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The circular pathfinder

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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

# Citation (APA)

van Dam, S., Bakker, C., de Pauw, I., & van der Grinten, B. (2017). The circular pathfinder: Development and evaluation of a practice-based tool for selecting circular design strategies. In C. Bakker, & R. Mugge (Eds.), *Plate Product Lifetimes And The Environment 2017: Conference Proceedings* (pp. 102-107). (Research in Design Series; Vol. 9). IOS Press. https://doi.org/10.3233/978-1-61499-820-4-102

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PLATE conference Delft University of Technology 8-10 November 2017



# The circular pathfinder: development and evaluation of a practicebased 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 productrelated 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 postevaluation 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:

Circular Pathfinder		
Chatbox	Cycles	Examples
Please answer the following few questions, while I keep track of the suitable cycles on the right.	Suitable Optional	These companies have already implemented circular design strategies:
	Prolong	
Which product you would like to analyse?	Upgrade	
The product I want to analyse is the bicycle	Reuse	× ili
How do you want to offer the bicycle to your users?	Repair	
	Refurbish	

Figure 1. Screenshot of the Circular Pathfinder tool.

- Whether the parts or materials of the product could -in principle- be collected.
- 2. The reason for discarding the product.
- Whether the product could be used again after the first use cycle (as a whole).
- Whether parts of the product are still useful to the company when the product is replaced or discarded.
- Whether users are interested to acquire the used product (in good condition).
- 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  $\geq 2x$  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 variablerelated 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.

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#### 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 secondhand 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

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wear away.

Questions and [multiple choice answers A / B / C...] or (open answer) and (dynamic content)

1) The product I want to analyze is the {product name}

2) How do you want to offer the product to users? We

3) When using this product, do any of its materials get

dissipated (...)? The *product* contains [no / some / only] consumables and [no / some / all] parts of the product

4) How long do people use the product and why do

reason why it is replaced or discarded is that [it broke

down / it degraded visually / it became outdated / the

END) This is a special outcome! Very few products will

never be replaced or discarded but instead be kept for

a lifetime and beyond. If your product is cherished

forever such as great works of art, nothing needs to

5) Since the product's use life is currently limited by it

being brokenORworn, the user may want a replacing

That implies the user replaces the product about

by the product for about {needed} years.

(=needed/useLife) times.

acquiring and using it.

product works well.

product. ( ) A user needs the function that is provided

6) Since the product's use life is currently limited by the

users need or want for it, does the product last long

last {productLife} years without functional failure

That would mean the product could in principle be

used (=productLife/useLife) times by a different user.

7) When a used product is (restored to / still in) good

8) Will clients that acquire a product require warranty?

Our customers [usually / sometimes / do not] demand

9) When the product is replaced or discarded after use,

are its parts still useful? (...) After (useLife) years of use

[production of the exact same product / next product

that uses some identical parts / supply of spare parts /

all: same product, next products and/or spare parts].

suggested Circular pathways for the case where users

acquire your product. If you are also considering other

business models, you can revisit the questions for these business models as well, simply by changing your

parts of the product [are still / are not] useful.

10) The product parts are mainly useful for the

END) Thank you. At the right, you will find the

a manufacturer's warranty on it to assure that the

condition, there [are / are no] people interested in

enough for another use life? The average product will

change for it to become circular; it can already

circulate for generations to come.

user no longer needs it / the user never discards it]

they stop using it? Our target customer uses the

product for (usel ife) years, after which the main

will [sell / lease out / charge per use of] the product.



#### Recycle IF (not all parts are consumed)

If you are able to collect the durable parts of the product, Design for Recycling can enable you to recover the material value of these parts. Furthermore, using recycled materials in your product helps to truly close material values.

#### ELSE; no recycling

Parts of the product are consumed and/or wear away, so they inevitably diffuse into the biosphere. Unless you are able to collect the consumed product, recycling will be no viable option.

Biodegrade IF ((some or all parts are consumed) OR (some or all parts wear)

As some/all parts of the product are consumed (and some/all parts wear away), the materials used in these parts inevitably diffuse into the biosphere. To prevent pollution and enable cyclic material flows, these materials should be biodegradable.

#### ELSE; still biodegrade

Even though the entire product could be recycled, you may still consider to use biodegradable materials, for instance when collection of the product is unfeasible. Biodegradable materials can still be recycled or downcycled if that fits the product lifecycle.

#### Upgrade IF (discarded because outdated)

Design for Upgradability is a relevant design strategy because the product becomes outdated, and is discarded while it is still functional. ELSE; no upgrading

Design for Upgradability is not a relevant design strategy because the product is not outdated after its first use.

#### Durability / life extension IF (needed > productLife)

Design for Durability can be a relevant design strategy because the user still has a need for this product after its typical lifetime.

As you have indicated that the user has no need for the product after its typical lifetime, Design for durability is not a relevant option.

#### Repair IF (needed > productLife)

Design for Reparability can be a relevant strategy because there is still a need for the product when it breaks down / looks too worn. ELSE; no repair

Design for Reparability is not a relevant strategy because product lasts at least as long as it is needed.

Reuse IF ((people are interested in paying for a used product) AND (productLife ≥ 2•useLife) AND (people do not usually demand warranty))

Design for Reuse can be a relevant strategy because there is a market for the second use of the product (without the need to refurbish or upgrade the product).

#### ELSE; no reuse

- Design for Reuse seems not relevant as a design strategy because...
- ...you have indicated there is no market for used products.
- ... a new user usually requires a warranty

Refurblish IF ((people are interested in paying for a used product) AND (people (usually OR sometimes) demand warranty)) Design for Refurbishment can be a relevant design strategy, because (some) users are interested to buy, lease, or buy access to the (refurbished) product when it is offered with a warranty. ELSE, no refurbishment

Design for Refurbishment is not a relevant design strategy because... ... people interested in a used product do not need a warranty, and the investment in refurbishment (compared to reuse) may not pay off. ... vou have indicated that there is no market for used products.

Remanufacture IF (after use parts are still useful)

Design for Remanufacturing can be a relevant design strategy because when the product has broken or degraded visually...

...there is still a market for the product, if it has the original quality ...its parts -once returned to original specification- can be used in the next generation

...products in the field can be repaired with the still functioning parts ELSE; no remanufacture

Design for Remanufacturing is not a relevant design strategy because when the product is discarded, the product parts are no longer useful

Link between conclusion and question

Pointing to the next question

answers above

Show me

Processing answers

Algorithm to ask the next

question and edit text

Replace all instances of

Replace all instances of

pay per use

acquire with buy / lease /

IF [the user never discards it]

Congratulate with the very

special outcome, ask no

further questions and

present the outcomes

IF [it broke down]

be useful.

restored to

it]

last

productLife = useLife.

brokenORworn = broken

ask how long the function of

parts of broken products can

the product is needs and if

IF [it degraded visually]

productLife = useLife,

brokenORworn = wor

(restored to / still in) =

ask how long the function of

the product is needs and if parts of broken products can be useful and if people might

pay for a used product

IF [it became outdated]

needed = useLife,

IF [there are people

interested]

interestedl

used

OR [the user no longer needs

(restored to / still in) = still in

ask how long the product will

ask if they require warranty

IF [there are no people

IF [parts are useful]

ask for what they can be

IF [parts are not useful]

skip the useful for question

Clicking 'Show me' unfolds

the conclusions panel and

link to the tools

skip the warranty question

product with {product name}

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 riskbenefit 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 'highrisk' 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 biocycles 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.

#### References

Atasu, A., Guide, V. D. R., & Van Wassenhove, L. N. (2008). Product Reuse Economics in Closed-Loop Supply Chain Research. Production and Operations Management, 17(5), 483-496. doi:10.3401/poms.1080.0051

Atasu, A., Lifset, R., Linnell, J., Perry, J., Sundberg, V., Mayers, C. K., . . . Gregory, J. (2010). Individual producer responsibility: A review of practical approaches to implementing individual producer responsibility for the WEEE Directive (INSEAD Working Paper No. 2010/71/TOM/1). Retrieved from https://ssrn.com/ abstract=1698695 or http://dx.doi.org/10.2139/ssrn.1698695

Bartels, B., Ermel, U., Sandborn, P., & Pecht, M. G. (2012). Strategies to the prediction, mitigation and management of product obsolescence (Vol. 87): John Wiley & Sons.

Burns, B. (2010). Re-evaluating Obsolescence and Longer Lasting Products: Alternatives to the Throwaway Society Longer Lasting Products: Alternatives to the Throwaway Society (pp. 39).

Ciacci, L., Reck, B. K., Nassar, N. T., & Graedel, T. E. (2015). Lost by Design. Environmental Science & Technology, 49(16), 9443-9451. doi:10.1021/es505515z

Cooper, T. (2004). Inadequate Life?Evidence of Consumer Attitudes to Product Obsolescence. *Journal of Consumer Policy*, 27(4), 421-449. doi:10.1007/s10603-004-2284-6

Daalhuizen, J., & Schaub, P. B. (2011). The use of methods by advanced beginner and expert industrial designers in non-routine situations: a quasi-experiment. *International Journal of Product Development*, 15(1/2/3), 54.

de Aguiar, J., de Oliveira, L., da Silva, J. O., Bond, D., Scalice, R. K., & Becker, D. (2017). A design tool to diagnose product recyclability during product design phase. *Journal of Cleaner Production*, 141, 219-229. doi:https://doi.org/10.1016/j.jclepro.2016.09.074

de Pauw, I. (2015). Nature-Inspired Design Strategies for Sustainable Product Design. (PhD), Delft Technical University.

den Hollander, M. C., Bakker, C. A., & Hultink, E. J. (2017). Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms. Journal of Industrial Ecology, 21(3), 517-525. doi:10.1111/jiec.12610

Goodall, P., Rosamond, E., & Harding, J. (2014). A review of the state of the art in tools and techniques used to evaluate remanufacturing feasibility. *Journal of Cleaner Production*, 81, 1-15. doi:https://doi. org/10.1016/j.jclepro.2014.06.014

Guiot, D., & Roux, D. (2010). A Second-hand Shoppers' Motivation Scale: Antecedents, Consequences, and Implications for Retailers. *Journal of Retailing*, 86(4), 355-371. doi:https://doi.org/10.1016/j. jretai.2010.08.002 Hatcher, G. D., Ijomah, W. L., & Windmill, J. F. C. (2013). Design for remanufacturing in China: a case study of electrical and electronic equipment. *Journal of Remanufacturing*, 3(1), 3. doi:10.1186/2210-4690-3-3

Hazen, B. T., Overstreet, R. E., Jones-Farmer, L. A., & Field, H. S. (2012). The role of ambiguity tolerance in consumer perception of remanufactured products. *International Journal of Production Economics*, 135(2), 781-790. doi:http://dx.doi.org/10.1016/j. iipe.2011.10.011

IDEAL&CO Explore, & DUT. (2016). BEST DESIGN PRACTICES ResCoM report D3.2, Public version. Retrieved from http://www. rescoms.eu/project/deliverables

Lifset, R., & Lindhqvist, T. (2008). Producer Responsibility at a Turning Point? *Journal of Industrial Ecology*, 12(2), 144-147. doi:10.1111/j.1530-9290.2008.00028.x

Lofthouse, V. (2006). Ecodesign tools for designers: defining the requirements. *Journal of Cleaner Production*, 14(15), 1386-1395. doi:http://dx.doi.org/10.1016/j.jclepro.2005.11.013

McDonough, W., & Braungart, M. (2010). Cradle to cradle: Remaking the way we make things: MacMillan.

Moss, M. A. (1985). Designing for minimal maintenance expense: the practical application of reliability and maintainability (Vol. 1): CRC Press.

Oraiopoulos, N., Ferguson, M. E., & Toktay, L. B. (2012). Relicensing as a Secondary Market Strategy. *Management Science*, 58(5), 1022-1037. doi:10.1287/mnsc.1110.1456

Saidi-Mehrabad, M., Noorossana, R., & Shafiee, M. (2010). Modeling and analysis of effective ways for improving the reliability of second-hand products sold with warranty. *The International Journal of Advanced Manufacturing Technology*, 46(1), 253-265. doi:10.1007/s00170-009-2084-x

Tanskanen, P. (2013). Management and recycling of electronic waste. Acta Materialia, 61(3), 1001-1011. doi:https://doi.org/10.1016/j. actamat.2012.11.005

van Weelden, E., Mugge, R., & Bakker, C. (2016). Paving the way towards circular consumption: exploring consumer acceptance of refurbished mobile phones in the Dutch market. *Journal of Cleaner Production*, 113, 743-754. doi:https://doi.org/10.1016/j. jclepro.2015.11.065

Wise, R., & Baumgartner, P. (1999). Go downstream: the new profit imperative in manufacturing. *Harvard business review*, 77(5), 133-141.