradeability, reuse, repairability, refurbishment, remanufacturing, recycling, and bio-cycling (biodegrading).

The Circular Pathfinder has so far been applied to approximately 40 cases, and used with companies directly or indirectly involved in the ResCoM project.

Scope of the tool

- The tool is based on best-practices of durables (e.g. office furniture) and products that combine durables and consumables (e.g. washing machines and reusable beer bottles). This excludes 'pure' consumables such as food.
- During the development of the tool it was discovered that the revenue model (i.e. sale/ lease/ charge per use) frames the circular pathways and options that are available: users may answers questions differently depending on the revenue model. Consequently, an additional question is asked at the start of the tool concerning the (desired) revenue model, and users are invited to revisit their choice.
- The pathfinder's premise is that factors that can be influenced by the manufacturer's operations (e.g. product design) do not hold back the potential of a circular pathway. Instead, they are the challenges to overcome if the pathway is perused.

Method and Approach

In order to scientifically validate the Pathfinder, the following approach was used. At first, we tried to find evidence in literature for the heuristics (see figure 2), such as:

"Reuse IF people are interested in paying for a used product AND product life ≥ 2x use life AND people do not usually demand warranty".

Finding support in literature for such (compounded) heuristics is difficult. Literature does describe variables relevant to circular pathways. However, their interplay is not described in the same type of logical statements. We thus decided to focus on the decision variables underlying the heuristics. The reasoning is as follows: if support for the consequences of these variables on the suitability of circular pathways can be found, it becomes more likely that a combination of variables (that form a heuristic) is also supported. For each of the six variables a (succinct) literature review was carried out, using relevant variable-related search terms and snowballing.

Results: validation of variables

Each of the six variables mentioned in the background section are clarified with a concise review of relevant literature.

1. Collectibility of parts/materials

Materials or parts that wear away or that are consumed (for instance detergents) may be practically impossible to collect for reuse or recycling. An example of a product that wears away is a car tyre, leading to dissipation of rubber and rubber compounds into the environment. According to Ciacci et al. (2015), "Dissipation of elements is caused by scattering and dispersion into the environment at concentrations that prevent any form of recovery". They argue that this can inhibit reuse and recycling strategies. Ciacci et al. (2015) propose to use restrictive measures (i.e. bans), better product/process design and the development of substitute materials in order to reduce dissipation. The cradle to cradle approach by McDonough and Braungart (2010) advocates the use of (non-toxic) biodegradable materials which would make dissipation less harmful for the environment. This is in line with the Circular Pathfinder's suggested design strategy.

For the materials and parts that could be collected, the Pathfinder tool suggests recycling as a relevant strategy. Literature suggests that there are still considerable barriers for recycling, because of "insufficient collection infrastructures and poor collection efficiencies" and the fact that "consumer recycling awareness can hamper the potential for recycling" (Tanskanen, 2013). Although there are best-practice examples of companies that have successfully tackled the recycling of their products (de Pauw, 2015), ensuring product recyclability through design is still in its infancy (Lifset & Lindhqvist, 2008), as are innovative take-back systems (Atasu et al., 2010)

2. Reason for discarding the product

To determine which pathway is potentially relevant, the Circular pathfinder distinguishes four main reasons why a product is discarded: Because it broke down, degraded visually, became outdated, or because the user no longer needs it. These reasons show a clear overlap with literature on product obsolescence. Academics for instance distinguish between functional obsolescence (a product breaks down), aesthetic obsolescence (a product becomes outmoded, or no longer visually attractive), technological obsolescence (a product becomes technically outdated, for instance a video player), and obsolescence of desirability (user no longer needs or wants the product) (Bartels et al., 2012; Burns, 2010). The literature also discerns different approaches to resolve product obsolescence. Den Hollander et al. (2017) present design strategies for preventing, postponing and reversing obsolescence, such as design for repair and maintenance, which can be used for product design in a circular economy.

Nevertheless, research has also suggested that product replacement decisions are determined by a complex range of factors that include design, technological change, the cost of repair and availability of parts, household affluence, residual resale values, aesthetic and functional quality, fashion, advertising, and social pressure (Cooper, 2004). The way this variable is used in the Pathfinder may therefore be too one-dimensional, as the real reason a consumer discards the product may be more complex.

3. Reusability of the product

This variable addresses the possibility for the product to be used again after first use, and is related to the product's functional life span. In other words: can the product be used again without functional failure? This question refers to the product's durability and reliability. Reliability is defined as "The probability that a product manufactured to a given design will operate throughout a specified period without experiencing a chargeable failure, when maintained in accordance with the manufacturer's instructions." (Moss, 1985). Reliability is closely linked to maintenance, which needs to happen regularly in order to keep a product in good working condition. From an OEM's perspective, having highly reliable, long-lasting products can be profitable because downstream activities, including after-sales service and sales of spare parts for maintenance and repair, may "represent ten to 30 times the annual dollar volume of the underlying product sales." (Wise & Baumgartner, 1999). Strategies to extend the life of a durable, high-quality (and reliable) product may therefore be worthwhile due to indirect profits from the sales of spare parts both during the first and following use cycles.

4. (Re)usability of parts

In the tool this variable is a key factor in the heuristic for remanufacturing. When there is still a market for the product, parts that are usable in a next generation or can replace broken parts in the field are suggested for remanufacturing. Hatcher et al. (2013) state as a general rule that "the product must be durable (able to withstand multiple lifecycles) and contain high value parts (worth investing in). Also, there must be market demand for the remanufactured products." However, Goodall et al. (2014) state that asides from market demand, "a supply of used cores" (i.e. products) is necessary. With regard to these used product cores being returned they highlight three uncertainties, namely their state or physical condition, the design and physical structure (e.g. presence of upgrades or modifications), and the unknown timings and quantities of product returns. This is exemplified by Atasu et al. (2008) who argue that the main bottlenecks can be found in product return acquisition and remarketing processes. The additional factors these authors pinpoint may indicate the current Pathfinder heuristic does not address enough factors.

5. Interest in used products

This variable addresses people's interest to acquire a used, or second-hand, product. Guiot and Roux (2010) distinguish ethical, economic and hedonic motivations for consumers to engage in second-hand shopping, noticing that these motivations are "extensively interwoven". From an OEM perspective, the current size of many second-hand markets force OEMs to form strategies to respond to it (Oraiopoulos et al., 2012). According to Oraiopoulos, a positive example is set by "IBM and Hewlett Packard, [who] create high resale values for their used equipment by facilitating the resale process and secondary use (e.g., charging small relicensing fees, offering maintenance and

Figure 2. Heuristics underlying the tool.

inspection)." They remark: "Such a proactive, and in a sense cooperative, relationship with third-party brokers and refurbishers, however, is not a standard policy among all … OEMs." Fearing cannibalization of new product sales, some OEMs attempt to actively eliminate second-hand markets. It follows that some companies may not wish to support second-hand markets and for whom this Pathfinder advice would be less useful. Furthermore, interest in acquiring used products may not automatically translate in willingness to pay (WTP) (Hazen et al., 2012; van Weelden et al., 2016).

6. Demand for warranty on reused products

The Pathfinder uses consumer demand for warranty as indicator of the potential for refurbishment or remanufacture, in contrast to reuse (second hand products) where users tend to feel little need to receive a (formal) warranty. In cases where users are concerned about the performance and durability of second-hand products, "The warranties play an important role in reassuring the buyer." (Saidi-Mehrabad et al., 2010) This is particularly the case for products such as household electronic appliances with high perceived risk (regarding health and safety, durability and likelihood of malfunction) (Guiot & Roux, 2010). van Weelden et al. (2016) found warranty and service "to be major determinants of the perceived risk-benefit balance when considering a refurbished mobile phone." The tentative conclusion that can be drawn from this short review is that in the case of perceived 'high-risk' products, warranties are appreciated by consumers, with little distinction being made between second-hand or refurbished products. This is in contradiction to the Pathfinder heuristic.

Discussion & Conclusion

This article has given a concise literature review to validate the variables used in the pathfinder. The review has highlighted a number of areas in which the pathfinder could be improved.

The variables and heuristics underpinning the tool are somewhat one-dimensional. While the developers deliberately chose to reduce the complexity present in circular design decision-making processes in order to create a practical tool, this does create some drawbacks. For example, the pathfinder has more attention for bio-cycles than techno-cycles, while currently this can be unfeasible for companies, and dissipation can be addressed with other strategies than biodegradability (Ciacci et al., 2015). Another example is that the reasons for discarding products are often more complex and intertwined than the pathfinder suggests. Likewise, whether a part can be reused is only one of the factors influencing the remanufacturability of products according to literature. As such, literature seems to indicate that the set of variables considered by the pathfinder is incomplete, and therefore the pathfinders heuristics may not have enough validity to provide companies with an accurate recommendation about which circular design strategies to follow.

An additional area of improvement is the use of terminology, both from a scientific, and a business point of view.

From a scientific point of view the use of circular economy terminology can be confusing. This is not a concern limited to the pathfinder but is also very much present in literature itself (den Hollander et al., 2017). Terminology such as repurpose, refurbish, remanufacture, recondition, and reuse are often used interchangeably, while some have distinctly different meanings. Likewise, the ambiguity surrounding recycling, bio-cycling, biodegradation, consumables, dissipation, and the distinction between collection and recovery therein can lead to confusion when filling in the pathfinder. The pathfinder does provide descriptions of terminology, but nonetheless the clarification of definitions (e.g. providing common synonyms) and attuning of terminology with literature could be improved.

While this approach may clarify terminology from a scientific point of view, this may not necessarily simplify the tool for OEMs who are the target of the tool. Here perhaps, incorporating more economic language and clear metrics may be beneficial. Examples of this are willingness to pay instead of consumer need/interest, residual value or revenue/profit from after sales service, instead of product lifetimes. This could improve the precision of the questions and the outcomes of the tool.

Acknowledgements

This work has been conducted as part of the ResCoM project that has received funding from the European Union's FP7 (seventh Framework Program) for research, technological development and demonstration under grant agreement No 603843.

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