PROMPT

Premature Obsolescence Multi-Stakeholder Product Testing Programme

Project Duration: **01/05/2019 - 30/04/2023**

Deliverable No.: **5.4**
Deliverable Title: **Design guidelines to prevent premature obsolescence from a user/market perspective – Final report**

Version Number: **1**

Due Date for Deliverable: **30/04/2023**
Actual Submission date: **28/04/2021**
Lead Beneficiary: **TU DELFT**

Lead Author: Ruth Mugge
Contributing Author: Lise Magnier, Renske van den Berge

Deliverable Type: R
- R = Document, report
- DEM = Demonstrator, pilot, prototype, plan designs
- DEC = Websites, patent filing, press & media actions, videos, etc.

Dissemination Level: PU
- PU = Public
- CO = Confidential, only for members of the consortium, incl. the Commission Services

Coordinator contact: Olaf Witler
Fraunhofer IZM
phone
e-mail

Contributing Partners
TUD, TA, OCU, UFC

Disclaimer

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 820331

Content

1 Introduction

1.1 Objectives

In this deliverable, we present the final design guidelines that designers and companies can use to prevent premature obsolescence from a user/market perspective. Premature obsolescence describes the phenomenon of 'the disposal of a product at a point in its 'life' that arrives too soon'. Too soon is defined in this report as a product being discarded when it is physically still functioning, or in need of repair. By preventing premature obsolescence, products are used for a longer time period, and this can thus contribute to a sustainable society. The specific focus of these design guidelines is the user and market perspective. In other words, what aspects related to the design of the product, service, and business model would encourage consumers to use products for a longer time period, thereby postponing their replacement. For this full report, we improved and detailed the guidelines presented in the intermediate report (cf. deliverable 5.1). Furthermore, the guidelines served as input for the testing programme in order to test products on their lifetimes.

1.2 Scope

The focus of PROMPT is on white goods and user electronics. Based on a Multi-Criteria analysis conducted by the project team the following four main product groups were selected: washing machines, vacuum cleaners, (smart) televisions, and smartphones. For this report on design guidelines, we however take a wider approach as some design guidelines may also be very applicable to other products.

1.3 Partners

TU Delft was responsible for collecting and analysing the scientific literature on consumers' replacement process and the existing design guidelines to prevent premature obsolescence. The user organizations (TA, OCU, UFC, BEUC, SW, Consumentenbond), iFixit, R.U.S.Z, IZM, and TU Delft have been involved in several workshops to brainstorm and complement the literature on the different replacement reasons (for an overview of these replacement reasons, see deliverable 2.6) and on new design opportunities to postpone replacement. TU Delft combined and integrated these insights in the design guidelines that are presented in this report.

1.4 Structure of the report

The remainder of this document is structured as follows. We start with a description of the method that we used to acquire, develop, and detail the design guidelines. Then, we provide an overview of consumers' replacement decision process based on insights from the scientific literature. Subsequently, we present a set of preliminary design strategies. For each design guideline, we explain why it would prevent premature obsolescence and added insights from our studies that further refined them. Additionally, we indicated the specific challenges that designers and companies interested in using these design guidelines should tackle. We end with a reflection on how consumers responded to these guidelines and how the design guidelines are incorporated into the final testing programme.

2 Method

The development of the user/market design guidelines
To develop a set of design guidelines, we pursued the following process. First, a scientific literature analysis was conducted on consumers' replacement process to better understand why consumers replace products and how the products, services, and business elements play a role in this decision. Next, we performed an analysis of the existing design strategies preventing premature obsolescence that are uncovered in the scientific literature. Subsequently, several workshops were held with the different members of the PROMPT consortium (TA, OCU, UFC, SW, Consumentenbond, BEUC, R.U.S.Z, iFixit, IZM, and TU Delft)

- In May 2019 a workshop was organized in Delft to kick-off the PROMPT project to both uncover existing, and creatively think of new, design opportunities, service designs, business models and other solutions to counteract the different reasons for premature replacement.
- In November 2019, a workshop was held in Berlin with the whole consortium to brainstorm on how consumers, companies, and policymakers can prevent premature obsolescence.
- in May 2020 (online), the participants were to think of user/market-related factors that could cause early replacement of the four product categories. Subsequently, participants were asked to think about potential product/service designs and/or business model solutions that could postpone this early replacement.

These outcomes of the literature study and workshops were analysed and categorized in a preliminary set of design guidelines, which were presented in deliverable 5.1 in the intermediate report about the Design guidelines to prevent premature obsolescence from a user/market perspective.

Improvement of the user/market design guidelines
The guidelines were further improved during the project. Specifically, the results of the empirical studies conducted in work package 5 (tasks 5.1 and 5.2) enabled us to refine the guidelines.

- In task 5.1. (i.e., related to reasons for replacement of well-functioning products), qualitative interview findings were complemented by a quantitative survey. This survey measured the extent to which the formulated design guidelines are likely to postpone product replacement. It also investigated how the product characteristics (e.g., brand positioning, model), it's market (e.g., the pace of technological innovations), and consumer characteristics (e.g., environmental concern, innovativeness) influence the expected and actual lifetime of a product, and users' satisfaction (cf. Deliverable 5.2)

- For task 5.2 (i.e., related to the choice for replacement over repair), we established a comprehensive overview of the reasons for deciding (not) to repair a broken products based on qualitative interview data. In addition, we explored the role of the product, its design features, and business model in making this decision based on data from different EU countries. Furthermore, we conducted experiments aiming at determining the effects of several design features (i.e., fault indication on the product, a modular design) on intentions to repair products (cf. Deliverable 5.2).

The final user/market design guidelines
The guidelines were included in the final testing procedures which were developed for task 5.3. In June 2021, a workshop was organized about the prioritization of the guidelines per product category, which served as input for the weighing of the user/market-related aspects in the final testing programme. More detailed information about the method of each of the workshops and the final overview of the user/market-related testing criteria can be found in Deliverable 5.3. After that, the formulated criteria were tested with several products from the selected categories in professional testing labs. The criteria were critically reviewed during physical meetings in November 2022 (Vienna) and January 2023 (Brussels) together with the testing experts. This provided input on the application and reliability of the guidelines, and the weighting of the formulated criteria, and served as a feasibility check for the inclusion of the criteria in the testing programme.

In this report, we present the final design guidelines along with the existing literature insights on how to successfully achieve this which resulted from our studies conducted for WP5.

3 Consumers' replacement decision process

When consumers are thinking of replacing a currently owned durable product by acquiring another one, there is a trade-off between the value that is provided by the currently owned product and the expected value as well as the costs of a potential new product. Products can deliver different kinds of values that are all included in this psychological process. Sheth et al. (1991) defined five different types of values influencing consumer choice. These values are important to understand consumers' decision to retain or to replace a product. The first is functional value, referring to the product's functional, utilitarian, and physical product performance. Emotional value relates to the extent to which the product arouses feelings and affective states. Epistemic value refers to the product arousing curiosity, providing novelty or the need for a change of pace. Social value refers to associations and belonging to a group. Finally, conditional value relates to how specific situations or circumstances influence consumer decisions.

During the replacement decision, trade-offs are made between the values of the currently owned product and those of a potential new product (Van Nes and Cramer, 2005; Okada, 2001, Van den Berge et al., 2021). On the one hand, the owned product offers specific values to the owner, such as functional value due to its performance and features. The product may also provide emotional value, for example, because it was a gift from a loved one. On the other hand, new products can provide improved performance (i.e., increased functional value) and arouse curiosity with new features (i.e., epistemic value), but require a financial investment. Marketing strategies (e.g., advertisements) can heighten the new products' values. During these trade-offs, some values are more salient than others, depending on the type of product, context, and specific consumer needs and desires (Bayus, 1991). While making the trade-offs, the consumer can either decide that the relative value of the new product in comparison to the owned product is worth the financial investment, resulting in replacement, or can decide that the relative value of the owned product is still high enough, resulting in retention (Guiltinan, 2010). Figure 1 illustrates consumers' replacement decision process and the trade-offs in value between the owned product and the new product.

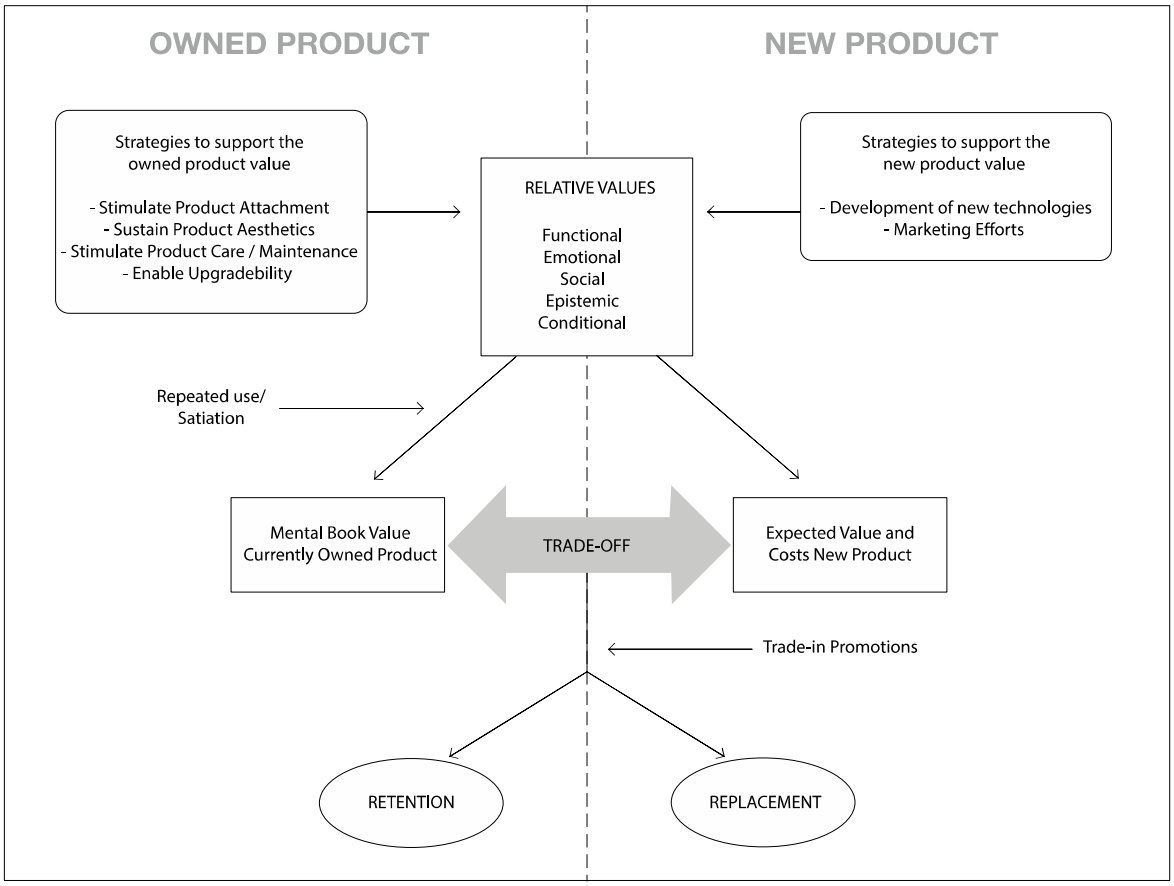

Figure 1: Consumers' replacement decision process (Van den Berge et al. 2021)

Product values are not static and can change over time. The functional value of the owned product can decrease if the product (partly) malfunctions. Traces of usage (i.e., wear and tear) can decrease the product's aesthetics and thus its emotional value (Baxter et al., 2017). Furthermore, repeated product usage triggers feelings of satiation (the phenomenon in which consumers enjoy a desirable stimulus less when it is repeatedly consumed) (Hou et al., 2020), which lowers the perceived value of the owned product. This negatively affects the 'mental book value' of the owned product, even without actual performance or aesthetic losses (Okada, 2001, 2006). Products and their values are mentally written off by the consumer during ownership. Based on the initial purchase price, consumers have expectations about how long a product should last. They incorporate this in their trade-offs, resulting in a greater tendency to replace 'older' products as they have made their money worth it. Consumers may also adjust their product value preferences over time, because of the introduction of new product features. The greater the dissimilarity of the features and appearance of the owned product compared to the new product, the more likely consumers will replace it (Okada, 2006, Sohn et al., 2019). Finally, trade-in promotions influence the likeliness to replace a still-functioning product (Okada, 2001), and therefore can provide the final push in the decision to replace.

To reduce premature obsolescence of products, the value of the currently owned product should be kept as high as possible to resist the attraction of the value of new products in the market. This can be realized by either sustaining the current value of the owned product or by increasing it (Van den Berge et al. 2021). Sustaining the owned product's value implies that potential value reductions in time resulting from repeated usage are either prevented from occurring or can be easily fixed if they occur. Furthermore, the relative value of the owned product can be sustained if consumers expect the product to last for a longer time. If consumers expect a product to have a long life, they will increase the time to mentally write off a product, making a premature replacement less likely as the product has not yet made its money worth. If the mental book value of a product is reduced more slowly, the decision to replace it is thus more likely to be postponed. Increasing the value suggests that the owned product's value is improved in comparison to its original performance. This can make the owned product a more appealing alternative for consumers and lower the relative value of new products.

Table 1 provides an overview of the different design guidelines and shows how each design guideline will influence the value of the owned product and in turn the value trade-offs in consumers' replacement decision process.

Table 1: Overview of design guidelines and how these influence the relative value

Value of owned product	**Design Guideline**
Sustain functional value	1. Use a physically durable design that will be less likely to break down
Sustain functional/emotional value	2. Support the user in repairing the product when it is (partly) malfunctioning
Sustain functional value	3. Provide extended warranty possibilities
Sustain functional/emotional value	4. Support the user in maintaining the product in the correct way
Increase functional/emotional/ epistemic value	5. Support the user in upgrading the product
Sustain emotional value	6. Select materials for the product that will remain positively evaluated over time
Sustain emotional value	7. Use a timeless design (aka classic design) for the appearance of a product
Increase emotional value	8. Use an emotionally durable design that will trigger an irreplaceable bond
Increase social value	9. Encourage a long life by making it socially desirable
Sustain mental book value	10. Encourage a long life in the entire customer journey

4 Design guidelines

4.1 Use a physically durable design (aka classic design) that will be less likely to break down

4.1.1 A durable design that prevents failure

According to the recently published standard EN 45552:2020[1], the term "durability" is defined as the "ability to function as required, under defined conditions of use, maintenance and repair, until a limiting state is reached". The first design guideline that designers and companies can use to sustain the functional value of the owned product is to implement a product with a physically durable design (Den Hollander et al., 2017; Mugge et al., 2005; Van Nes and Cramer, 2005). A physically durable design is made up of materials and components that are more robust and are less likely to break down or show signs of wear and tear. In other words, there has been special attention to designing the parts and components so that they are reliable and less likely to be damaged. Damaged parts and components will negatively affect the product's performance, lower the total value of the product, and trigger a replacement need. On the contrary, if the product is less likely to break down, the consumer is less likely to be confronted with a loss in its functional value and thus the relative value of the owned product will be high for a longer period of time. In many cases, a durable design will influence the product's functional value. However, if the durable design is also less likely to show signs of wear and tear, it can also help to sustain its aesthetic value (cf. guideline 6)

An example of a durable design is illustrated in Figure 2. This Kyocera smartphone is made of a mix of polycarbonate and thick rubber and as a result, it is less fragile than most smartphones. Of course, it is not possible to create a smartphone that is indestructible, but via changes in the design it is possible to create a more durable smartphone that can withstand repeated drops to the ground, and that is shockproof and waterproof.

Figure 2: Example of a physically durable smartphones (https://www.mbreviews.com/toughest-smartphones/#show7)

[1] https://standards.cen.eu/dyn/www/f?p=204:110:0::::FSP_PROJECT:65712&cs=172013EBF93BAB457F0700C444181FD03

Another example is illustrated in Figure 3. L'increvable is the first washing machine that was designed to last due to a durable design that is also repairable (cf. guideline 2) and upgradable over time (cf. guideline 5). The washing machine is inspired by the professional world. Its frame is sized to last decades, it possesses a stainless-steel drum, a brushless engine and the heating element has an anti-calc technology. The project is however currently suspended due to a lack of investments.

Figure 3: Example of a physically durable washing machine – L'increvable https://www.lincrevable.com/en/

4.1.2 Value of durable design for alternative ownership (renting and pay-per-use models)

Today, most products are directly sold to consumers, thereby providing them with the ownership of the product. However, from an environmental perspective, interest is growing in alternative ownership models, in which consumers gain access to the product but do not necessarily own the product (Edbring et al., 2016; Tukker, 2004, 2015). Some business models such as renting or pay-per-use are indeed likely to encourage the use of products that are physically durable (Bocken, Mugge, Bom& Lemstra, 2018). An example is the BlueMovement of Bosch in which consumers obtain a subscription for various household appliances (e.g., washing machine, dryer, refrigerator) and pay a monthly fee for using them. Another example is Homie, illustrated in Figure 4, which is a Dutch company offering pay-per-use services for household appliances.

Such product-service systems (PSS) may result in longer product lifetimes because of several changes in product use. First of all, durable appliances are often very expensive to purchase, and renting and pay-per-use models enable consumers to enjoy the functions of a (high-quality) appliance without having to spend the initial purchase price. In addition, these PSSs may enhance repair because the company is responsible for keeping the products functioning and thus the consumer is less likely to weigh the costs and effort of repair (cf. guideline 2 on repair) with the benefits and costs of purchasing a new product. When the product is malfunctioning, the consumer will simply call the service helpdesk and the company will try to repair the product to keep the costs of the (sustainable) business model as low as possible. Second, when consumers terminate the subscription contract, the product can easily have a second (and third, etc.) life via another subscription, thereby again preventing premature obsolescence of the product.

Implementing a durable design is valuable for companies that are offering such alternative ownership models. A durable design would lower the costs of repair and increase the chance that the product can be used for an extended usage period. The longer a product can be used, the more profit will be obtained from the subscription.
One limitation that should be mentioned is that PSSs are interesting for certain consumer segments. However, other segments see important barriers that are difficult to overcome (Edbring et al., 2016). For example, from a financial perspective, it is often cheaper for consumers to purchase a product themselves. In addition, consumers may desire a new product and therefore not be willing to accept a used, refurbished product in a subscription contract. Furthermore, renting products might also make consumers less concerned about handling the product with care, because they do not own the product.

Figure 4: Homie – Pay-per-use services for household appliances

4.1.3 A durable design that increases the lifetime expectancy of the product

In addition to influencing replacement due to actual failure, a durable design can indirectly prevent premature obsolescence via the expected lifetime of a product. As explained in the replacement decision process (Van den Berge et al., 2021), consumers have expectations about the lifetime of products, which are transferred into the product's mental book value. Findings from our qualitative interview study among Dutch consumers confirm this by showing that expectations about the lifetime can influence actual lifetimes (Van den Berge et al. 2023a). If consumers expect the product to last relatively longer, for example because it looks very reliable and robust (Mugge et al., 2018), the reduction in mental book value will thus slow down over time. In other words, it will take more time before consumers perceive that the product has made its money worth, which can also prevent premature obsolescence.

4.1.4 Point of attention for durable designs

Finally, it is important for designers to consider the fact that durable designs can also have a potential negative effect on consumers' preferences. Robust and massive shapes may not be aesthetically appreciated by all consumer segments. In fact, Snelders et al., (2014) suggested in their study that 'tough' designs that show similarity in the design characteristics (e.g., massive, and solid appearance) of physically durable designs are mostly preferred by lower educated consumers. For other consumer segments, the low aesthetic appreciation may thus prevent adoption of physically durable designs if it is shown in the appearance.

4.2 Support the user in repairing the product when it is (partly) malfunctioning

The second design guideline that can be used to sustain the functional value of the owned product is to support the user in repairing the product when it is malfunctioning (Den Hollander et al., 2017; Mugge et al., 2005; Van Nes and Cramer, 2005). Consumers often decide to replace products because they have a minor defect or are malfunctioning (see deliverable 2.6 for more details). As a result of the (minor) defect, the product's functional value is decreased, thereby negatively affecting the value trade-off, which can eventually result in a replacement decision. In order to prevent premature obsolescence, it would be worthwhile to encourage consumers to repair their products, thereby sustaining the functional value of the owned product.

Even though from an economic perspective, repair should generally be preferred over replacement (Brusselaers et al., 2019), many consumers do not consider repair as a viable option for many products and see many barriers, such as high price of repair, lack of spare part availability, lack of repair knowledge, lack of tools, and lack of time (Ackermann et al., 2018; Sabbaghi et al., 2017; Sabbaghi and Behdad, 2018). As a result, encouraging repair would imply a behaviour change. In the literature on behaviour change (e.g., Fogg, 2009), it is suggested that people change their behaviour if they are motivated to change, have the ability to change, and if there is a trigger. Motivation and ability jointly influence the likelihood of a behaviour change in a way

that when motivation is low, the ability to perform the behaviour should be high. Translating this behaviour theory to a repair situation suggests that a trigger is likely to be there in terms of the product's reduced performance. Consequently, designers and companies should stimulate both motivation and ability in order to encourage repair behaviours (Ackermann et al., 2018).

4.2.1 Increasing motivation to repair products

Emphasizing the financial value of repairing

In order to feel motivated to repair their products, consumers should see the value of repairing the product in comparison to replacing it by purchasing a new product. If designed well, repairing can bring about various types of values to consumers. First of all, repair can bring about financial value as there is no need to purchase a new product. Nevertheless, the financial value gained by repair strongly depends on how much costs are involved with labour and components that are needed for the repair. It is important to make components that are fragile and more likely to break down (priority parts) easily accessible so that repair can be fast and relatively cheap. Also, spare parts should not be too expensive to make repair economically interesting in comparison to replacement. The appropriate price of spare parts depends on the age of the product, slowly reducing annually (Sabbaghi and Behdad, 2018).

Stressing the environmental benefits related to repair

In addition to financial value, repair can also bring about environmental value and fit with people's positive attitude toward longevity (Ackermann et al., 2018). Unfortunately, many consumers are not aware that repair is the more desirable option from an environmental perspective. It would thus be worthwhile to communicate this to make consumers aware of the environmental value of repair. For consumers who have a higher environmental concern, this awareness may increase their motivation for repair.

Repair as an enjoyable activity

Repair may also provide value to consumers because they consider it fun to do. At the moment, most people perceive repair as time-consuming and troublesome, limiting their tendency to perform these activities, which was confirmed by our qualitative findings showing a discouraging attitude towards potential future repair (van den Berge et al. 2023a). However, by purposefully designing the repair context in such a way that consumers enjoy it and potentially feel proud of the repair result, the motivation to do so will increase (Ackermann et al., 2021). An existing example of an enjoyable repair context is repair cafes (Madon, 2021). Some consumers greatly enjoy collaborative repair activities, thereby increasing their motivation to repair malfunctioning products.

Finally, designers and companies may design repairs in a way that the end result will exceed the original value of the product (Ackermann et al., 2021). An example of such a repair activity is the Japanese repair technique Kintsugi (see Figure 5). With Kintsugi ("golden joinery"), broken pottery is repaired by using glue mixed with powdered gold, silver, or platinum. Rather than hiding the repair activity, Kintsugi treats it as a part of history. The end result is pottery that is more aesthetically appealing but that has also gained more emotional value. Understanding this consequence of the repair activity may also boost consumers' motivation.

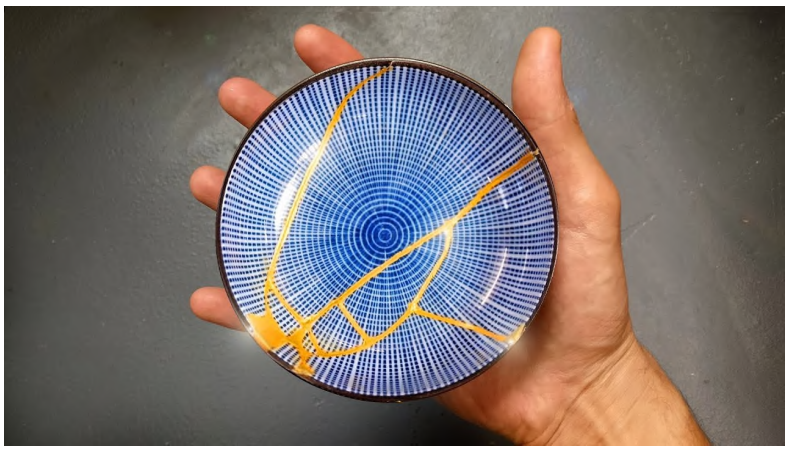

Figure 5: Kintsugi repair technique

4.2.2 Increasing ability to repair products

Next to being motivated, consumers need to be able to repair their products. Ability to repair depends on the product design, and the consumer.

Decreasing the effort for repairing a product

First, the product should be designed in a way that it is possible and easy to repair it. In this respect, ability is increased if the product is easy to disassemble, and frequently malfunctioning components are easily accessible, using standard tools (cf. Deliverable 4.5). For example, glued connections/parts in many of today's smartphones may greatly complicate the opening of the product, making repair more time-consuming and expensive. A possibility is to have a modular design (Bonvoisin et al. 2016), which is made up of modules or building blocks. By replacing these modules with new ones, it is possible to easily replace certain malfunctioning or damaged components/ parts of the products. For example, Fairphone offers a smartphone with a modular design that only takes a few minutes to completely disassemble. If repair takes less time and effort, the ability to repair will increase. It is important to note that designers should balance the size of the modules and their price. When bigger modules are used, prices will increase, therefore decreasing the consumers' willingness to replace these modules. Furthermore, there might be a trade-off between better reparability through increased modularity and the reliability of the device (e.g., protection from water and dust ingress, shock resistance, etc.).

In addition, even though modular products are physically designed to be repaired, this does not guarantee that consumers will act accordingly (Makov&Fitzpatrick, 2021). While earlier research demonstrated promising results with current modular smartphone users (Ahmend et al, 2022), these findings may not reflect the average consumer because modular products are not (yet) the norm. For WP5, we conducted an experimental study with washing machines and smartphones to test the effect of modularity on consumers' likeliness to repair. The first study showed that a modular design increased the general likeliness to repair and decreased the task difficulty compared to a conventional design. Interestingly, the likeliness to use professional repair increased, while the likeliness to DIY repair remained low. To investigate how to encourage consumers to execute DIY ('do-it-yourself') repair on modular products, we conducted a second experiment with smartphones by adding two different design cues (i.e., a notch on the outside and icons on the inside). These design cues had the objective of actively guiding the user with the repair action. The results showed that for DIY repair, consumers also need guiding support to repair, and thus for a product being technically repairable is not enough. The findings of this study will be published for in PLATE 2023 conference proceedings (van den Berge et al. 2023b) and implemented in the repair-related testing criteria of PROMPT.

Availability and price of spare parts
The unavailability and the high price of spare parts often constitute a major barrier to repair. Consequently, to increase the ability of consumers to repair their products, companies may give the supply of spare parts for their products at a reasonable price (i.e., which is proportional to the initial purchase price) which is a central place in their business model. As an example, Seb, a French brand of cookware, is committed to a ten-year repairable product (Figure 6).

Figure 6: Seb's 10-year repairable products (https://www.groupeseb.com/en/reparability)

Next to having revamped the design of their products to make them easy to dismantle, they ensure the repairability by providing spare parts at a low price, available 10 to 15 years after the discontinuation of the product and delivered in 24 to 48 hours in Western Europe (cf. Figure 7). In addition, they have relations with a significant network of trained repairers while ensuring optimal regional coverage.

Figure 7:Seb's central warehouse in Faucogney (Fr) where nearly 6 million spare parts are ready to be delivered.

Figure 8: Example of a vacuum cleaner clip 3D-printed during a repair Masterclass of the Sharepair project[1]

3D printing

3D printing can also offer opportunities to improve the reparability of products when spare parts are not available anymore. Companies offering the on-demand 3D printing of spare parts both simplify their inventory management and increase availability to lifetime. Some companies, such as Seb, offer these services. The NWE-Interreg project Sharepair (illustrated in Figure 8) is another example that aims to scale-up citizen repair

[1] https://www.nweurope.eu/projects/project-search/sharepair-digital-support-infrastructure-for-citizens-in-the-rep air-economy/events-and-activities/3d-printing-for-repair-masterclass/

initiative using digital tools. The tools developed in the project target both consumers at home and more skilled repairers in repair cafés. They map and guide citizens towards high-quality professional repair services, and assemble, with the help of designers, a database of 3D-printing designs (open-source) for printing replacement parts.

Easy diagnosis of faults

Second, our qualitative findings confirm earlier research that showed consumers often do not have the required knowledge and skills to repair products and feel it is unsafe to do it themselves. Many consumer durables have electronic components for which it is difficult to determine the fault that is causing the product's malfunctioning. As a result, consumers often do not know what exactly is wrong with a malfunctioning product and obviously also do not know how to fix it, resulting in a lack of confidence in the repair process (Van den Berge et al. 2023a). A failure to diagnose the fault thus lowers consumers' ability to repair it, which may result in a preference for replacement. For designers and companies interested in preventing premature obsolescence, it is important to search for ways to provide consumers with more guidance in the fault diagnosis to initiate repair. For example, it would be valuable if products communicate the most frequently occurring faults directly to the consumer. Figure 9 presents an example of a Miele washing machine that shows a common error on the display. Consumers can then use the (online) manual to obtain a step-by-step guidance on how to proceed to tackle this fault successfully. The easier it is to obtain such a step-by-step guidance, the greater the ability to repair.

Figure 9: Fault diagnosis on a Miele washing machine

To further investigate the impact of easy fault diagnosis on the willingness to repair products, we tested the effect of a fault indication in an experimental setup. Our results showed a significantly higher willingness to repair coffee makers, handstick vacuum cleaners, and cylindric vacuum cleaners, when a fault indication was present, which is explained by a higher level of perceived self-efficacy (i.e., ability to repair). However, this result was not significant for washing machines. In our experiments, we showed that a fault indication mainly increases the likelihood to repair products that are relatively less likely to be professionally repaired, such as coffee makers and (handstick cordless) vacuum cleaners because the fault indication then helps the user to diagnose the problem and initiate repair. Nevertheless, for products that are professionally repaired, such as washing machines, the repairer is expected to diagnose the problem. Diagnosis usually takes significant amount of time during professional repair, so fault indication potential eases professional repair process, which may in-turn decrease the overall repair price but needs further research attention. Nevertheless, it is important to mention that the overall willingness to repair a washing machine was relatively high compared to the other product categories.

All in all, we can conclude that a fault indication is generally an effective method to increase users' willingness to repair failures that are less prone to be professionally repaired and is therefore embedded in the testing programme as a criterion within repairability, cf. Deliverable 5.3 (and 6.3). More information about the

conducted experiments can be found in deliverable 5.2 and the scientific paper about the experiments published for the DRS 2022 conference (Van den Berge et al. 2022).

Services offered by professional repairers

It should be noted that 'design for repair' does not necessarily imply that repair is conducted by consumers themselves. Companies may offer or team up with professional repair services that can help to execute the repair. However, similar barriers may be relevant for these services. Consumers will only contact repair services if they have confidence in a successful repair that is not too expensive. Furthermore, other service characteristics, such as the time needed for repair, the responsiveness of the helpdesk, and the availability of a temporary replacement product can increase the likelihood to use these services.

Finally, ability to repair is increased if other third parties are also allowed to perform repair activities and are offered professional repair guides by the OEM.

4.3 Provide extended warranty possibilities

The third guideline to sustain the owned product's value is to provide extended warranty possibilities. As discussed above, many consumers experience significant barriers for repair. However, consumers will have a different attitude towards repair if the malfunctioning takes place within the warranty period. Then, manufacturers will generally repair the product without any costs involved for the user. As a result of this free repair, consumers' value trade-off (see Figure 1), in which the costs and value of the currently owned product is compared with that of a potential replacement product, is more likely to rule in favour of the currently owned product.

The legal warranty period is two years, but manufacturers can also offer extended warranties. An example is Bosch which provides consumers with special offer and extends the two-year legal warranty by a further three years (see Figure 10) to a total of five years on selected Bosch appliances. By extending the warranty possibilities, consumers will be more inclined to repair their products and thereby prevent premature obsolescence. This was confirmed in our qualitative interview findings, which showed that if a product failed during warrantee, the users will be more likely to have it repaired because the costs are covered (Van den Berge et al. 2023a). Furthermore, an extended warranty may be considered as an (additional) incentive to choose for this specific brand and thus serve as a promotion strategy.

Figure 10: Extended warranty of Bosch appliances

4.4 Support the user in maintaining the product in the correct way

The next design guideline that designers can use to prevent premature obsolescence is to design for maintenance. According to EN 45552:2020, maintenance is defined as an "action carried out to retain a product in a condition where it is able to function as required". Product maintenance (aka as product care) consists of activities of care and maintenance as well as other protective measures (e.g., a smartphone cover) that can keep the product in a proper working condition for a longer period of time (Ackermann et al., 2018; Den Hollander et al., 2017).

4.4.1. Supporting user to remain products' physical functionality

By supporting the user to take good care of their products, the functional value of the product can be kept at a high level for a longer period of time. Furthermore, proper maintenance can positively affect the emotional value as it can result in a better preservation of the aesthetics of products.

Maintenance differs from repair in the way that it addresses the functional value of the owned product. Whereas regular maintenance can prevent the product's functional value to drop, repair can solve a defect and thereby return the reduced functional value of the product to its original state. We acknowledge that there might be an overlap between maintenance and repair. For example, a coffee maker that needs decalcifying may mistakenly be interpreted as 'broken' by the consumer and be prematurely replaced, even though simple maintenance activities could have solved this problem.

For most products, some advice on maintenance activities is provided. For example, in online or physical manuals or labels (e.g., for clothing items) specific care instructions are generally provided to consumers. Unfortunately, many consumers still fail to execute maintenance activities on their products on a regular basis (Ackermann et al., 2018), often resulting in a premature loss of value. This implies that design for maintenance should not only focus on providing instructions on how to execute maintenance activities but also on truly supporting users to do this when the time is right.

People only take proper care of products when they are motivated, have the ability to take care (in terms of time, expertise, and money) and experience a trigger to do so (Ackermann et al., 2018). All three factors (motivation, ability and trigger) should be present in order to change one's behaviour and designers should thus pay attention to all three when designing for maintenance (Fogg, 2009). Several detailed product care strategies have been proposed to encourage people to perform maintenance activities for their products (Ackermann et al., 2021). For example, motivation can be enhanced by making maintenance activities more enjoyable or by doing these activities in a social context. A better understanding of the value of maintenance for increasing the product lifetime may also increase motivation. Ability can be improved by not only informing users about maintenance, but by for example explaining it step by step via physical information on the product. Manuals are often lost, which represents a barrier for performing maintenance activities, whereas the product interface can also be used to communicate to users about them. In addition, the necessary equipment and supplies for maintenance should be easily available and not too expensive to increase users' ability. Finally, push messages are an example of a trigger that can remind users of required care activities at the right moment in time.

It is important to mention that with providing support to users, we do not only mean helping consumers to perform maintenance activities by themselves. Regular maintenance service can also be provided by professional service companies (e.g. via a maintenance contract). Such maintenance services are already common for heating system and cars but could also be valuable for other products. Especially for products that are difficult to maintain because it would require technological equipment and/or knowledge, regular maintenance services can provide a solution to keep the product's value at the original high level.

4.4.2 Supporting users with maintaining software via updates

Software updates can also enable consumers to keep the functional value of their products at a high level. Software updates consist in small, frequent improvements that happen on the existing software programmes

of a product. Updates are needed for many products to continue running successfully during usage, because they fix, for example, new security issues, recently discovered bugs and add support for newly developed hardware that should communicate with the product (e.g., communication between smartphone and a car's audio system). Updates thus make sure that the functional value of the product is maintained throughout time. The discontinuation of software support represents an important source of obsolescence for smart products. In this case, the hardware can still be functional but with a lack of updates, the system may become vulnerable to security threat or may not support the Internet leaving the device unusable for its user. Companies aiming to prevent premature obsolescence should thus offer users an update guarantee that enables users to frequently update the product throughout its entire life.

Making the software updates and upgrades available is the first step. However, companies should actively persuade consumers to make use of these updates by encouraging their motivation and ability and by providing triggers that the appropriate time for an update has arrived.

4.5 Support the user in upgrading the product

4.5.1 Enabling physical upgrades

Physical upgrades consist in raising a product's performance to a higher standard by adding or replacing physical components in the product. According to EN 45554:2020, an upgrade is defined as "process of enhancing the functionality, performance, capacity or aesthetics of a product". An upgrade to a product may involve changes to its software, firmware and/or hardware. Thus, upgrades can be related to the appearance of the product or to its functionalities. Upgradeable products are modular and provide options to improve certain modules / components/ parts in the future (Michaud, Joly, Llerena, & Lobasenko, 2017), and therefore represent a product lifetime extension strategy (Khan, Mittal, West., 2018). Upgradeability is also referred to as evolvability (Haines-Gadd, Chapman, Lloyd, Mason, Aliakseyeu , 2018) and entails designing products that can have different phases of use and adjust to developing needs and/or technology with more advanced parts and additional functionalities. By doing so, upgradeability enables to sustain the product's functional and epistemic values and can persuade consumers to retain the owned product longer. Upgradeability can also enable to improve the physical appearance of a product thereby improving the emotional value attached to it. While past research proposed upgradeability as a valuable strategy and consumers express positive attitudes to upgradeable products (Ülkü, Dimofte, & Schmidt, 2012; Sabbaghi, Cade, Behdad,&. Bisantz, 2017; Brusselaers, Bracquene, Peeters, & Dams, 2019); product upgradeability remains rather underdeveloped in the market.

However, there are some notable examples of upgradeable products, such as the Framework laptop and the Fairphone 3+. The Framework laptop illustrated in Figure 11, is completely modular, and the entire mainboard can be swapped to boost performance as updated versions are launched with new CPU generations. The company also claims that they will release new upgrade modules regularly and that they are opening up the ecosystem to enable a community of partners to build and sell compatible modules through the Framework Marketplace.

Figure 11: Framework laptop

Figure 12: Modules for Fairphone 3+ including upgraded camera modules

The Fairphone 3+ (cf. Figure 12) is the upgraded version of the Fairphone 3. It comes with two new camera modules and audio improvements, which improve the technical performance of the phone. The new camera modules are also sold separately, so that owners of the Fairphone 3 can upgrade their device by replacing the modules.

4.5.2 Supporting software via upgrades

Next to maintaining software updates (cf. Guideline 4.4.2) companies can also provide software upgrades to consumers that provide significant improvements. A software upgrade is a new version of the software that incorporates new functionality. The software upgrade will thus supersede the functionality of the old product. In other words, the product's functional value is increased as a result of the software upgrade. Next to functional value, a software upgrade can make the product feel 'new' and thereby provide epistemic value. An example is a new user interface with several new features for the product.

4.5.3 Select materials for the product that will remain positively evaluated over time

Products can offer emotional value to consumers via their aesthetics (Sheth et al., 1991). In most situations, signs of wear and tear resulting from using the product decrease its aesthetic value because people perceive scratches and usage signs as unattractive and less desirable. A study on consumer response to vacuum cleaners demonstrated that a dirty appearance would decrease its lifetime (Harmer et al., 2019). Over time, signs of usage may thus lead to premature replacement and there is a need for products' aesthetics to be resilient towards wear (Haug, 2018). In order to prevent premature obsolescence, it is therefore important to select materials that are not easily damaged or contaminated during use, and that are easy to clean so that the aesthetic value for the user is sustained over time.

Another new technological opportunity that is gaining more interest in this field is the use of self-healing materials and coating. Self-healing materials and coatings have a built-in ability to automatically repair damages to the material surface, such as wear and tear or scratches (Chang et al., 2020; Sumerlin 2018). For example, applying these materials in smartphones would help to mend broken screens.

In the selection of materials, it is also interesting to consider the effect on the expected lifetime of the product. As indicated before, the mental book value of a product depends on the expected lifetime. By using materials in a product that are perceived as more durable (e.g., metals rather than plastics), consumers may unconsciously lengthen the time to write off a product, thereby sustaining its value for an extended period.

Finally, past research has also explored other possibilities to prevent this decrease in aesthetic value, for example, by embodying products in materials that tend to wear gracefully over time, such as leather, bamboo or wood (Lilley et al., 2016, 2019; Mugge et al., 2005). Although these materials do change, this change is often considered appealing and interesting, thereby sustaining the aesthetic value of the owned product.

Next to materials that are stable over time or age gracefully, solutions to restore the initial appearance of a product could be provided to consumers and would enable to increase the aesthetic / emotional value of an owned product. In the garment industry, Patagonia provide their customers with sweater stones to restore the appearance of their clothes (see Figure 13).

Figure 13: Patagonia employee explaining how to remove pilling with the sweater stone 'How to better your sweater' https://www.youtube.com/watch?v=2aFbPb6Rn8o

4.6 Use a timeless design (aka classic design) for the appearance of the product

Products can also loose (some of) their aesthetic value as a result of fashion style changes. In time, consumers' preferences regarding aesthetics change. However, not all styles are equally susceptible for moving to a state of distaste. Some styles enjoy a short-lived popularity and disappear quickly, while others continue to be popular and remain accepted over a long period of time. By implementing a design that is less susceptible to fashion changes, such as a classic or timeless design, the aesthetic value of a product can be sustained for a longer period of time (Flood-Heaton and McDonagh, 2017; Mugge et al., 2005; Wallner et al., 2020).

Timeless or classic designs are visually simplistic, ordered and harmonious. Furthermore, timeless designs generally make use of neutral colours, such as black, white and grey. Because this design style adheres to people's evolutionary desire for symmetric and simple appearances, it is generally preferred across social groups and endures throughout time (Snelders et al., 2014; Veryzer and Hutchinson, 1998).
Although we acknowledge that it is probably impossible to create a truly timeless design, as all products are in a certain sense susceptible to fashion cycles, paying attention to this design guideline can help designers to avoid product appearances that are likely to be short-lived as they make use of fashionable colours or eccentric shapes (cf. Figure 14 Figure 15). A famous example of a timeless design in furniture is the Barcelona Chair. Since its launch in 1929, this chair has remained aesthetically appealing for many consumers (cf. Figure 16).

Figure 14: Yellow and blue iPhone XR

Figure 15: Miele 41GFE036USA Complete C3 Calima Canister Vacuum, Canary Yellow

Figure 16: Barcelona chair

Product form is a delicate topic when it comes to premature obsolescence. The change in product form at each introduction of new product makes the previous product look old in comparison, which may decrease the emotional value that is attached to it and its mental book value. It is therefore advised to use a timeless design to decrease satiation for the product appearance, and to combine it with an upgradable design (cf. Guideline 5).

4.7 Use an emotionally durable design that will trigger an irreplaceable bond

Product attachment can be defined as 'the strength of the emotional bond consumer experiences with a product' (Schifferstein & Zwartkruis-Pelgrim, 2008; Mugge et al., 2009). Literature has underlined the role of strengthening the person-product relationship to prevent the premature replacement of products (Chapman, 2009; Chapman, 2015). Individuals become attached to products that have a special meaning to them, which gives these products an extra emotional value (Mugge et al. , 2005). When individuals are attached to their products, they tend to maintain them and have a higher willingness to repair them, resulting in longer lifetimes (Page, 2014; van Nes & Cramer, 2006).

Several determinants of product attachment exist, such as memories, self-expression, group affiliation, and pleasure (Schifferstein & Zwartkruis-Pelgrim, 2008; Mugge et al.,2008). Memories and self-expression are recognized as most influential for product retention because these may bring about irreplaceable possessions (Grayson & Shulman, 2000), which suggests that the special meaning is not present in other products and replacement would thus imply that the product's unique emotional value is lost (Schifferstein & Zwartkruis-Pelgrim, 2008; Mugge et al., 2005; Grayson & Shulman, 2000). Memories suggest that products can serve as a reminder of a person or past event. The narratives that such products provide can trigger deep emotional bonds, and products can even obtain an heirloom status (Chapman, 2015; Jung et al, 2011). Consequently, individuals tend to keep products that are associated with memories for a longer period of time (Schifferstein & Zwartkruis-Pelgrim, 2008 ; Niinimäki & Hassi, 2011). Even though memories often develop automatically, products can also actively invite individuals to form associations by offering a context or activity to reflect, thereby stimulating emotional value (Casais et al, 2018). Furthermore, research demonstrated that it is possible to bring emotional value to products by using life stories for embodying significant aspects of a person's identity in the design (Orth, Thurgood, van den Hoven, 2018). People can also develop irreplaceable

attachments to products that express their identity. Such self-expression can be triggered via product personalisation (Niinimäki & Koskinen, 2011). By personalising products via DIY-activities, individuals attach self-expressive value to the product, which in turn strengthens their emotional bond (Jung et al., 2011; Mugge et al. 2009; Niinimäki & Koskinen, 2011; Armstrong, Niinimäki & Lang, 2016). An example of a product that is personalized and shares an important part of the owner's personal history is the Concept Lamp in Figure 17 (Padro, 2014). The front of this lamp is covered in black paint. The user is expected to scratch lines in this paint, based on the height of their children. Keeping track of the height of one's children is a common routine for many families with children. By integrating this activity in the design of the lamp, in time a unique, emotionally laden object is created that is considered irreplaceable to its owner. Replacing this lamp with another one would imply that the emotional value (visualized by the growth of the children) is lost.

Nevertheless, we would like to argue that it is often challenging to purposefully design for attachment. First of all, there are only so many products one can be attached to. Second, even though many people claim to be attached to their electronic products (e.g., smartphones), they are mostly attached to their functionality and digital content. Both can easily be taken over by new electronic devices. It remains difficult to design products that will embody a deep emotional value that cannot be replaced by another product.

In addition, although emotionally durable design has been repeatedly highlighted in the literature as promoting longer life for the products, recent literature pinpointed specific cases where emotional attachment to products can negatively influence the environment. People may choose to keep an object of attachment in ownership although it has been functionally replaced by another (Haws et al., 2012). Such product hibernation (Bakker et al., 2014) can have negative environmental consequences because it prevents usable goods to have a useful second life or be recycled. Additionally, unemotional design has recently been advocated as a strategy to remove the emotional aspects linked to conspicuous consumption (Thornquist, 2017). By doing so, consumers would acquire emotional detachment to products and in turn more sustainable consumption patterns.

Figure 17: Concept lamp (designed by Padro, 2014)

4.8 Encourage a long life by making it socially desirable

One of the most powerful leverage to shift individuals to behave sustainably is to use social influence (White et al., 2019). Prior literature has demonstrated that social factors are among the most influential factors in terms of effecting sustainable consumer behaviour change (Abrahamse and Steg 2013). Currently, social norms do not conflict with the high pace with which consumers replace their products. Next to the functional and emotional values attached to consumption, choices are often related to social prestige and status. Individuals replace their products and switch to most recent product introductions for status reasons (Sivanathan & Pettit, 2010; Yoo et al., 2007).

Research has shown that the use of social norms is effective to encourage individuals to choose more sustainable options or to behave more sustainably. 'Norm-nudges' have a mechanism of action which relies on social norms, eliciting or changing social expectations. For example, simple social nudges have shown to be an effective means for suppressing harmful behaviours and for promoting a range of environmentally beneficial behaviours, such as making people reuse towels at hotels and save energy at home (Goldstein et al. 2008; Schultz et al. 2008).

In the domain of product longevity, examples of initiatives using social norms to encourage consumers to postpone replacement of their products are still uncommon. Design solutions could focus on emphasizing the social desirability of keeping products longer. A first step for that would be to stress the link between product longevity and environmental benefits (cf. Guideline 4.2.1.2.) which is not always clear to consumers and some mechanisms could be developed to foster environmental competence and social pride among consumers who keep their product longer. Findings from our qualitative interviews confirm this and imply that more awareness of environmental impact may encourage consumers to extend product lifetimes (Van den Berge et al. 2023a).

As an illustration, TU Delft graduate student Eveline Beukers (2019) has designed a sticker that consumers can place on their products and that socially encourages product longevity (cf. Figure 18). The stickers are translucent and customizable so that consumers can match the date on the sticker with the year in which their product was purchased. The sticker serves several purposes. First, it can serve as a conversation starter about the environmental consequences of premature obsolescence. The sticker also represents a public environmental statement that can lead to more commitment to keep the product for as long as possible. Finally, the date on the sticker can make people more proud of owning products for a long time and appreciate their old age.

Figure 18: Sticker socially encouraging product longevity designed by Eveline Beukers (2019)

4.9 Encourage a perception of a long life in the entire customer journey

Consumers' decision to replace a product depends on the degree to which an owned product has made its money worth. Replacement is more likely when the product has no remaining mental book value for consumers (Okada, 2001; Van den Berge et al., 2021). Therefore, this design guideline aims to sustain the mental book value for a longer period by encouraging a perception of long life in the customer journey. By encouraging such a long-life perception, the expected lifetime of a product will increase, and premature obsolescence can be prevented.

Even though it is difficult (if not impossible) for consumers to give detailed estimations of the lifetime of products, the expected lifetimes differ between brands and models (see D.5.2: Premature replacement of well-functioning products and choice for replacement over repair). For example, most consumers tend to associate a Miele washing machine with much longer lifetimes than the brand Beko. Consequently, the mental book value of a Miele washing machine will decrease with a slower speed than that of a Beko washing machine. As long as consumers feel that the product has not yet made its money worth, they may be more likely to retain it, thereby preventing premature obsolescence.

Triggering perceptions of long life can be done in different ways. One possibility is to actively communicate the long life of products in advertisements. Figure 19 illustrates a Miele ad in which it is suggested that a Miele washing machine is built to last 20 years. Such ads will influence the mental book value of these washing machines with users. For example, in case a defect occurs after 10 years, they will still be more likely to try repair.

Figure 19: Advertisement of the long life of Miele washing machines.

When designing products that will have a long lifetime, it is also important to consider the degree to which the components and design are future proof. For example, products may require specific connections to other products. If these connections change, it should not be required to change the entire product. For example, modular components can help consumers to update products throughout their long lifetime (cf. guideline 5, figure 20).

Another marketing aspect that companies should pay attention to when aiming for a 'long life' strategy is that they should carefully think through the timing of new product models. Especially for products that have a social value (e.g., smartphones, laptops, TVs), certain groups of consumers (e.g., innovators and early adopters) have a strong need to stay up to date and thus own the latest model (Sahin, 2006). The introduction of a new

model may then increase consumers' perception that they own an outdated model, thereby suddenly reducing the currently owned product's mental book value. This phenomenon is evident for smartphones where, for example, the new iPhone model attracts a lot of attention from the media, resulting in substantial sales of this new model and thus premature replacements of the older models. A slower substitution of product models can prevent these effects.

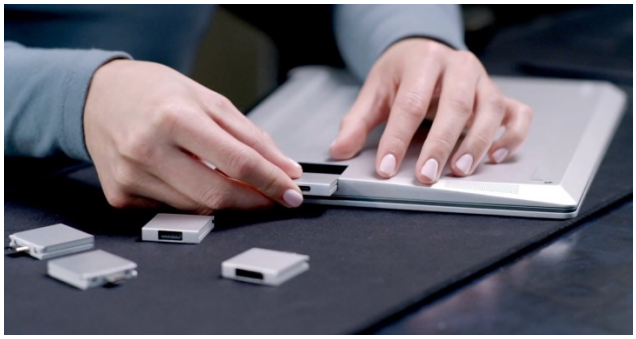

Figure 20: Modules for the USB connection of the Framework laptop

Of course, we do not conclude that companies should not introduce new models at all. Innovations can provide consumers and society at large with important benefits. However, we would like to recommend that the differences between the old and new models should be ample to warrant the substitution. Small functional changes or merely aesthetic changes should not be encouraged via the launch of a new model, but can for example, be offered to consumers via upgrading the currently owned product (cf. guideline 5).

Encouraging a long life in the entire customer journey also suggests that companies do not actively stimulate premature replacement via their promotions. A commonly used promotion strategy of many companies is to encourage sales by providing consumers with a trade-in discount for their old product (see Figure 21). By offering such a trade-in, consumers receive compensation for the remaining mental book value of the currently owned product, making them more willing to replace the product. Scientific research has shown that due to this compensation of the remaining mental book value, trade-ins are more likely to result in (early) product replacement than the same financial compensation offered as a normal price discount (Okada, 2001). To aim for a long life, we thus recommend refraining from providing such trade-ins. During purchase, it would be desirable to offer a free collection and disposal of the old device so that proper recycling will take place.

Figure 21. Trade-in promotion for TVs

A frequently mentioned comment on encouraging perceptions of long life is that this is undesirable for companies as they need to sell products to realise sales. However, this comment undermines the value of triggering a more positive brand identity as a result of these perceptions. This positive brand identity can influence future purchases of other products. The example of Miele illustrates that communicating long life can actually serve as a valuable brand strategy. Finally, certain segments of consumers are greatly aware of the environmental consequences of consuming products and search for ways to reduce them. Companies that actively tackle the detrimental effects of their products on the environment can also have a unique appeal for these environmentally concerned consumers. The success of sustainable brands, such as Patagonia, demonstrates that a brand focus on sustainability, for example via aiming for a long product life, can provide companies with a unique selling point.

5 Reflection on design guidelines

To test the importance of the different design guidelines for postponing the replacement of products, we conducted a survey among 617 European participants who had recently replaced their smartphone, TV, vacuum cleaner or washing machine (Magnier and Mugge, 2022). Data for the main questionnaire was gathered in May 2021 through an online questionnaire. The purpose of this questionnaire was to uncover whether participants considered that the design strategies to prolong product lifetime would have been effective to postpone the replacement of their old product. As some of the previous design guidelines consist of multiple underlying strategies, we adapted these in order to assess their importance from a user perspective (see Table 1). Participants were presented with a short description of each of the different design strategies and were asked to think about the extent to which the design features and behaviour could have prevented or postponed their decision to replace their product. In the instructions, we acknowledged that the proposed features may not have been present in their product but asked them to answer the question based on the assumption that they would have been.
First, strategies related to long-lasting product design were presented to participants. These strategies were durable / reliable design, upgradeable design (physical and software), design for graceful ageing (i.e. self-healing materials), and timeless design. Second, participants were presented with strategies of design for repair. These strategies consisted of extended warranty, modularity, presence of a self-repair guide, subscription to a contract including repair services, better availability of spare parts, and cheaper spare parts. Third, the strategies of design for maintenance, users' care behaviour and subscription to maintenance services, were presented to them. The extent to which they believed the strategies could have postponed the replacement of the old product was measured on 7-point Likert scales going from 1='very unlikely' to 7='very likely' for each of these strategies.

Table 1 represents the mean scores for each of the four product categories. These findings showed that overall, consumers were not truly convinced that different lifetime extension strategies could have postponed the replacement of their product with all mean values either below or close to the mid-point of the scale. While research has demonstrated that the lifetimes of many electronic products have decreased in the past decades, this decrease does not necessarily create dissatisfaction among consumers (Echegaray, 2016). This could explain the fact that consumers do not yet seriously seek ways to extend the lifetime of their products. In addition, literature has demonstrated that consumers believe that companies do not have incentives to increase the lifetimes of the products they put on the market (Echegaray, 2016). Consequently, they may lack trust that these strategies would be really effective to extend the lifetime of products. Finally, consumers often replace well-functioning products when they feel they have made their money's worth (Okada, 2001; van den Berge et al., 2021). In that case, lifetime extension strategies may not be deemed effective to postpone replacement because consumers do not perceive much value in their product anymore and are psychologically ready for their replacement.
A limitation of this survey is that we asked participants to respond to the effectiveness of these design strategies after they had already replaced the product for some time. After making such a decision, it is difficult to reconsider this choice because this may bring about cognitive dissonance with their prior choice. Cognitive dissonance is typically experienced as psychological stress when new information is perceived, which is conflicting with the person's actions, ideas, beliefs etc. To prevent cognitive dissonance, individuals usually try to find a way to resolve this contradiction and reduce their discomfort. The design guidelines may have been perceived as conflicting with the person's prior decision to replace the product, due to which participants may have reduced their discomfort by giving overall low effectiveness scores to the design strategies. Future research should aim to investigate the design strategies before the actual replacement has taken place.

Among the strategies that were considered effective, a durable/reliable design, which may help to keep the perceived value of a product high for a longer amount of time, generally seemed to be the most effective. This also confirms prior literature demonstrating that consumers have a higher preference for durability over reparability (Cerulli-Harms et al., 2018). Consumers were generally not convinced that strategies enabling them to repair their products more easily would help them to do so, which confirms prior literature advancing that consumers generally do not seek reparability in products (Bovea et al., 2018; Sabbaghi et al., 2016). Too often, consumers do not consider product repair a necessary step toward a sustainable society. Instead, they

often wrongly consider that it would be a bad investment and consider replacement as a more rational decision (Makov & Fitzpatrick, 2021).
When comparing the differences between product categories, it appeared that strategies were considered the most ineffective for the television category with all scores below the neutral midpoint. All in all, many of the strategies were considered less effective for televisions than for other product categories. This could be explained by the fact that televisions are hedonic products with evolving technology and that, nowadays, a majority of them are replaced for reasons other than malfunctioning (e.g. screen size, screen quality) (Hennies & Stamminger, 2016).

Table 1 Descriptive statistics of the effectiveness of the strategies to prolong lifetimes (7-point scales)

	Smartphones	Vacuum cleaners	Televisions	Washing Machines	Total
Durable / reliable design	**4.37[a]** (2.06)	**4.73[a]** (2.02)	**3.46** (2.05)	**4.81[a]** (2.06)	**4.34** (2.17)
Physical upgradeability	**4.31** (2.09)	3.58[a] (2.08)	**3.70[a]** (2.06)	3.44[a] (1.85)	**3.80** (2.05)
Software upgradeability	3.71[a] (2.13)	2.34[b] (1.88)	**3.68[a]** (2.26)	2.96[b] (2.10)	3.26 (2.17)
Self-healing materials	3.70[ac] (2.06)	3.07[bc] (1.90)	2.69[b] (2.02)	3.32[c] (2.04)	3.22 (2.04)
Timeless design	2.92[a] (1.94)	2.83[a] (2.10)	3.10[a] (1.96)	2.64[a] (1.89)	2.88 (1.97)
Extended warranty	3.10[ac] (2.05)	3.08[ac] (2.20)	2.78[bc] (2.13)	3.63[a] (2.28)	3.13 (2.17)
Modularity	**4.03[a]** (1.99)	3.76[a] (2.14)	3.07 (2.02)	**4.07[a]** (1.96)	**3.74** (2.06)
Self-repair guide	2.92[a] (1.89)	3.19[a] (2.08)	2.25 (1.84)	3.33[a] (2.04)	2.91 (2.00)
Subscription to repair services	2.90[a] (1.89)	2.97[a] (2.08)	2.44 (1.90)	3.61[a] (1.88)	2.96 (1.98)
Better spare parts availability	3.51[a] (2.02)	**3.81[a]** (2.18)	2.44 (1.88)	3.70[a] (2.09)	3.37 (2.11)
Cheaper spare parts	3.68[a] (2.11)	**3.88[a]** (2.20)	2.72 (2.14)	**3.89[a]** (2.11)	3.54 (2.18)
User care activities	3.37[a] (1.83)	3.38[a] (1.97)	2.39 (1.68)	3.61[a] (1.92)	3.19 (1.90)
Subscription to maintenance services	2.71[ac] (1.76)	2.89[ac] (2.05)	2.30[a] (1.75)	3.30[b] (1.81)	2.79 (1.87)

SD in parentheses
Best scores per product category in bold
Identical superscripts indicate no difference between the means

6 Conclusion

In the consumers' decision process to replace a product, consumers make a trade-off between the value of the currently owned product and the potential value of a new product. Specifically, we highlighted 5 different values relevant to the consumption of electrical and electronic products: functional, emotional, social, epistemic, and conditional. Several design guidelines were formulated based on a thorough literature analysis on product lifetimes, workshops with experts, qualitative interviews with Dutch, French, and Spanish consumers, a survey with European consumers, and various experiments. These guidelines all aim to keep these products' values as high as possible, and thus to lengthen the lifetime of the products consumers have in their possession.

The guidelines formulated in this report paved the way towards criteria regarding user and market-related factors of premature obsolescence for the testing programme developed in work package 6. In the context of task 5.3., we created testing criteria based on the formulated guidelines presented in this report. We conducted workshops with testing experts of consumer organizations who supported us in formulating the criteria. For the final testing criteria of PROMPT, the input of WP5 was incorporated during these meetings and will thus be reflected in deliverable 6.3 which presents the final list of criteria, an overview of the inclusion of the design guidelines in the testing programme is shown in table 2.

Table 2: Inclusion of the design guidelines in the testing programme.

Design Guidelines	Inclusion in the testing programme
1. Use a physically durable design that will be less likely to break down - A durable design that prevents failure - Value of durable design for alternative ownership (renting and pay-per-use models) - A durable design that increases the lifetime expectancy of the product	This guideline is included in the reliability part of the testing programme. Various stress tests (e.g. drop tests) are performed to assess the robustness of the products. It is important to note that perceived robustness and measured robustness are different concepts. Although it is arguably more subjective, perceived robustness is important because it can influence the mental book value of a product. As a result, it would ideally be integrated in the testing programme. It is however not the case in the current version of the testing programme due to the fact that it was considered difficult to evaluate in a repeatable manner. Several recommendations regarded elements that could be considered as proxy for robustness by consumers such as weight or product sound could be further tested and potentially integrated in future versions of the programme. Alternative business models are currently not included in the testing programme However, some recommendations regarding their future inclusion were formulated. Specifically, we recommend specifying that the alternative business models should have a financial incentive for consumers to keep their products longer. This could for example be shaped as a decreasing subscription fee as the products get older. Second, these business models should include free repairs and support for maintenance, as well as the free replacement of parts that can be considered consumables (e.g., such as screen protectors and batteries for smartphones). Third, we recommend that companies offering these business models should not necessarily offer new products to new customers. By doing so, refurbishment should be encouraged and the number of product lifecycles should increase. By including these aspects in testing

	criteria about alternative business models, it is possible to ensure that these models are used in a way that extends product lifetimes.
2. Support the user in repairing the product when it is (partly) malfunctioning Increasing motivation Emphasizing the financial value of repairing Stressing the environmental benefits related to repair Increasing ability Decreasing the effort for repairing a product Availability and price of spare parts 3D printing Easy diagnosis of faults Services offered by professional repairers	Motivational aspects of repair are at the moment not included in the testing programme. Ability aspects are however included in the repairability part of the testing programme, such as support in diagnosis of faults. Specifically, various aspects of the repair policy of the manufacturer are tested. These aspects concern the presence of repair manual, the price, and the availability of spare parts. In future versions of the testing programme, we also recommend a repair service network rating which would help in decreasing consumers' efforts to find a certified repairer.
3. Provide extended warranty possibilities	The availability of free extended warranties (which go beyond legal warranties) is included as a criterion in the user and market aspect part of the testing programme
4. Support the user in maintaining the product in the correct way	Various aspects of maintenance are tested in the programme such as the availability of protective supplies, the availability, and the quality of instructions for physical maintenance, the presence on the product of indicators of need for maintenance. In addition, the maintenance of software via firmware and security updates are taken into account by testing the duration of the updates availability.
5. Support the user in upgrading the product Enabling physical upgrades Supporting software via upgrades	Upgrades are not included in the testing programme as they could only take the form of manufacturer commitment. At the time of the test, only the modularity of the upgradeable products could be objectively tested, which does not ensure that upgrades would be proposed to consumers

6. Select materials for the product that will remain positively evaluated over time	Aging and wear tests are integrated into the testing programme to ensure that products would remain attractive for as long as possible.
7. Use a timeless design (aka classic design) for the appearance of a product	The timelessness of the product design is currently not integrated in the testing programme due to issues regarding the repeatability of the test. Several recommendations were formulated to include this criterion in a future version of the programme. It would then be especially important for lab testers to evaluate timelessness in a holistic manner.
8. Use an emotionally durable design that will trigger an irreplaceable bond	These guidelines are at the moment not included as criteria in the testing programme. Although emotions and social influence are likely to influence how long people keep their product, there is sparse research into how such emotional and social aspects can be effectively integrated into product design and brand communications.
9. Encourage a long life by making it socially desirable	
10. Encourage a long life in the entire customer journey Via advertisement Future proof components Timing of new introductions Avoid trade-in promotions	To encourage a long life, free extended warrantees and communication about the lifetime and durations are added as a criterion. An attention point for these criteria is to consider potential greenwashing marketing. Therefore, it is recommended to design regulations that prevent manufacturers to make invalid statements about the lifetime on their products.

The guidelines presented in this document were illustrated by examples of good practice in different fields. They can serve as inspiration for companies to develop long-lasting products thereby facing their responsibility to purposefully design against premature obsolescence and contribute to a more sustainable society.

Some of the guidelines presented in this deliverable were integrated into various testing programme sections. Although these guidelines are part of WP5 on user and market factors of premature obsolescence, it is to be noted that some guidelines have been translated in testing criteria in the reliability and repairability parts of the programme to ensure that their weight was sufficiently high, thereby corresponding to their likelihood to influence product lifetime. Details regarding the technical specificities of some of these guidelines are available in the deliverables of work packages 3 and 4. Specifically, guideline 1 proposes to use a physically durable design that will be less likely to break down and will in turn increase the actual lifetime of the product while deliverable 3.4. provides the test results and specification regarding the reliability of electronics / batteries and deliverable 3.5 provides the same for mechanics. This knowledge is complemented by deliverables 4.1 and 4.3 regarding design for physical durability. Guidelines 2 and 4 which propose to support the user in repairing the products and in maintaining the product are also complemented by analyses provided in deliverable 4.3 regarding design for diagnosis, maintenance, and repair.

Lastly, it is to be noted that at the moment of the creation of the testing programme, it was not possible to include all their aspects in the criteria of the testing programme, partly due to their innovativeness or their subjective character which could not be tested in a repeatable manner.

7 References

Abrahamse, W., & Steg, L. (2013). Social influence approaches to encourage resource conservation: A meta-analysis. *Global Environmental Change*, 23(6), 1773-1785.

Ackermann, L., Mugge, R., & Schoormans, J. (2018). Consumers' perspective on product care: An exploratory study of motivators, ability factors, and triggers. *Journal of Cleaner Production*, 183, 380-391.

Ackermann, L., Tuimaka, M. Pohlmeyer, A. E. & Mugge, R. (2021). Design for Product Care – Development of design strategies and a toolkit for sustainable consumer behaviour. *Journal of Sustainability Research*, forthcoming.

Amend, C., Revellio, F., Tenner, I., & Schaltegger, S. (2022). The potential of modular product design on repair behaviour and user experience–Evidence from the smartphone industry. Journal of Cleaner Production, 367, 132770.

Armstrong, C. M., Niinimäki, K., & Lang, C. (2016). Towards design recipes to curb the clothing carbohydrate binge. *The Design Journal*, 19(1), 159-181.

Bakker, C., Wang, F., Huisman, J., & Den Hollander, M. (2014). Products that go round: exploring product life extension through design. *Journal of Cleaner Production*, 69, 10-16.

Baxter, W., Aurisicchio, M., & Childs, P. (2017). Contaminated interaction: another barrier to circular material flows. *Journal of Industrial Ecology*, 21(3), 507-516.

Bayus, B. L. (1991). The consumer durable replacement buyer. *Journal of Marketing*, 55(1), 42-51.

Beukers, E. (2019).Stimulating consumers to exclusively purchase products of long-term psychological value. http://resolver.tudelft.nl/uuid:3f42c984-6566-4d30-b65e-50d3fe0def69

Bonvoisin, J., Halstenberg, F., Buchert, T., & Stark, R. (2016). A systematic literature review on modular product design. *Journal of Engineering Design*, 27(7), 488-514.

Bovea, M. D., Ibáñez-Forés, V., Pérez-Belis, V., Juan, P., Braulio-Gonzalo, M., & Díaz-Ávalos, C. (2018). Incorporation of circular aspects into product design and labelling: consumer preferences. *Sustainability, 10*(7), 2311.

Brusselaers, J., Bracquene, E., Peeters, J., & Dams, Y. (2019). Economic consequences of consumer repair strategies for electrical household devices. *Journal of Enterprise Information Management*.

Casais, M., Mugge, R., & Desmet, P. (2018). Objects with symbolic meaning: 16 directions to inspire design for well-being. Journal of Design Research, 16(3-4), 247-281.

Cerulli-Harms, A., Suter, J., Lanzaat, W., Duke, C., Rodriguez Diaz, A., Prosch, L., . . . Svatikova, K. (2018). Behavioural Study on Consumers' Engagement in the Circular Economy. Final report. LE Europe, VVA Europe, Ipsos, ConPolicy, Trinomics.

Chang, T., Panhwar, F., & Zhao, G. (2020). Flourishing Self- Healing Surface Materials: Recent Progresses and Challenges. *Advanced Materials Interfaces*, 7(6), 1901959.

Chapman, J. (2009). Design for (emotional) durability. *Design Issues*, 25(4), 29-35.

Chapman, J. (2015). Emotionally durable design: objects, experiences and empathy. Routledge.

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.

Echegaray, F. (2016). Consumers' reactions to product obsolescence in emerging markets: the case of Brazil. *Journal of Cleaner Production, 134*, 191-203.

Edbring, E. G., Lehner, M., & Mont, O. (2016). Exploring consumer attitudes to alternative models of consumption: motivations and barriers. *Journal of Cleaner Production*, 123, 5-15.

Flood Heaton, R., & McDonagh, D. (2017). Can timelessness through prototypicality support sustainability? A strategy for product designers. *The Design Journal*, 20(sup1), S110-S121.

Fogg, B. J. (2009, April). A behaviour model for persuasive design. In *Proceedings of the 4th international Conference on Persuasive Technology* (pp. 1-7).

Grayson, K., & Shulman, D. (2000). Indexicality and the verification function of irreplaceable possessions: A semiotic analysis. Journal of Consumer Research, 27(1), 17-30.

Goldstein, N. J., Cialdini, R. B., & Griskevicius, V. (2008). A room with a viewpoint: using social norms to motivate environmental conservation in hotels. *Journal of Consumer Research*, 35, 472–481.

Guiltinan, J. (2010). Consumer durables replacement decision-making: An overview and research agenda. *Marketing Letters*, 21(2), 163-174.

Haines-Gadd, M., Chapman, J., Lloyd, P., Mason, J., & Aliakseyeu, D. (2018). Emotional durability design nine—A tool for product longevity. *Sustainability*, 10(6), 1948.

Harmer, L., Cooper, T., Fisher, T., Salvia, G., & Barr, C. (2019). Design, Dirt and Disposal: Influences on the maintenance of vacuum cleaners. *Journal of Cleaner Production*, 228, 1176-1186.
Haug, A. (2018). Defining 'resilient design'in the context of consumer products. *The Design Journal*, 21(1), 15-36.
Haws, K. L., Naylor, R. W., Coulter, R. A., & Bearden, W. O. (2012). Keeping it all without being buried alive: Understanding product retention tendency. *Journal of Consumer Psychology*, 22(2), 224-236.
Hennies, L., & Stamminger, R. (2016). An empirical survey on the obsolescence of appliances in German households. *Resources, Conservation & Recycling, 112*, 73-82.
Hou, C., Jo, M. S., & Sarigöllü, E. (2020). Feelings of satiation as a mediator between a product's perceived value and replacement intentions. *Journal of Cleaner Production*, 258, 120637.
Jung, H., Bardzell, S., Blevis, E., Pierce, J., & Stolterman, E. (2011). How deep is your love: Deep narratives of ensoulment and heirloom status. *International Journal of Design*, 5(1).
Khan, M. A., Mittal, S., West, S., & Wuest, T. (2018). Review on upgradability–A product lifetime extension strategy in the context of product service systems. *Journal of Cleaner Production*, 204, 1154-1168.
Lilley, D., Bridgens, B., Davies, A., & Holstov, A. (2019). Ageing (dis) gracefully: Enabling designers to understand material change. *Journal of Cleaner Production*, 220, 417-430.
Lilley, D., Smalley, G., Bridgens, B., Wilson, G. T., & Balasundaram, K. (2016). Cosmetic obsolescence? User perceptions of new and artificially aged materials. *Materials & Design*, 101, 355-365.
Madon, J. (2021). Free repair against the consumer society: How repair cafés socialize people to a new relationship to objects. *Journal of Consumer Culture*, 1469540521990871.
Magnier, L., and Mugge, R. (2022) Are short product lifetimes ineluctable? An exploration of consumers' perceptions of lifetime extension strategies, in Lockton, D., Lenzi, S., Hekkert, P., Oak, A., Sádaba, J., Lloyd, P. (eds.), *DRS2022: Bilbao*, 25 June - 3 July, Bilbao, Spain. https://doi.org/10.21606/drs.2022.507
Makov, T., & Fitzpatrick, C. (2021). Is repairability enough? big data insights into smartphone obsolescence and consumer interest in repair. *Journal of Cleaner Production*, 127561. https://doi.org/10.1016/j.jclepro.2021.127561
Michaud, C., Joly, I., Llerena, D., & Lobasenko, V. (2017). Consumers' willingness to pay for sustainable and innovative products: a choice experiment with upgradeable products. *International Journal of Sustainable Development*, 20(1-2), 8-32.
Miller, C. J., Wiles, M. A., & Park, S. (2019). Trading on up: An examination of factors influencing the degree of upgrade: Evidence from cash for clunkers. *Journal of Marketing*, 83(1), 151-172.
Mugge, R., Schifferstein, H. N., & Schoormans, J. P. (2010). Product attachment and satisfaction: understanding consumers' post- purchase behaviour. *Journal of Consumer Marketing*, 27:271–282.
Mugge, R., Schoormans, J. P., & Schifferstein, H. N. (2008*). Product attachment: Design strategies to stimulate the emotional bonding to products*. In Product experience (pp. 425-440). Elsevier.
Mugge, R., Schoormans, J. P., & Schifferstein, H. N. (2009). Emotional bonding with personalised products. *Journal of Engineering Design*, 20(5), 467-476.
Mugge, R., Dahl, D. W., & Schoormans, J. P. (2018). "What you see, is what you get?" Guidelines for influencing consumers' perceptions of consumer durables through product appearance. *Journal of Product Innovation Management*, 35(3), 309-329.
Mugge, R., Schoormans, J. P., & Schifferstein, H. N. (2005). Design strategies to postpone consumers' product replacement: The value of a strong person-product relationship. *The Design Journal*, 8(2), 38-48.
Niinimäki, K., & Koskinen, I. (2011). I love this dress, it makes me feel beautiful! Empathic knowledge in sustainable design. The Design Journal, 14(2), 165-186.
Okada, E. M. (2001). Trade-ins, mental accounting, and product replacement decisions. *Journal of Consumer Research*, 27(4), 433-446.
Okada, E. M. (2006). Upgrades and new purchases. *Journal of Marketing*, 70(4), 92-102.
Orth, D., Thurgood, C., & van den Hoven, E. (2018). Designing objects with meaningful associations. *International Journal of Design*, 12(2), 91-104.
Padro, M. B. (2014). Emotionall Durable Lighting. Master thesis report, http://resolver.tudelft.nl/uuid:8d939e87-a0fe-4f81-b739-0c513fd300ed
Page, T. (2014). Product attachment and replacement: implications for sustainable design. *International Journal of Sustainable Design*, 2(3), 265-282.
Sabbaghi, M., & Behdad, S. (2018). Consumer decisions to repair mobile phones and manufacturer pricing policies: The concept of value leakage. *Resources, Conservation and Recycling*, 133, 101-111.

Sabbaghi, M., Cade, W., Behdad, S., & Bisantz, A. M. (2017). The current status of the consumer electronics repair industry in the US: A survey-based study. *Resources, Conservation and Recycling*, 116, 137-151.
Sabbaghi, M., Esmaeilian, B., Cade, W., Wiens, K., & Behdad, S. (2016). Business outcomes of product repairability: A survey-based study of consumer repair experiences. *Resources, Conservation and Recycling, 109*, 114-122.
Sahin, I. (2006). Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory. *Turkish Online Journal of Educational Technology-TOJET*, 5(2), 14-23.
Schifferstein, H. N., & Zwartkruis-Pelgrim, E. P. (2008). Consumer-product attachment: Measurement and design implications. *International Journal of Design*, 2(3).
Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2008). The constructive, destructive, and reconstructive power of social norms. *Psychological Science*, 18, 429–434.
Sheth, J. N., Newman, B. I., & Gross, B. L. (1991). Why we buy what we buy: A theory of consumption values. *Journal of Business Research*, 22(2), 159-170.
Sivanathan, N., & Pettit, N. C. (2010). Protecting the self through consumption: Status goods as affirmational commodities. *Journal of Experimental Social Psychology*, 46(3), 564-570.
Snelders, D., Mugge, R., & Huinink, M. (2014). Using social distinctions in taste for analysing design styles across product categories. *International Journal of Design*, 8(3), 23-34.
Sohn, Y. S., Yoo, K. W., & Han, J. K. (2019). Perceived product creativity and mental contrasting: Desired future on consumers' product replacement decisions. *Psychology & Marketing*, 36(1), 41-56.
Sumerlin, B. S. (2018). Next-generation self-healing materials. *Science*, 362(6411), 150-151.
Thornquist, C. (2017). Unemotional design: an alternative approach to sustainable design. *Design Issues,* 33(4), 83-91.
Tukker, A. (2004). Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. *Business Strategy and the Environment*, 13(4), 246-260.
Tukker, A. (2015). Product services for a resource-efficient and circular economy–a review. *Journal of Cleaner Production*, 97, 76-91.
Ülkü, S., Dimofte, C. V., & Schmidt, G. M. (2012). Consumer valuation of modularly upgradeable products. *Management Science*, 58(9), 1761-1776.
Van den Berge, R. B. R., Magnier, L., & Mugge, R. (2021). Too good to go? Consumers' replacement behaviour and potential strategies for stimulating product retention. *Current Opinion in Psychology*, 39, 66-71.
van den Berge, R. B. R., Magnier, L. B. M., & Mugge, R. (2022). Enhancing consumers' willingness to repair electronic products: How design can nudge sustainable behaviour. In DRS Conference Proceedings.
van den Berge, R. B. R., Magnier, L. B. M., & Mugge, R. (2023a). Until death do us part? In-depth insights into Dutch consumers' considerations about product lifetimes and lifetime extension. Journal of Industrial Ecology. https://doi.org/10.1111/jiec.13372
van den Berge, R. B. R., Magnier, L. B. M., & Mugge, R. (2023b). The influence of a modular design and facilitating cues on consumers' likeliness to repair electronic products. In PLATE 2023: the5th Conference on Product Lifetimes and the Environment (to be published) Aalto University, Finland
Van Nes, N., & Cramer, J. (2006). Product lifetime optimization: a challenging strategy towards more sustainable consumption patterns. *Journal of Cleaner Production*, 14(15-16), 1307-1318.
Van Nes, N., & Cramer, J. (2005). Influencing product lifetime through product design. *Business Strategy and the Environment*, 14(5), 286-299.
Veryzer Jr, R. W., & Hutchinson, J. W. (1998). The influence of unity and prototypicality on aesthetic responses to new product designs. *Journal of Consumer Research*, 24(4), 374-394.
Wallner, T. S., Magnier, L., & Mugge, R. (2020). An exploration of the value of timeless design styles for the consumer acceptance of refurbished products. *Sustainability*, 12(3), 1213.
White, K., Habib, R., & Hardisty, D. J. (2019). How to SHIFT consumer behaviours to be more sustainable: A literature review and guiding framework. *Journal of Marketing*, 83(3), 22-49.
Yoo, S., Chung, S. W., & Han, J. K. (2006). A durable replacement model for symbolic versus utilitarian consumption: An integrated cultural and socio-economic perspective. *Global Economic Review*, 35(2), 193-206.