Fighting premature obsolescence

Design guidelines to increase (expected) product lifetimes

Graduation report - Simone Koek

TUDelft

FIGHTING PREMATURE OBSOLESCENCE

Design guidelines to increase (expected) product lifetimes

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ABSTRACT

Scientists have been warning for years about the consequences of the current take-make-waste system. Incremental change is needed to enable the environment to regenerate and move towards a sustainable society. Especially electronic waste (e-waste), is an increasing concern and an opportunity for improvement.

This project addresses the problem of premature obsolescence. The project investigates how to increase the lifetime of electronic consumer durables. By fully understanding how the consumers make replacement decisions, the decisions people make can be influenced. It turns out that as a product moves towards the expected lifetime, the perceived value of the product goes down, and the consumer is less likely to take care of the product or repair it when it breaks.

Consequently, this project investigates how to increase the expected lifetime of products. This contributes to the Premature Obsolescence Multi-stakeholder Product Testing Program (PROMPT). PROMPT is working on a test program to assess the lifetime of products from a technical, user, and market perspective.

The formulated assignment is to generate design guidelines that help to improve the expected product lifetime and illustrate this on a case example. The products that will be investigated are washing machines, televisions, vacuum cleaners, and smartphones. Two studies were performed. One qualitative study to get more insights in an explorative way, and a quantitative study to measure the most effective way to increase the expected lifetime.

From the first study, it was concluded that people determine the expected lifetime at several moments throughout the lifetime of the product. Also, past experiences with the product, the average lifetime, the amount of warranty and expected change in demographics are factors that were considered by the participants while determining the expected lifetime of their products. Also, it was concluded that many people are not aware of their expectations of the (expected) lifetime of products, and therefore creating more awareness could lead to increased lifetime of products.

In the quantitative study, only vacuum cleaners were studied. It turned out that warranty and the availability of spare parts are the most effective strategies to increase the expected lifetime of vacuum cleaners. However, the strategies build upon each other while increasing the expected lifetime. Therefore, to address all consumers, more strategies should be integrated in a product for the optimal result.

The findings from this study can be used by PROMPT as a starting point for testing criteria. For example, criteria about the attempts of companies to increase the expected lifetime of products could be integrating in the testing program. However, before doing this, more research is needed about the influencing factors of the expected lifetime of products.

Timeless design

Repairable design

Extended warranty

Self-healing materials

Physical upgradeability

Durable design

Care and maintenance

Software updates

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PART 1: INTRODUCTION

The first part of this report contains the introduction to the project. It explains why it is important to increase the expected lifetime of products and the reason to do a project about the expected lifetime of products.
After giving a brief introduction about the context, the problem definition, the assignment, and the scope are defined.

1.1 Context

Scientists have been warning for years about the consequences of the current take-make-waste system. Consumers are overwhelmed by innovations, new functionalities, and advertisements that encourage them to replace products before they break down. But at the same time, natural resources are getting scarce and environmental consequences are already visible. In this project, the problem of premature obsolescence will be addressed. In this project, premature obsolescence is defined as the the disposal of a product when it is not physically broken beyond repair (van den Berge et al., 2021).

There are design strategies that aim to minimize the impact of manufacturing or the use of products, but this is not enough. Incremental change is needed to enable the environment to regenerate and move towards a sustainable society.

One of the newer strategies to restore the environment is the Circular Economy. This model aims to design, make, and use products to minimize the human impact. The idea is that everything from earth, can be given back to earth, and therefore create a circular model. Existing literature mainly emphasizes reducing the throughput of resources (Klopffer, 2003; De Medeiros et al., 2014; Van Weenen, 1995; etc.). However, the role of product longevity is rarely mentioned (Cooper, 2005). As about half of the products are discarded prematurely (so before they are physically obsolete), there is a big opportunity to tackle the problem of material scarcity and moving towards a circular economy.

When speaking about product longevity, Cooper (1994) distinguishes two types of product life spans. The technical lifetime refers to the amount of time a product can physically perform its function. The other product lifetime is the 'service lifetime' which refers to the period between the purchase of the product and the point of discard. In this report, when talking about 'lifetime' or 'actual product lifetime' the so-called 'service lifetime' is meant. In this case, life extension methods such as reselling are left out of scope.

Especially electronic waste (e-waste), which currently increases three times faster than regular waste and is hard to collect and recycle (The World Bank, 2021), is an increasing concern and an opportunity for improvement. Research shows that many people replace electronic household products for other reasons than being broken beyond repair (31% of washing machines, 66% of vacuum cleaners, 56% of TV's and 69% of smartphones, see figure 1) (Wieser & Troger, 2018; Harmer et al., 2019; Hennies & Stamminger, 2016). That means other factors than physical durability influence the replacement behavior of consumers. Consumers fail to see the connection between longevity and sustainable consumption (Echegaray, 2016). This is a problem because even though people want to behave sustainably, they are not aware of the easiest and most efficient way of sustainable consumption, so this is a missed chance on the way to a sustainable society.

| 31% | 56% | 66% | 69% |
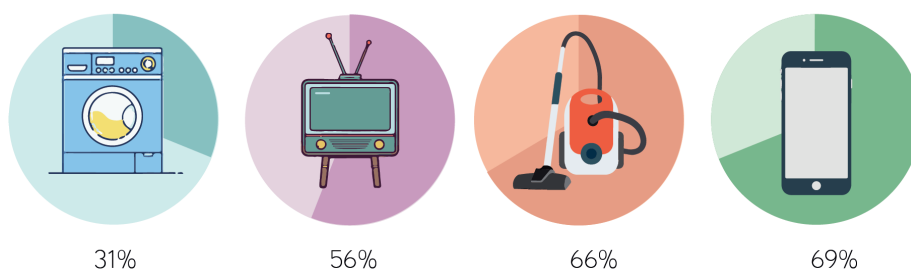
Figure 1: Percentage of products that are discarded prematurely

Therefore, this project investigates how to increase the lifetime of electronic consumer durables. According to Echegaray (2016), the lifetime of products is highly influenced by the expected lifetime of products. When a consumer purchases a product, they have expectations about the lifetime of products. It turns out that as a product moves towards the expected lifetime, the perceived value of the product goes down, and the consumer is less likely to take care of the product or repair it when it breaks (Wieser et al., 2015). For example, when a washing machine breaks. The consumer must decide whether it is still worth it to repair the washing machine, or whether they expect the product to break soon, so is more convenient to replace the washing machine with a new one.

Echegaray (2016) found out that two-thirds of the participants in his survey feel an urge to replace products after a certain period, regardless of whether this is based on psychological obsolescence or technical failure. It is likely that this 'certain period' refers to the time somebody expects the product to break soon and therefore has less trust in the product.

By understanding how the consumers make these replacement decisions, the decisions people make can be influenced. Figure 2 shows the framework of replacement decision-making. This framework shows the psychological process of product replacement including the value trade-offs that people make. According to van den Berge et al. (2020), there is a value trade-off between the mental book value of the currently owned book value and the expected value and costs of the new product. The book value of a product is determined by the different relative values. When the mental book value of the currently owned product is lower than the expected value of the new product (including costs), the product is likely to be replaced. So, when the mental book value of a product can remain high for a longer period, the product life will increase. Further explanation on replacement decision making can be read in chapter 2.4.
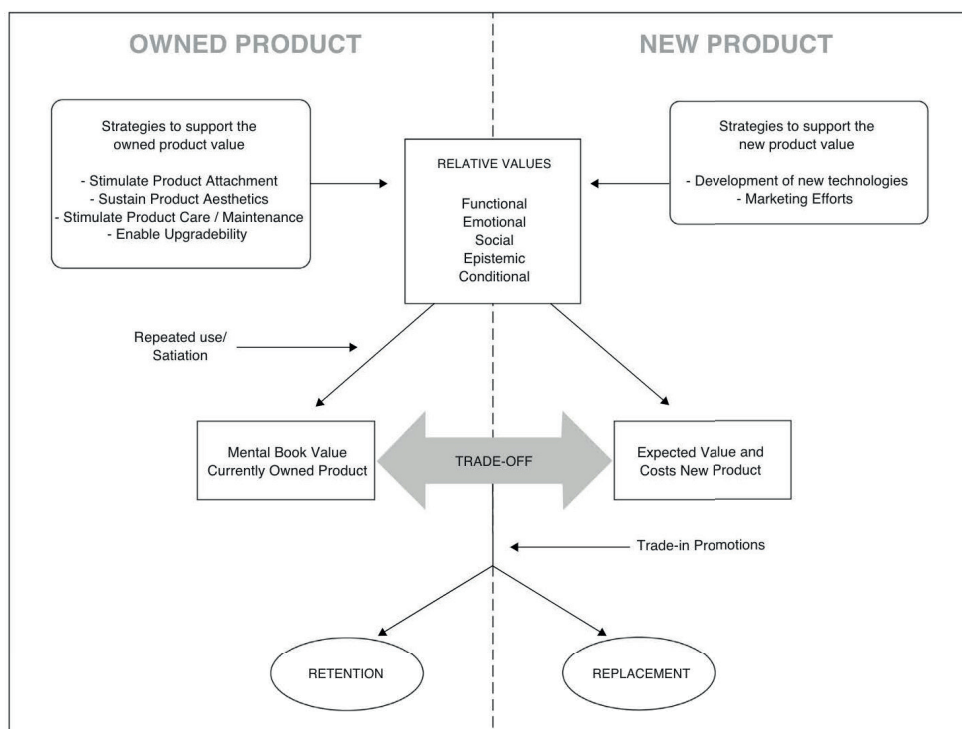
Figure 2: Psychological process of product replacement (Mugge & Magnier, 2020)

Consequently, this project investigates how to increase the expected lifetime of products. This contributes to the Premature Obsolescence Multi-stakeholder Product Testing Program (PROMPT). PROMPT is a collaboration between Fraunhofer Institute for Reliability and Microintegration (IZM) and the Delft University of Technology, together with several national consumer organizations, umbrella consumer groups, and repair companies and platforms. It aims to develop a testing program for assessing the lifetime of washing machines, smartphones, vacuum cleaners, and televisions.

At this moment, PROMPT is working on a test program to assess the lifetime of products from a technical, user, and market perspective. Research shows that the physical state of a product is not the only reason to discard a product. To measure the lifetime of a product, it is also important to take consumer behavior into account. At this moment, it is still unclear what factors influence the expected lifetime of products, and what design features or business models can increase the expected product lifetime.

For this project, I argue that the expected lifetime plays a big role in the actual lifetime of a product. And if we can influence the expected lifetime of products, we can indirectly increase the actual lifetime of products.

1.2 Assignment

The formulated assignment is to generate design guidelines that help to improve the expected product lifetime and illustrate this on a case example. This will be done by studying the expected product lifetime of consumer durables in three studies.

First, a literature review, which investigates the expectations for product life and the replacement decision-making. The aim is to provide insights into the factors that play a role in establishing expectations for the product lifetime and how the expected lifetime can be extended. The research specifically aimed at consumer behavior regarding replacements.

Then, a qualitative study to learn about expected lifetimes in general. How do people determine expected lifetimes and what factors play a role? This study aims to find more insights into how consumers think and feel about the expected lifetime and the effect of strategies that could potentially increase the expected lifetime of products.

After that, a quantitative study to quantify the relative influence of certain design strategies on the expected lifetime of products using conjoint analysis. The conjoint analysis is combined with cluster analysis and correlation analysis to find out more about different consumer segments.

From this, the design guidelines with the most influence on the expected lifetime are selected and are illustrated in an example.

1.3 Scope

The products that will be investigated are washing machines, televisions, vacuum cleaners, and smartphones. These product categories were selected by the PROMPT consortium. They were selected because the four categories are very diverse (in size, portability, whether they contain batteries or cords, used to clean or not, visible to other people or not, and more). Also, most people own these products, and not the least important: there is a lot to win for these categories. Many products in these categories suffer from premature obsolescence, but they also have much environmental impact. Therefore, longevity can have much impact on the environment for these products.

Within these products, the focus will be on extending their lifetimes by increasing the expected lifetime of products.

Key take-aways

Context: Scientists have been warning for years about the consequences of the current take-make-waste system. One promising strategy to help is the circular economy. In literature about the circular economy, longevity is often overlooked, which makes it difficult for the circular economy to succeed. It will be investigated whether mental accounting can help to increase the lifetime of electronic durables. This project will contribute to the PROMPT project by focusing on the expected lifetime.

Problem definition: Although there is knowledge about sustainable product design and longevity, knowledge about the expected lifetime of products is still limited. However, this is a big opportunity to increase product lifetimes and thereby successfully moving towards a circular economy.

Assignment: Generate design guidelines that help to improve the expected product lifetime and illustrate this on a case example

Scope: The expected lifetime of washing machines, televisions, vacuum cleaners, and smartphones.

Introduction to the throwaway society

Circular economy

Premature obsolescence

Consumer decision-making

Mental accounting

Strategies

| Repairable design | Repair services | Upgradeable hardware | Upgradeable software |
| Care and maintenance | Self-healing materials | Timeless design | Durable design |
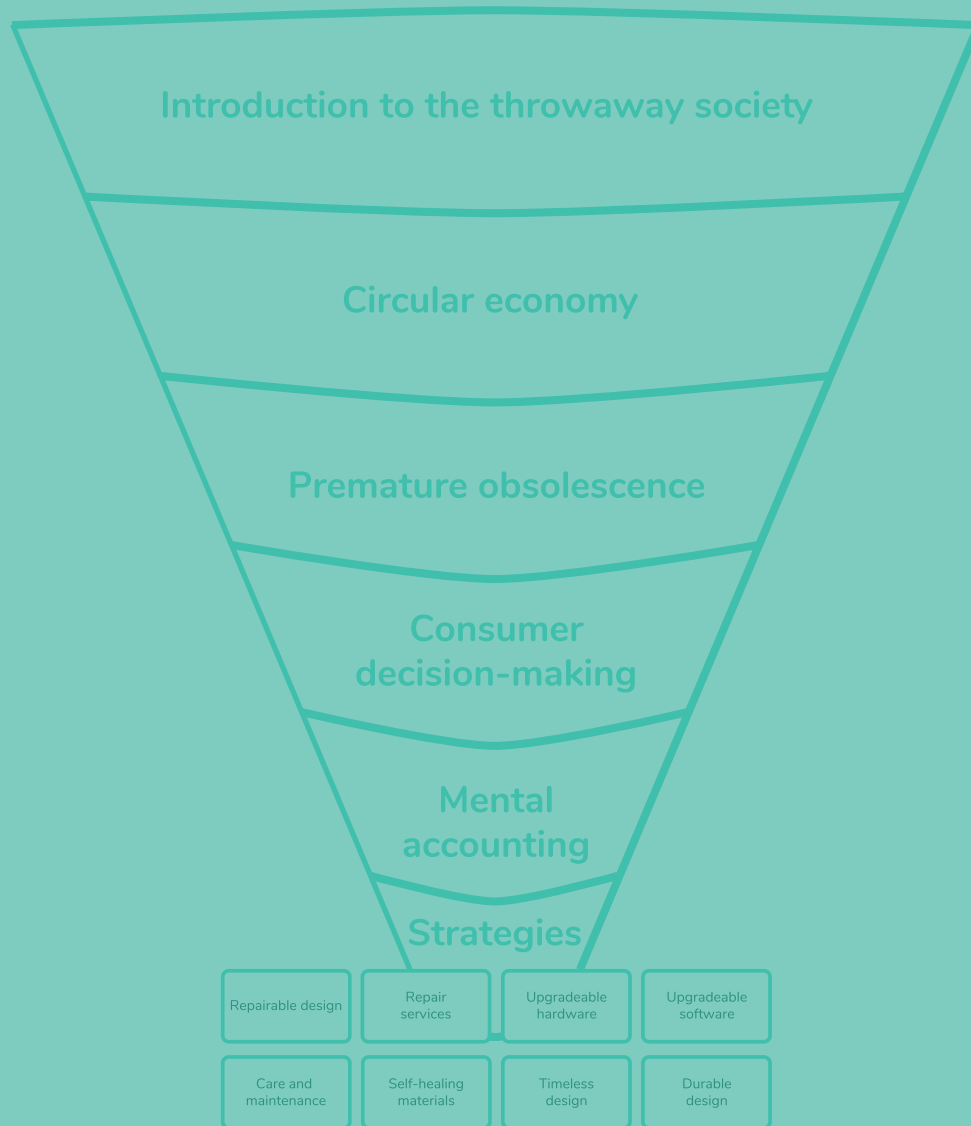
PART 2: LITERATURE REVIEW

This literature review was written to provide a good impression on the current replacement behavior of consumers, why product longevity is important, and how product lifetimes can be extended by increasing the expected lifetimes of products.

As shown in the figure above, the literature review is structured like a funnel. The literature review starts with a brief introduction of the current situation regarding replacement behavior and resource depletion. Following, the concept of the circular economy is explained, as well as the importance of increasing product lifetimes on the chance of success of the circular economy. Having this background information, the literature review continues with the role of the consumer in waste reduction. Different angles are highlighted: (1) premature obsolescence, (2) consumer replacement behavior in general, and (3) expected product lifetime. The last part lists design strategies that will act as the basis for the rest of the study. Concluding, the research questions for the qualitative research are determined.

2.1 Introduction to the "Throwaway Society"

Today, we live in a so-called "Throwaway Society", also known as the take-make-waste economy (Allwood et al., 2010). This means we take resources from the earth, turn them into valuable products, use them until they are not valuable anymore and the products are being discarded in a linear direction (see figure 3). This traditional, open-ended material- and energy flow is not sustainable (Frosch and Gallopoulos, 1989), as the resources aren't infinite, and the earth is not capable of processing this current throughput of waste.

Before the industrial revolution, product efficiency was more common because of the relative value of materials compared to labor, and products were better maintained, upgraded, and repaired (Allwood et al., 2010). However, since the 1950s, when products became cheaper and mass-produced, regular changes in styles were promoted by the industry to stimulate economic activity. As a reaction, the debate started from dissatisfaction and concern about these developments.
In 1960, Vance Packard wrote a book called 'The Waste Makers', expressing his concern about the consequences of premature and planned obsolescence on the environment. Nonetheless, until today the debate about replacement behavior and obsolescence is still going on (Papanek, 1972; OECD, 1982; Cooper 1994, 2004; Kostecki 1998; Slade, 2006).

Economists and experts have been warning about the consequences of resource depletion and the CO_2 emission caused during the manufacturing of the products (Meadows et al., 1972, Simpson et al., 2005, Gordon et al., 2006; etc.). And even though products are becoming less environmentally destructive because we learn more about the consequences on the environment, one feature has become worse: Longevity. While before, products were made to last as long as possible, this seems not always to be the case anymore (Cooper, 2010).

As explained in the introduction, e-waste is a big part of the problem. The market is expanding rapidly, and the obsolescence rate is rising (InfoDev/World Bank, 2012). Therefore, to achieve a more sustainable society, waste reduction is a central focus (OECD, 2011). According to the Global E-waste Monitor 2020 (Forti et al., 2020), the amount of e-waste has increased by 21% during the last five years, to a level of 53.6 million metric tons of electronic waste (see figure 4).

Also, the physical state of a product is not always the reason for replacement: about 31% of washing machines, 66% of vacuum cleaners, 56% of TV's and 69% of smartphones (Wieser & Troger, 2018; Harmer et al., 2019; Hennies & Stamminger, 2016) are still functioning properly at the moment of replacement. The product lifetime is thus

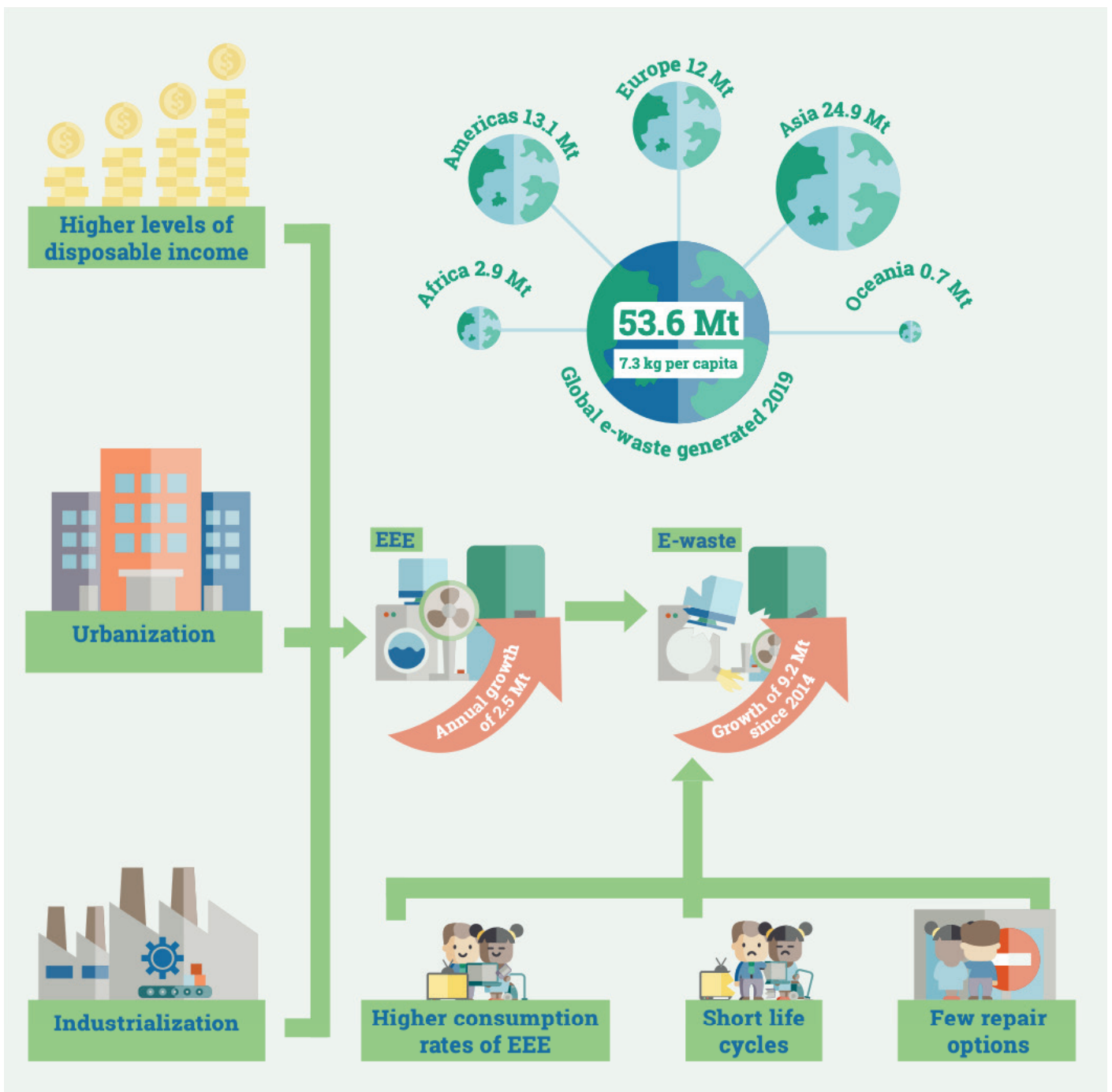# Take - Make - Waste

Figure 3: Take-make-waste system

Figure 4: Causes of the increase of global e-waste(Global E-waste Monitor, 2020)

determined primarily by the user (Stahel, 1986), and therefore, to achieve more sustainable consumption, behavior change is necessary.

At the same time, there is dissatisfaction amongst consumers about the decreasing product lifetimes (Cooper, 1994, 2010; Cooper & Mayers, 2000; Hekkert, 2010; Park, 2010; Peattie, 2010; Van Nes & Cramer, 2005). According to a survey about household appliances (white goods, televisions, stereos, etc.) amongst the British population by Cooper and Mayers (2000), participants replaced their products after about 4 to 12 years, depending on the type of product. And 45% of the householders think the products did not last as long as they would like. However, 38% of the householders said that they hardly ever got products repaired and 10% of the products still functioned when they were discarded.

Despite the importance of sustainable behavior, most people make decisions without thinking about the environment and just satisfy their needs (Trudel, 2018). Therefore, it is crucial to critically look at our current consumption patterns, to understand the psychology behind consumer behavior to achieve more sustainable behavior.

Every decision made about what and how much to buy, how to consume and dispose of, directly influences our environment and future generations. Currently, the world is not able to keep up with the overconsumption and the consequences are already showing: temperatures and sea levels are rising (Cramer et al., 2014), there is an increase in natural disasters, and resources are running out. The production of minerals such as gasoline, zinc, and copper is expected to run out within the next 20 years (Valero and Valero, 2010). To enable the earth to keep up with our consumption, a change in consumption is needed.

Key take-aways

Problem history: Since the 1950s, when products became cheaper and mass-produced, regular changes in styles were promoted by the industry to stimulate economic activity. Even though products are becoming less environmentally nowadays, destructive because we learn more about the consequences on the environment, one feature has become worse: Longevity. The physical state of a product is not always the reason for replacement, especially for electronic durables, this problem is increasing.

Consumer dissatisfaction: There is dissatisfaction amongst consumers about the lifetime of products. At the same time, many products are discarded while still functioning or in need of (minor) repair.

Change is needed: Every decision made about what and how much to buy, how to consume and dispose of, directly influences our environment and future generations. To enable the earth to keep up with our consumption, change in consumption is needed.

To be determined next: One of the strategies to change the current consumption pattern is circular economy. In the next chapter, we dive into the circular economy and why longevity is so important.

Chapter 2.2 Circular Economy

One approach to shifting from a linear economy model towards a more sustainable society is the circular economy (CE) (see Figure 5). The circular economy aims to design, make and use products within planetary boundaries, and it is built on three principles: Designing out waste and pollution, keeping products and materials in use, and regenerating natural systems (Ellen Macarthur Foundation, 2017) (Figure 6).

As you can see in Figure 5, the circular economy exists of several loops: Recycle, Remanufacture/ Refurbish, Reuse/Redistribute, Maintain/Prolong, and Sharing. The smaller the circle, the more energy-efficient it is. In this project, the focus is on maintaining and prolonging the use of products on the consumer level. Recycling, remanufacturing, and refurbishment are great ways of increasing the efficiency of products but increasing the first use time of a product will always be the most efficient one, yet also seems to be neglected the most.

RENEWABLES / **FINITE MATERIALS**

RENEWABLES FLOW MANAGEMENT — **STOCK MANAGEMENT**

FARMING/COLLECTION[1]

BIOCHEMICAL FEEDSTOCK

PARTS MANUFACTURER

PRODUCT MANUFACTURER

SERVICE PROVIDER

REGENERATION — BIOSPHERE

RECYCLE

REFURBISH/ REMANUFACTURE

SHARE

REUSE/REDISTRIBUTE

MAINTAIN/PROLONG

BIOGAS

CASCADES

CONSUMER — USER

COLLECTION — COLLECTION

ANAEROBIC DIGESTION

EXTRACTION OF BIOCHEMICAL FEEDSTOCK[2]

1 Hunting and fishing
2 Can take both post-harvest and post-consumer waste as an input

SOURCE
Ellen MacArthur Foundation
Circular economy systems diagram (February 2019)
www.ellenmacarthurfoundation.org
Drawing based on Braungart & McDonough,
Cradle to Cradle (C2C)

MINIMISE SYSTEMATIC LEAKAGE AND NEGATIVE EXTERNALITIES
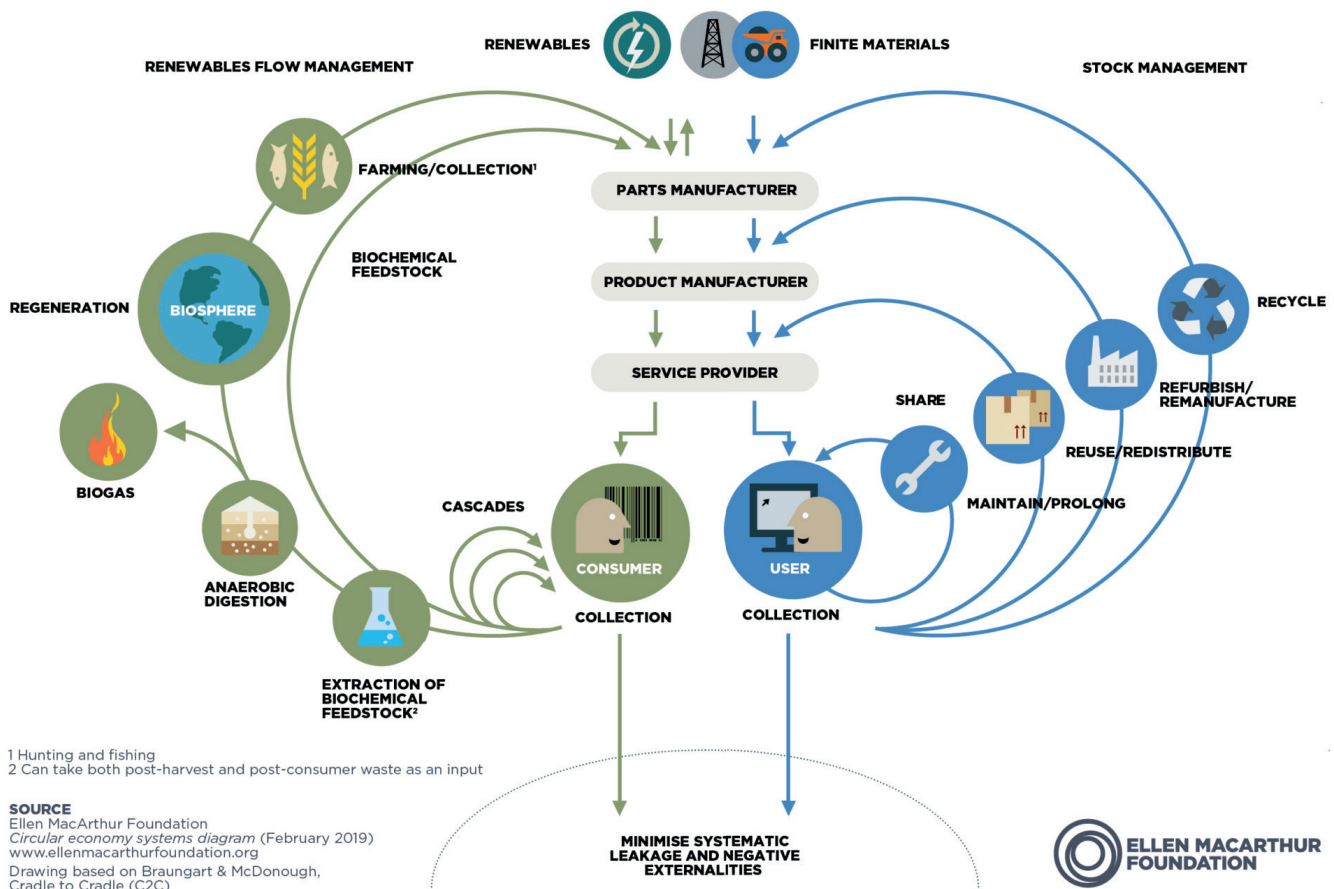
ELLEN MACARTHUR FOUNDATION

Figure 5: Circular economy (Ellen Macarthur Foundation, 2019)

2.2.1 Potential benefit of circular economy

One of the advantages of the circular economy concept is that it not only decreases the pressure of human beings on the environment, but the concept also creates opportunities for economic growth. The circular economy provides efficient use of resources, which is economically attractive. Also, circular business models like subscription-based products are financially attractive and at the same time environmentally attractive, as manufacturers can take back defective products, improve their products and at the end of life break down and sustainably recycle the materials. This is important, because many other strategies towards more sustainable consumption are not attractive for the market, and are therefore harder to push through.

Besides the recurring revenue that is created in these models, it also creates more job opportunities. For example, in the field of logistics and the (dis) assembly of products. In the Dutch market only, the transition to the circular economy will result in 54.000 new job opportunities according to Bastein et al. (2013). Also, it could cause the annual reduction of 17.000-kilo tons CO2 and 100.000-kilo tons of raw material (Bastein et al., 2013).

2.2.2 Potential risk of circular economy

It may seem that there are only positive sides to the Circular Economy model, but there are also some pitfalls. One of the risks of the CE model is Jevon's paradox, also called the rebound effect (Polimeni et al., 2015). When the impact of products decreases (for example, by donating old products for recycling or buying something that was produced CO2 neutral), it is easier for people to rationalize more consumption. This will boost the throughput of resources and makes it harder to close the loop. To counteract Jevon's paradox, it is important to find a way to make people less attracted to replacing their products too quickly.

Besides keeping the product in a good physical state for a longer period and making the product more suitable for refurbishment and remanufacturing, people must treasure their products for a longer period. In that case, they take better care of their products, repair them when necessary, and feel less need to replace their products as frequently as in the current situation.
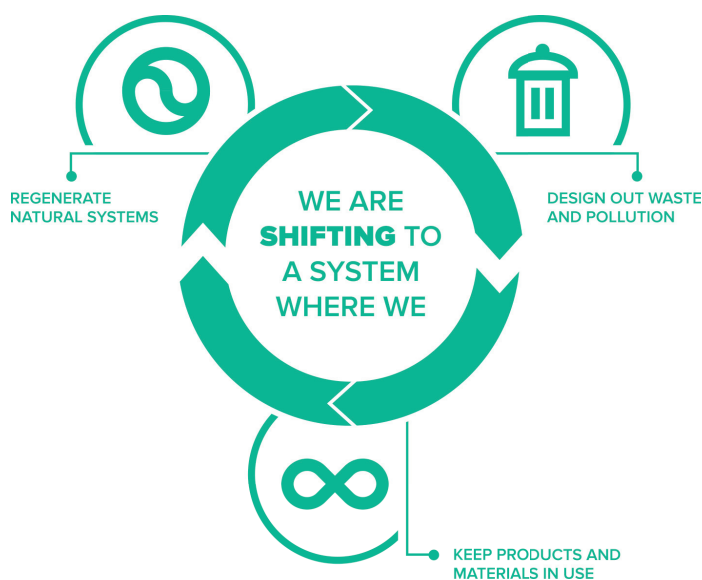

REGENERATE NATURAL SYSTEMS

WE ARE **SHIFTING** TO A SYSTEM WHERE WE

DESIGN OUT WASTE AND POLLUTION

KEEP PRODUCTS AND MATERIALS IN USE

Figure 6: CE principles (Ellen Macarthur Foundation, 2019)

2.2.3 Importance of longevity

The circular economy is something many researchers and designers are working on. As explained before, the longevity of products is very important to start with, because if the throughput of materials is too high, there will never be enough resources to make a circular system work. To give an example, wood could be processed circularly. Meaning, the tree is cut down, used, and after that, the wood is shredded and put back into the woods. However, there are only so many trees you can plant, and it takes time for the wood to become a tree again. Therefore, the fact that the wood is processed circularly, does not mean you have unlimited access to wood. Above that,

the risk of the circular economy is the rebound effect. As explained in paragraph 2.2.2, when the environmental impact of a product is small, people could rationalize more consumption.

Therefore, longevity should be the main focal point of the circular economy. But, before you can improve longevity, we need to understand why the lifetime of the product is decreasing. Technologically it should be possible to make products very long-lasting, but it seems that consumers replace their products before they are broken beyond repair. To solve that problem, we need to find out how this works. Therefore, chapter 2.3 focuses on premature obsolescence.

Key take-aways

Circular economy: The circular economy aims to design, make and use products within planetary boundaries, and it builds on three principles: Designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.

Potential benefit: One of the biggest advantages of the circular economy, besides the environment, is the economic opportunity that comes with it.

Potential risk: One of the risks of the CE model is the rebound effect. When the impact of products decreases, it is easier for people to rationalize more consumption.

Importance of longevity: Even though products could be manufactured circularly, does not mean we have unlimited access to resources. To give nature time to restore, we need to increase the lifetime of products.

To be determined next: To increase the lifetime of products, we need to find out why the lifetime of products is the way it is, and why products are replaced before they are broken beyond repair.

2.3 Premature obsolescence

Many factors influence whether a product is being replaced or not. Research shows that the physical state of the product is not always the biggest factor. According to a survey by Echegaray (2016) amongst 806 Brazilians, for almost half the number of discarded products, it was the inability to meet the consumer's identity aspirations instead of defects in the functionality of the product.

In this report, premature obsolescence is defined as the disposal of a product when it is not physically broken beyond repair, so it still functions or needs (minor) repair. There are many different types and causes of premature obsolescence, which are described in the following chapter.

According to Granberg (1997), there are two fundamental types of obsolescence: absolute and relative obsolescence. Absolute obsolescence is related to the physical state of a product. Due to wear and tear or other reasons, a product breaks and cannot be repaired. Another form of absolute obsolescence is when a product is not compatible anymore with other products or services in the market; for example, you cannot run an update on your computer because it doesn't have the processing power to handle the newer software.

This project focuses on relative obsolescence, this is when the product is still functioning or only in need of minor repair. Instead, the consumer perceives the product as being 'worn out' in their minds compared to a newer product (Packard, 1960, pp. 58-59). Sometimes, when a product has been functioning for a certain period, the product becomes 'worn out' in the mind of the consumer: it has been functioning for long enough, and it has made their money worth (Packard, 1963: 58-9, see also Van Nes, 2003). This is not an exceptional situation.

Companies play a role in this mental 'wearing out'. For example, when they bring new, innovative products to the market, at the expense of 'old' products (Cooper, 2005; Thompson et al., 2005; Verbeek, 2006; Park, 2010). By adding new features to the new products, a desire to replace the old product is created (Echegaray, 2016). Also, when the consumer feels good about the benefits of a new product, they feel less bad about the costs of the product and about discarding the old products (Hirst et al., 1994; Kahneman & Tversky 1984). Even though the companies play a role in these replacement decisions, technically speaking, the user determines lifetime of these products (Antonides, 1991).

This report distinguishes nine types of obsolescence (Wilson et al., 2017) and their definitions can be found in Figure 7. While some of these types of obsolescence can be absolute, only relative obsolescence is discussed.

Key take-aways

Premature obsolescence: Premature obsolescence is defined as 'the disposal of a product when it is not physically broken beyond repair', in other words: the product is replaced while it was still functioning or in need of (minor) repair.

Relative obsolescence: There are two types of obsolescence. This project focuses on relative product obsolescence. Relative obsolescence happens when the product is replaced while it is still physically functioning.

Consumer choice: Even though many people blame companies for early product obsolescence, consumers make the final decision to replace a product.

To be determined next: In this chapter, we learned more about how products become obsolete prematurely, and in the following chapter we will focus on the mind of the consumer, what forces play a role and how consumers value a product?

1. **Quality obsolescence** occurs when a part of the product breaks, and therefore the functionality performance of the product decreases, yet overall, the product still fulfills its function. For example, the reduced battery performance of a computer (Packard, 1960; Van Nes et al., 1999; Mugge et al., 2005; Guiltinan, 2009). In this case, the consumer might perceive the product's performance to be decreased to the extent that they perceive the costs of maintaining the product to be higher than the benefits of the product (Roster, 2001; Van Nes, 2003).

2. **Technological obsolescence** seems similar to quality obsolescence, as the technological state of the old product is outperformed by newer products. In this case, the perceived benefit of the old generation product drops and a need to replace the product grows because the consumer is confronted with new technologies or features. However, the product itself still functions. For example, the development from videotapes to DVDs to USB sticks and currently online storage (Packard, 1960; Antonides, 1991; Cooper, 2004).

3. **Economic obsolescence** occurs when it is financially more attractive to replace an old product with a newer product. For example, because television consumes less energy and is, therefore cheaper during the use phase (Antonides, 1991; Van Nes et al., 1999; Cooper, 2004; Khan et al., 2018).

4. **Ecological obsolescence** takes place when the newer product is less environmentally harmful than the older product. It must be noted that ecological obsolescence mainly goes hand in hand with economic obsolescence as saving energy also means saving money. For example, replacing a washing machine because the new one uses less water (Van Nes et al., 1999; Wilson et al., 2017).

5. **Aesthetic obsolescence** is about the looks of the product. Does it look new or worn, does it have scratches or dirt that doesn't come off? It depends on the type of product whether this has a lot of influence. For example, a phone might lose a lot of value when the screen has scratches, but certain types of shoes start to become more stylish when they look worn (Packard, 1960; Antonides, 1991; Cooper, 2004; Mugge et al., 2005; Burns, 2010).

6. **Psychological obsolescence** happens when a new product has a lot of emotional meaning, making the other product unnecessary. For example, when you get a new watch from a loved one, and you stop wearing your old watch (Van Nes et al., 1999; Cooper, 2004; Burns 2010; Wilson et al., 2017).

7. **Social obsolescence** happens when societal changes make a product obsolete. For example, every time a new PlayStation launches. Then, people want the newer version even though the old PlayStation still functions, but to be able to play games with friends, you need to keep up with the gamer society. In this case, fashion plays a big role, as people express their identity and social status with the products they use (Bayus, 1991; Bayus and Gupta, 1992; DeBell and Dardis, 1979; McCracken, 1986; Van Nes, 2003).

8. **Legal obsolescence** plays a part when legislation changes which influence the product. For example, when there are restrictions on certain materials or emissions (Bayus, 1991; Bayus and Gupta, 1992; DeBell and Dardis, 1979; McCracken, 1986; Van Nes, 2003).

Figure 7: Types of premature obsolescence

2.4 Sustainable consumer decision-making

For years, marketers used the understanding of consumer behavior and psychology to drive consumers to purchase more and behave less sustainably by using advertising, business models, and product design (Cramer et al., 2014). In this report, the understanding of consumer behavior will be used to counteract this unsustainable behavior and fight premature obsolescence. The following chapter explains the way people make sustainable decisions. At first, system 1 and system 2 thinking of Kahneman (2013) is explained, to learn more about the different types of decisions. After that, mental accounting is explained, to learn more about product replacement decisions in particular

.
According to Morewedge and Kahneman (2010), the psychology of decision-making consists of two types of processes: System 1 and System 2 (see Figure 8). System 1 is fast, intuitive, and instinctive thinking, the decisions you make without really thinking about it. System 2 is more rational and cognitive, it makes decisions based on available information and considers the options carefully (Sloman, 1996). This is important to know, as the

results of a sustainable decision are long-term, and the direct impact is hard to measure (Manning, 2009) therefore, system 2 is needed to make a conscious, sustainable decision (Morewedge & Kahneman, 2010). At the same time, the unsustainable choice often only takes system 1 and is more effortless and attractive in the short term. For example, throwing an empty soda can in the regular bin next to you instead of keeping it until you found a recycling bin (Brothers et al., 1994). It directly rewards throwing the soda can in the bin next to you, as you get rid of it. The benefits of keeping it and making the more sustainable choice are harder if noticed at all.

This shows that people tend to go for the more short-term benefit instead of considering the trade-off of the long-term benefit (O'donoghue & Rabin, 1999). The result of this is that the sales of durable products lag, as the up-front costs are higher, even though this is more than compensated by future savings (Gillingham et al., 2009).
To influence the behavior of humans, it is important to be aware of this and make sure the sustainable

SYSTEM 1
Intuition & instinct

95%

Unconscious
Fast
Associative
Automatic pilot

SYSTEM 2
Rational thinking

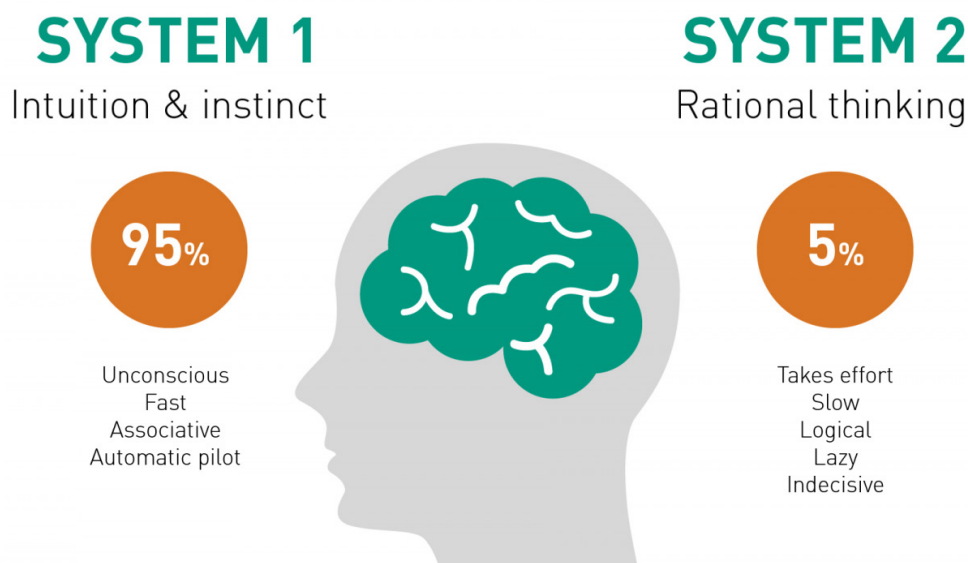5%

Takes effort
Slow
Logical
Lazy
Indecisive

Figure 8: System 1 and 2 thinking (Kahneman, 2013)

outcome is a system 1 decision, or the purchase decision itself is experienced as a system 2 decision. An example is when people made a larger donation to global warming charities on warmer days and were more concerned about global warming than when they were questioned on colder days (Li et al., 2011). In that case, people feel confronted with the consequences of their behavior and decide to donate money. When the consequences are not visible at all, it is more difficult to make a decision that truly considers all consequences, and then, people will go for short-term benefit.

This theory is also called the construal level theory (Trope & Liberman, 2003), and explains that people perceive present situations differently from future events. Therefore, it is important to either make the future benefits more evident or have consumers think more abstractly and with a future focus. Because the consequences of unsustainable choices are often shown many years later, the sustainable choice is often a system 2 choice and people are more likely to choose the unsustainable option when making a system 1 decision.

This is very important to take into account while designing for sustainable behavior change. Either, we have to make sure that while making the decision, the consumer carefully considers the long-term benefit of the replacement decision, or it should be made easier for people to choose the more sustainable option, and make sure they go for the more sustainable option 'when not thinking about it'.

This psychology of decision-making shows that not all choices are rational choices. This is something that also shows in the numbers regarding product longevity. As pointed out in the introduction, according to Cooper (2004), almost half of the British interviewees (45%) felt that products do not last as long as they think products should last. At the same time, research shows that the majority of products are discarded without being broken beyond repair (Wieser & Tröger, 2018; Harmer et al., 2019; Hennies & Stamminger, 2016). So ideally people think that products should last longer than they currently do, yet they often discard them before they are absolutely obsolete.

Key take-aways

Consumer decision-making: There are two types of decision-making: System 1 and System 2. System 1 is fast, intuitive, and instinctive thinking, the decisions you make without really thinking about it. System 2 is more rational and cognitive; it makes decisions based on available information and considers the options carefully.

Sustainable decisions: To influence the behavior of humans, it is important to be aware of this and make sure the sustainable outcome is a system 1 decision, or the purchase decision itself is experienced as a system 2 decision.

Construal level theory: This theory explains that people perceive present situations differently from future events. Because the consequences of unsustainable choices are often shown many years later, the sustainable choice is often a system 2 choice and people are more likely to choose the unsustainable option when making a system 1 decision.

To be determined next: Sooner or later, people will make the unsustainable choice to replace their product. To make people want to keep their product (and postpone product replacement), people must value their product. How this works, will be explained in the next chapter.

2.5 Mental accounting

As mentioned in paragraph 1.2, about two-thirds of the participants in the research of Echegaray (2016) admitted replacing their products before necessary as they felt these products provided diminishing benefits. However, these same people also declared feeling uncomfortable about doing so. People find themselves in situations that feed psychological obsolescence beyond their control. To understand the rationale behind these premature replacements, the influence of other forces like social pressure, socioemotional and psychological forces such as consumerism, time famine, and social pressure for frequent product replacement should be recognized (Evans & Cooper, 2010; Cox et al., 2013). This chapter explains how these forces interact.

When a consumer purchases a product, they open a mental account for that product (Gourville & Soman, 1998; Okada, 2001). This means, the product has a certain mental value, and when the product has made its money worth it, it is okay to replace the product.

Therefore, when the product almost made its money worth it, and the consumer is faced with a newer version of the product, the expected value of the newer product is probably higher than the currently owned product, and therefore they are more likely to replace their currently owned product (Hirst et al., 1994; Kahneman & Tversky 1984). This means, the replacement decision is dependent on both the mental book value of the existing currently owned product value compared to the potential value of the new product (van den Berge et al., 2021). Therefore, to increase the product use lifetime, it is key to increase the mental book value of incumbent products.

Seth et al. (1991) distinguished five product values that influence the purchase behavior of consumers: Functional value, social value, emotional value, epistemic value, and conditional value (Figure 10). Whether the consumer chooses to replace their products is an interplay of these values. It could be a combination of different values, and the values can also counteract each other. Figure 9 shows how the values work in relation to the product. When the net value of the new product is higher than the net value of the old product, he/she will probably replace it.
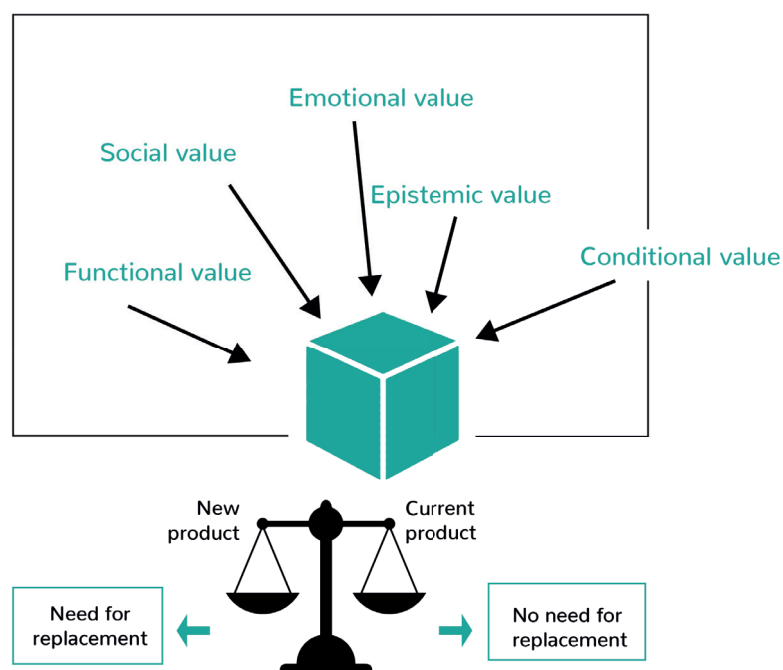
Figure 9: Replacement decision model (based on Van Nes et al., 1999 and Van Den Berge et al., 2021)

Functional value refers to the physical attributes and how the product functions. The old product's functions might lower because of wear and tear and is linked to quality obsolescence. On the other hand, innovations might come to the market making the new product superior to the old product. Characteristics that drive the functional value can be for example reliability, durability, and expense (Ferber, 1973).

Social value is derived when the consumer positively links the products to certain social groups. Especially highly visible products (for example jewelry or a car) are evoked but also functional products such as kitchen appliances can be selected because of the social value (Seth et al., 1991).

Emotional value is acquired when the new product is associated with the feeling of arousal or affective states. For example, when your heart starts beating as a beautiful car drives by. Old products can have increased emotional value as well, as the product might be associated with loved ones or feelings of nostalgia.

Epistemic value has to do with the consumer's feeling of curiosity and desire for knowledge about the product. According to research, humans have an internal need for novelty and gaining new knowledge (Hirschman, 1980). This explains why people might get bored with their owned products and feel the need to purchase something new, even when the product still functions.

Conditional value refers to changes in the value of the product due to contextual changes extrinsic to the product (Bayus, 1991; Van Nes & Cramer, 2005). Manufacturers can take this into account by offering temporary offers, or by adjusting certain product features for certain circumstances. For example, an extra big washing machine in the case of new family members (demographic changes), or an air conditioner in the summer (seasonal changes).

Figure 10. Types of values

2.5.1 Decreasing value

Just like regular accounting, the 'mental book value' decreases over time, as the product makes its purchase price 'worth' (van den Berge et al., 2021). When the product's mental book value is zero, the consumer is likely to replace the product. Even though the product is still functioning, many consumers feel the need to replace their products for several reasons.

First of all, when the product gets older and the product has no mental book value left, the consumer might also expect the product to break in the near future. This is a risk for the consumer, because in that case, they temporarily have no functioning product anymore. In that case, consumers might replace their product pre-emptively.

Secondly, the perceived value of the product might decrease because of wear and tear in the product (lower emotional value), and the consumer just wants to upgrade their product. For example, because there is qualitative obsolescence or because they think the product does not look representative anymore.

And finally, when the consumer has used the product many times, satiation might occur. Satiation happens when the consumer's enjoyment of a product decreases and the consumer has less desire to keep using that product after repeated exposure to the product (Coombs and Avrunin, 1977; Galak et al., 2012; Redden, 2007). You could say that the consumer is 'bored' with the product.

According to Belezza et al. (2017), when the consumer gets tired of their product and they expect the product to break in the near future, they are more likely to neglect maintenance and even act more recklessly with their products. This behavior might be triggered, for example, when the consumer is confronted with newer technologies or when they feel a desire for novelty (Hirschman, 1980).

This 'motivated carelessness' is a way to justify a replacement decision for a product that is not broken yet. Consumers don't want to appear irresponsible because they replace a well-working product (Okada, 2005) and therefore handle the product more carelessly (Belezza et al., 2017).

This could also be explained by the so-called sunk-cost effect (Okada, 2006). The sunk-cost effect explains that replacement decisions are hindered by the psychological costs associated with the purchase price spent on the previous product. When people pay a higher price for a product, stronger psychological costs are attached to the product, and therefore it might feel difficult to replace that product when the newer product is similar to the older product (Trudel & Argo, 2013). However, when the older product looks very different compared to the new product, it is easier for people to justify the replacement decision and convince themselves they upgraded (Okada, 2006). Therefore, it is easier for people to replace products that look dirty, old, or outdated with newer models.

It is assumed that consumers feel the need to replace their product when the product has reached its expected lifetime. At this moment, the consumer might expect the product to break soon, and they might also show 'motivated recklessness', which will make the product obsolete soon. This theory confirms the idea that one of the strategies to increase product lifetimes is to increase the expected lifetime of a product.

When the consumers expect the product to last for many more years, they might take better care of the product, and when the product shows signs of malfunctioning, the consumer will be more likely to repair, instead of replacing the product. To increase the expected lifetime, it is important to know how the expected lifetime is determined and what factors play a role, and that will be explained in the next chapter.

Key take-aways

Mental book value: When a consumer purchases a product, they open a mental account for that product. This means, the product has a certain mental value, and when the product has made its money worth it, it is okay to replace the product.

Replacement decision: To postpone the replacement decision, the mental book value of a product must remain high.

Pre-emptive replacement: The perceived value of a product decreases over time. One of the reasons is that the product is reaching its expected lifetime, and therefore people expect the product to break soon. Therefore, people might replace their product out of precaution.

Motivated carelessness: Another thing that happens is satiation with a product. After repeated exposure to the product, people might get bored with their product. In that case, motivated carelessness might take place. Consumers don't want to appear irresponsible because they replace a well-working product, and therefore handle the product more carelessly, to justify early product replacement.

To be determined next: To increase the expected lifetime, it is important to know how the expected lifetime is determined and what factors play a role, and that will be explained in the next chapter.

2.6 Determining the expected lifetime

As explained in chapter 2.5, the consumer opens a mental account of products at the moment of purchase. Then, they also make judgments on how long the product will probably last: the expected lifetime of the product. Echegaray (2016) showed that only a minority of products have more use time than the expected lifetime: only around 10 to 20% of the products investigated by Echegaray exceeded the expected lifetime. At the same time, Wieser et al. (2015) found out that consumers expect to use the products for a shorter period (expected use lifetime) than the actual lifetime of a product. This shows the role of the consumer, and that people might replace the product sooner, even if the products last as long as they would like them to last. Therefore, it is important to investigate the factors that influence the expected lifetime for products. When the expected lifetime increases, it is assumed to increase the actual use time for products too.

First of all, **past experiences** with similar products play a big role in formulating the expected lifetime of a product (Cooper & Mayers, 2000). Two things have to be noted: First, it seems that negative experiences play by far a bigger part in formulating the expectations than positive experiences (Wieser et al., 2015). While many participants lowered the expected lifetimes of their products because of negative experiences, none of the participants increased the expected lifetimes of their products in case of good experiences. Besides that, negative experiences with products also influenced the expected lifetime of other products. One explanation suggested by Wieser et al. (2015) is that people expect manufacturers to accelerate obsolescence on purpose and bad experiences confirm their convictions.

Besides past experiences, consumers also rely on proxies like **brand and price** (Cooper, 2004). As explained in paragraph 2.5.1, paying a higher price at the purchase, increases the psychological attachment to a product. Also, buying a product with a good reputation or paying more for a product increases the perceived quality of the product. This builds on the previous parts, when people have good experiences with a specific brand, their expectations of the new products will also be good.

Boone et al. (2001) explained that the **frequency of new introductions** of products influences the expected lifetime of products. They introduce a model where the consumer's decision whether to purchase depends on the pattern of introduction and the frequency of introduction. These influence the perceived performance gain of buying the newer product, and the expected performance lag of the old product, and this trade-off. The more new products are introduced, the older the incumbent product is perceived and the sooner it might be perceived as outdated.

Another factor is the **intensity of use**. Some products are used very frequently and some less frequently. The more frequently a product is used, the shorter the expected lifetime is (Cooper, 2004). This can be declared by the fact that people perceive the product as having made their money 'worth'. An example named by Cooper is washing machines; it depends on the size and age of the family how often the machine is used, and as the machine is used more intensively, they are expected to last less long. Important to note, this could be because of two reasons. At first, some product groups are used more intensively (mobile phones or certain kitchen appliances) than others (washing machine or vacuum cleaner). On the other side, the intensity of use also differs for different conditional factors. For example, big families might use the washing machine more often, than smaller families, and therefore they might expect their product to break sooner.

Another finding, by Echegaray (2016), is the **portability of a product**. They found the more portable an electronic device is, the lower the expected lifespan. However, also the expectations-experience gap got bigger, meaning raising awareness about longevity might be a successful strategy for portable electronic devices (Cooper, 2004; Echegaray, 2016).

The factors that are believed to influence the expected lifetime for products are named above. However, the amount of research about the determination of the expected lifetime for products is limited, and further exploration on this topic is needed. This will be done in qualitative study 1, later in this report. Before diving into study 1, a list of strategies will be elaborated that could increase the expected lifetime of products.

Key take-aways

Factors for the expected lifetime: Based on the literature, the following factors influence the expected lifetime. First, past experiences, where negative experiences are more effective than positive experiences. Also, brand and price play a role, frequency of product introductions, the intensity of use, and the portability of a product.

To be determined next: With this knowledge, we get a better understanding of how people determine the expected lifetime. However, this project also aims to increase the expected lifetime. In the next chapter, a list of strategies that could lead to an increased expected lifetime will be explained.

2.7 Proposed strategies

Many factors play a role in determining the expected lifetime of products. However, this project aims to formulate design guidelines that help designers to design products with a longer expected lifetime. Therefore, in the following chapter, a list of design guidelines is explained that aim to increase the actual lifetime of products. These design strategies are formulated by the PROMPT consortium and are believed to increase the actual lifetime of products. In this project, I will investigate these strategies and see if they also influence the expected lifetime, and whether these strategies are good strategies to increase the expected lifetime of washing machines, vacuum cleaners, televisions, and mobile phones too.

2.7.1 Repairable design

The first design guideline is to make the product repairable. Repairable design means the product supports the consumer to repair the product when it is malfunctioning (Den Hollander, 2017; Mugge et al., 2005; Van Nes & Cramer, 2005). By encouraging the consumer to repair their products, they can sustain the functional value of the product, as the functional value can decrease because of defects. Therefore, the replacement decision can be delayed.

One of the problems with repairable design is that it requires action from the consumer: They need to repair the product. According to research, there are several barriers when it comes to repairing: 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 & Behdad, 2018).

Behavior change is needed to make people repair their products. According to literature (e.g. Fogg, 2009), three things are needed to change people's behavior: Motivation, ability, and a trigger. In this case, a trigger would be the decreased performance of the product, and it is up to de designers to create the motivation and ability to repair (Ackermann et al., 2018).

There are possibilities to increase the motivation to repair a product:

1. The **financial value** can be emphasized by the manufacturer of the product. Of course, to be able to do this, the repair costs should be kept as low as possible. In this case, repairing the product will be more attractive as it is a more economical choice than replacing the product.
2. **Stressing the environmental benefits** of repairing a product. When purchasing new products, people tend to consider the sustainable impact of the product. However, somehow, people are not aware of the environmental value of keeping a product and repairing it when it breaks. Especially for people with high environmental concerns, emphasizing the environmental impact might increase their motivation to repair.
3. Making the repair action **enjoyable** is a technique to increase the motivation to repair. At the moment, most people associate repairing products with time-consuming and troublesome, but a purposefully designed repair context might make the activity more enjoyable. Also, it is possible to design in such a way that the consumer is proud of the result.

Besides motivation, the consumer also must be able to repair the product. This either means the consumer should be able to repair the product or knows where to go with a malfunctioning product to have it repaired by somebody else.

1. The first step in enabling the consumer to repair is to **decrease the effort** for repairing the product. For example, by making the product easy to disassemble and make frequently malfunctioning components replaceable using only standard tools. Modular design is also increasingly popular. In modular design, the product consists of several modules that can be easily replaced.

2. Another option to enable repair is improving the **availability and price of spare parts**. It turns out that the unavailability or high prices of spare parts are a major barrier to repair. This means spare parts should be available for a longer time, have a low delivery time and low price. One opportunity for the availability of spare parts is the arrival of 3D printing. This enables manufacturers to have many spare parts available for a longer period without the need to store them and they can easily produce extra parts at a low price.

3. The last recommendation to increase the ability to repair is helping the consumer with the **diagnosis of errors**. When a consumer does not know what is wrong with their product, they might lack the confidence to start repairing the product. People might think it will be too expensive or difficult and they might not even look at the problem. By giving the consumer clear guidance by communicating the most frequently occurring faults directly, the consumer might gain confidence to repair. For example, light or sound notifications or displays could communicate possible errors.

An example of a repairable design is shown in figure 11. In this figure, you see an iron that you can disassemble with only one screw. Using this image, you can also see in one glance how the iron can be assembled again. When it is this approachable to disassemble a product, the threshold to repair, or at least see what is wrong, will be lower for consumers.
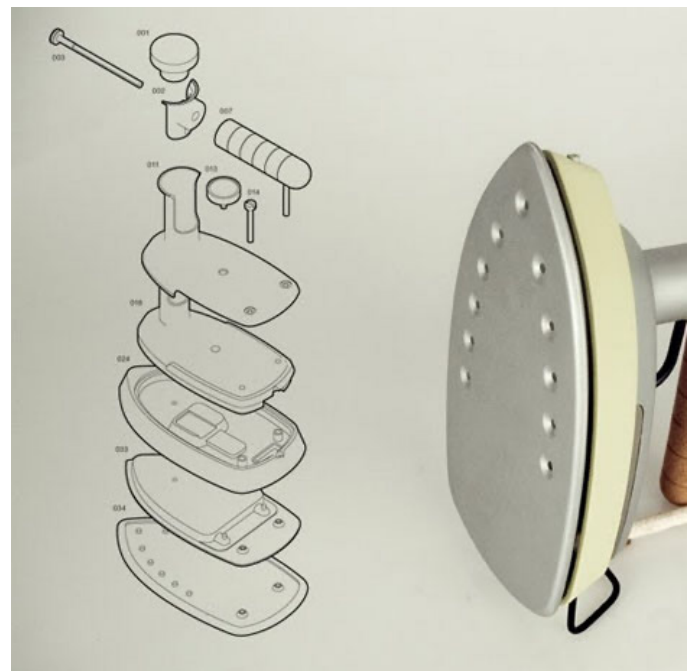

Figure 11: Example of repairable design

2.7.2 Extended warranty

The second design guideline is an extended warranty. This means, that when a product breaks during the warranty period, the product will be replaced or repaired by the manufacturer of the product.

The legal warranty is two years, but by extending the amount of warranty, brands can differentiate themselves and the warranty can work as an additional incentive to choose for this specific brand. It seems that when there are no costs and little effort involved, the value trade-off is more likely to rule in favor of keeping the owned product. Also, when the malfunctioning happens during the period of warranty, consumers will have a different attitude toward the repair.

An example is GoWarranty (see figure 12). This company is specialized in providing extended warranties to products. Instead of advertising good quality, they advertise with the warranty on the products. But of course, you don't need an entire company only focusing on extended warranty, also the manufacturer can develop good warranty plans. This design guideline could be very interesting for the expected lifetime too because the amount of warranty could work as a benchmark of how long the product should be functioning. This will be tested later on in this report.

2.7.3 Upgradeable hardware

Another strategy to increase the lifetime is implementing upgradeable hardware (Khan et al., 2018). An upgrade is defined as 'the process of enhancing the functionality, performance, capacity or aesthetics of a product' by NEN 4554:2020.

Upgrading a product enables to sustain both functional and epistemic values. First of all, features can be upgraded to improve the functioning of the product, but also appearance could be updated. When the owner gets bored with a product, they can change the appearance of the product and increase the consumer's attachment to the product. Although this strategy is quite underdeveloped in the market, research showed that this strategy is valuable and received positive reactions from consumers (Ülkü et al., 2012; Sabbaghi et al., 2017; Brusselaers et al., 2019).

One example is the FairPhone company (see figure 13). This is one of the first mobile phones that provide modules for their phones to upgrade. For example, it is possible to upgrade the cameras of the older versions to the cameras that are also in the newer versions of the FairPhone. This way, you don't have to sell an entirely new phone, but can upgrade the older version and still enjoy the performance of the new updates.

Figure 12: Extended warranty: GoWarranty

Figure 13: Upgradeable product: Fairphone

2.7.4 Upgradeable software

The following strategy only applies to products that contain software, namely upgradeable software. Software updates are used to either improve the functional value of products, by adding or improving features, but also to keep the functional value. For example, when apps are increasing in size, adding the amount of storage could make sure a phone keeps the same speed.

Many software updates go unnoticed, for example when debugging new software, fix new security updates or support newly developed hardware. Sometimes, it is necessary to install the new update yourself, as shown in figure 14. Then, the manufacturer must convince people to install the new software.

However, companies only update their products for a certain period. The discontinuation of software support is a cause for the obsolescence of smart products. Therefore, increasing the number of years of software updates might increase the lifetime of smart products.

2.7.5 Product care and maintenance

Maintenance is defined by EN 4552:2020 as 'activities carried out to retain a product in a condition where it can function as required'. Opposite to repairing a product when it already is broken, maintenance activities help to prevent the product from breaking. Therefore, it will help to preserve the functional value. At the same time, care activities like cleaning a product will help to preserve both the functional and emotional value as it keeps the product looking decent.

In figure 15, you can see some spare parts that often come with vacuum cleaners. If you get these parts for free, it might lower the threshold to have a cleaning session for the vacuum cleaner.

Unfortunately, product care and maintenance cannot simply be designed in a product, it requires actions from the consumer. Therefore, consumer behavior change is needed and that requires ability, motivation, and triggers (Fogg, 2009; Ackermann et al., 2018). Also, maintenance services could be part of the design for care and maintenance, especially for complex products that require much maintenance.

Figure 14: Software update: Windows

Figure 15: Tools to perform care and maintenance

2.7.6 Durable design

Durability is defined by EN 45552:2020 as 'the ability to function as required, under defined conditions of use, maintenance, and repair, until a limiting state is reached'. Durable designs are made up of components and materials that are robust and less likely to break down or show signs of wear and tear. Durable design also helps to maintain the functional value. At the same time, it could sustain emotional value. For example, when the product shows fewer signs of wear and tear, the product remains aesthetically pleasing.

On the other hand, durability could harm the aesthetic value of a product. Robust shapes and materials may not be appreciated by all consumer segments. Therefore, durability is especially interesting for products that have alternative ownership (for example, renting or pay-per-use), in that case, the product is purchased by a company that benefits from longevity and less from appearance.

An example is this CAT phone (figure 16), which is drop, water, and dustproof. Also, the battery is made to be very long-lasting. But, as you can see, this model is less elegant than the commonly known iPhones and Samsung's you see every day. Therefore the consumer segment that is aesthetically attracted to this phone may be limited.

2.7.7 Self-healing materials

One way of creating a durable design is to implement self-healing materials in the product. These materials have the built-in ability to repair damages to the surface, such as scratches and wear and tear (Chang et al., 2020; Sumerlin, 2018). This either means that the product is made of self-healing materials or it has a coating that is self-healing.

Because this prevents the product from showing signs of wear and tear, the product will keep its emotional value (Sheth et al., 2019). Also, research about vacuum cleaners showed that dirty appearances have a big influence on the lifetime of the vacuum cleaner (Harmer et al., 2019).

Self-healing materials are also potentially suitable to extend the expected lifetime of products. When the product is perceived to be more durable, people might unconsciously lengthen the expected lifetime and therefore increase the book value of the product. This could then extend the actual lifetime of the product.

As you can see in figure 17, one of the applications of self-healing materials is in the screens of phones. This is a way of making a phone more long-lasting without having to hand in on the appearance of a product.

Figure 16: Durable design: Unbreakable CAT phone

Figure 17: Self-healing: Nissan scratch shield

2.7.8 Timeless design

Over time, products lose aesthetic value because of wear and tear, but also because of changes in trends or fashion styles. Therefore, one of the design strategies for longevity is a timeless design. Timeless designs are focused on being less susceptible to fashion changes and can therefore preserve their aesthetic value (Flood-Heaton and Mcdonagh, 2017; Mugge et al., 2005; Wallner et al., 2020).

Even though it is hardly possible to truly make a timeless design, as it is impossible to predict trends, designers should avoid product appearances that are more likely to be quickly old-fashioned. However, there are some guidelines for timeless design: visually simplistic, ordered and harmonious, and also neutral colors (black, white, and grey) help to design timelessly.

Also, by introducing new products that look very differently from previous products, the previous products will look older compared to the new products. Therefore, the emotional value decreases. To diminish the effect on the mental book value, timeless design can be combined with upgradeable design. This way, the product can be perceived to be more up-to-date even when it is of an older generation.

In figure 18, you can see an advertisement of Volvo, where they advertise with the longevity of the design of the car. In this case, Volvo shows that they only need to make minor changes to the design of the car, because the cars themselves already last very long. Also, you can see the differences between the cars throughout the years, but the older the car looks, it is more a sign of how good the car is, because it managed to get so old.

Figure 18: Timeless design: Volvo

Key take-aways

Proposed strategies: A list of design guidelines is explained that aim to increase the actual lifetime of products. the next study will investigate these strategies and see if they also influence the expected lifetime, and whether these strategies are good strategies to increase the expected lifetime of products.
- Repairable design
- Extended warranty
- Upgradeable hardware
- Upgradeable software
- Product care and maintenance
- Durable design
- Self-healing materials
- Timeless design

To be determined next: The information given above works as the starting point for the two studies that follow. After this, the conclusion of the literature study follows, which leads to the research questions that will be answered in study 1.

2.8 Conclusion of the literature

In conclusion, even though scientists have been warning about the consequences of the current consumption pattern for decades, not enough changes have been made. Therefore, it is crucial to start changing society's consumption pattern and turn around the 'throwaway society' towards a more sustainable society.

The circular economy model seems to be a very promising concept, but according to chapter 2.2, it seems that one aspect of moving towards a circular economy is being neglected: the longevity of products. Even though the materials move in loops, the loops must be 'small' enough to be sustainable, and therefore, besides looking at energy resources and recycling materials, it is crucial to look at ways to increase the lifetime of products.

Concluded from chapter 2.3, many products are still being discarded before being broken beyond repair, and it turns out that the expected lifetime of products has a large impact on the actual lifetime of products, regardless of the physical state of these products.

According to chapter 2.4, consumers don't realize it is up to them to change their behavior, and designers should help them to move in the right direction. To achieve more sustainable behavior, the more sustainable choice should either be a system 1 choice, where it is easier to choose the more sustainable option. In that case, consumers don't have to weigh all of the options and you are nudged to behave sustainably. The other option is that the more sustainable option stays a system 2 decision,

but in that case, consumers must be aware of the consequences of their choices in the long run. However, since it is hard for people to realize the consequences of their actions in the long term, the more preferred way is to make the sustainable choice a system 1 choice. Therefore, the way people make these choices is explained in chapter 2.4.

In chapter 2.5, mental accounting was explained. By making sure the product value of the current product remains high, the mental book value can remain high, and therefore the replacement decision is postponed.

While making the replacement decision, the expected lifetime of a product is very important. By increasing the expected lifetime, the mental book value stays higher, and the consumer (unconsciously) increases the lifetime of their product.

To learn more about increasing the expected lifetime, a list of product life extension strategies is explained in chapter 2.7. This list of strategies will be used later in the report to test their influence on the expected lifetime and as a means to learn more about how people determine the expected lifetime of their product.

2.9 Research questions

As a result of the literature review, the research questions for the following studies were developed. Even though the concept of mental accounting is not new (Gourville & Soman 1998; Heath & Fennema 1996; Thaler 1980, 1985, 1999), and also research has been done on increasing the lifetime of products (Stahel, 1986; Cooper, 2004, 2005, 2010; Echegaray, 2016; Mugge et al., 2005, etc.), the factors influencing the expected lifetime of products have barely been touched.

As the expected lifetime does have much influence on the actual lifetime, the research question for the qualitative study was defined as the following:

RQ: How could the expected lifetime of products be extended?

This will be studied by focussing on three sub-questions:

SQ1: How do people determine the expected lifetime of products?

SQ2: What is the influence of the proposed strategies on the expected lifetime of products?

SQ3: How do people view their own responsibility on product longevity?

SQ1 aims to learn more about the way people determine the expected lifetime in an explorative manner. The current literature is limited and therefore, this study will complement existing literature with new insights about the expected lifetime.

SQ2 aims to learn more about the role of the strategies as explained in chapter 2.6 on the expected lifetime. These strategies are formulated as a list of strategies to extend the actual lifetime, in this study. This sub-question aims to find out how consumers perceive these strategies regarding expected lifetime.

The last research question (SQ3), is about the way people see their role in the longevity of their products. It would be interesting to see if people think longevity is their responsibility and whether they take longevity into account when thinking of sustainable behavior, or whether they think the market is responsible. This might be interesting when considering the strategies that extend (expected) the lifetime of products. For example, when people think they are responsible for themselves, strategies like repairability might be more relevant. On the other hand, when they think the market is more responsible, people might think the amount of warranty is the most important.

PART 3: STUDY 1 - QUALITATIVE INTERVIEWS

As explained in chapter 2, the expected lifetime is one of the factors that can help in the transition towards a circular economy. As knowledge is lacking about how the expected lifetime is determined, and strategies to increase the expected lifetime have not yet been tested, this study will investigate the expected lifetime for products. In the first study, a qualitative research study will be executed to explore the replacement decisions of consumers and the way expected lifetime plays a role. Also, people's attitudes towards life extension strategies will be investigated, and the way they think they influence the expected lifetime for new products.

3.1 Method

To investigate the expected lifetime, how people determine it and what factors play a role, a qualitative approach was chosen using semi-structured, in-depth interviews. In-depth interviews, because they fit the exploratory objective for this study, and they allow gathering rich information about the experiences and perspectives of the consumers (Jamshed, 2014). The semi-structured approach was used because it is suitable for exploring motivations and perspectives about the topic but also leaves space for unexpected insights.

For this study, people who replaced one of the following products within the last six months were interviewed: Washing machines, Televisions, Smartphones, and Vacuum cleaners.
Long story short, distinguishing these four different categories can help to get a broader view of how consumers make replacement decisions.

3.1.1 Participants
The main criterion to recruit the participants is that they have replaced their product within the last six months to make sure the interviewees have fresh memories about the replacement decision. Also, they haven't used their product for too long, so they can reflect on how long they expect the product to last, without satiation, signs of wear and tear, and new product offers to play a role.

This way, more detailed answers can be provided and their perspective on the expected lifetime of products is based on the moment of purchase.
To keep cultural differences out of the study, only Dutch people were interviewed, and the interviews were performed in Dutch. The interviews were also analyzed in Dutch and translated at the reporting phase. This is to minimize the nuances that go lost in the translation of interviews.

The study consists of eight interviews, meaning two interviews per product category. Of the participants, three were male and five were female aged between 21 and 29. Convenience sampling with a quota of two people per product category was used. The participants were recruited through social media.

3.1.2 Stimuli and products
TThe focus of the study is to explore the way people determine the expected lifetime, and how they see their responsibility in the longevity of their products. Also, the study focuses on evaluating the list of proposed strategies (as explained in chapter 2.6) regarding their role in the expected lifetime.
To do this, the interview guide (Appendix 1) is split up into three parts. In the first part, the interviewees reflected on their latest product replacement decision, and in the second part, they reflected on the proposed strategies, in the last part, the

interviewees reflected on their replacement decision and sustainability. To keep the study as realistic as possible, they answered questions about their real product that was purchased within the past six months before the interview. For the proposed strategies (as explained in chapter 2.6), a slide show was used (Appendix 2), explaining the definitions of the strategies to make sure the participants all reflected on the same strategy.

Before the actual study, two pilot interviews were run, and improvements were made based on the procedure set up and recommendations of the participants. Some questions were changed because the answers turned out not to be relevant for the study, some questions were left out due to time constraints and it turned out it was necessary to give the participants proper explanations about the definitions of the strategies, therefore the slideshow (Appendix 2) was added.

3.1.3 Interview setup

In appendix 1, the interview guides can be found. The setup for the interviews is based on a study to be conducted by van den Berge (to be published) who studies whether the proposed strategies are likely to postpone product replacement on behalf of the PROMPT project. Also, the study by Echegaray (2016) was used as inspiration for the interview guide about the replacement decision.

As explained in paragraph 3.2.1, the interview was split up into three parts. The first part of the interview focused on the latest replacement decision of the participant. For example, why they replaced their products and what they think they could have done to postpone replacing the product.

Also, in case the participant replaced the product because of malfunctioning, questions were asked about the repair. For example, whether they considered repairing the product and why, or whether they would repair their current product if it would show the same signs of malfunctioning. These questions aimed to find out to what extent the participants take action to increase the lifetime of their product.

Then, questions were asked about the expected lifetime. Whether the product reached the expected lifetime and the expectations of the new product. These questions aimed to learn more about how the participants determine the expected lifetime of the products.

After the replacement decision questions, the strategies followed. These questions aimed to find out how the participants perceived the strategies and their role in the expected lifetime of their product.

And finally, some questions were asked about the role of sustainability in the replacement decision. These questions aimed to find out whether people link longevity to sustainability, and how people took their responsibility in extending the lifetime of their product.

3.2 Procedure

The interviews were conducted through online video calls. Due to COVID safety measures, interviewing in person was not possible, and video calls were chosen as they provide the opportunity for a dynamic conversation. This way, facial expressions, and body language are involved and can be used as prompts for further questioning.

The interviews took between 30 to 65 minutes, and all started with a short introduction about the research setup and procedure. Then, informed consent was given by all participants, and they got the opportunity to ask questions.
Following, the actual interview started, starting with some introductory questions about their latest replacement decision. This allowed the participants to go back to the moment they purchased their new product and think about their experiences and motivations while doing so.

After that, the participants were asked about the expected lifetime of their old and new products. They were asked about their expectations but also opinions on the expected and actual lifetime and how they think the lifetime could be extended. This way, they were involved in the topic but not influenced by the questions yet.

In the second part of the interview, the listed extension strategies were discussed. At first, the strategies were introduced with a short definition after which the participants were asked whether and how this would influence the expected lifetime of their product. The interview ended with some final questions about the role of sustainability during the replacement decision.

3.3 Analysis

After the interviews were performed, they were analyzed using coding, clusters, and memos. This approach suits well as it allows an explorative study about individuals as well as larger social processes and helps to analyze motivations, personal experiences, and emotions in a structured way.

After performing the interviews, they were transcribed and analyzed using the software program Atlas. To turn the large amounts of data into something accessible, the transcripts were coded. The interviews were initially coded using line-by-line coding and contained a total of 223 codes. Then, the codes were studied and clustered and it was concluded that some of the codes had overlap and some of the codes had to be split up into subcodes to highlight certain details.

Finally, 196 codes made it to the final codebook, and were then categorized into 10 big clusters and, all strategies got their own cluster. Visuals of the clusters can be found in appendix 3. These clusters were used to create structure and analyze the research questions without losing too much detail. During the entire process, eight memos were written about things that stood out.

3.4 Results

The following chapter explains the results of the qualitative study of this project. A total of eight qualitative interviews were conducted, with two participants per product category. The findings were compared and integrated to form a complete image of the way people form expectations while buying a new product and their attitude towards product life extension strategies.

The results for the study are structured according to the research questions as defined at the beginning of Study 1. At first, the three sub-questions are answered, followed by the main research question. It is attempted to use the research to form a complete image of the expected lifetime of products that could later be tested in the quantitative research.

RQ1: How could the expected lifetime of products be extended?

SQ1: How do people determine the expected lifetime of products?
SQ2: What is the influence of the proposed strategies on the expected lifetime of products?
SQ3: How do people view their own responsibility on product longevity?

3.4.1 Determining the expected lifetime of products

To answer the first research sub-questions, the participants answered questions about the expected lifetime of products. For example, how long do you think your product will last and whether you are happy with the lifetime of your previous product? In the following two sub-chapters, the results from the questions about sub-question 1 will be shown. At first, the re-evaluation of the expected lifetime will be explained and after that, the way people determine expectations for product lifetimes will be described.

Re-evaluation of expected lifetime
One of the unexpected insights is about the re-evaluation of the expected lifetime of products. Before going into the qualitative study, it was assumed that people determine the expected lifetime for a product only at the moment of purchase. However, the interviews showed that the expected lifetime is something that's being re-evaluated multiple times during the lifetime. This happens, for example, when (part of) the product **breaks**. Then, the person needs to undertake action to keep the product working, and they decide whether it is worth it to put in the

effort and money or not. But a **new product offer** could be a trigger to evaluate whether it is time to replace the product, and if not, to re-evaluate the remaining expected lifetime. At last, **demographic changes** might also be a moment to re-evaluate the expectations of product lifetime. The demographic change itself might not damage the product itself, but it could be a trigger for the consumer to assess whether the product needs to be replaced and if not, what are the expectations of the product. One of the interviewees expected her phone to last three years, but when the back of her phone broke, she had to re-evaluate her product and now thinks it will only last 1 more year.

"Well, when I bought it, I think I paid something like € 300 for it. Then I thought it would last 3 years or something. However, now the back is broken ...
... Of course, I still hope it will last 3 years, but I think it just doesn't. I think in the end it will just be another year or so. Because the back is broken, it's more vulnerable to even more damage from dust entering it and water damage."

When the interviewee's phone screen broke, she had to re-evaluate whether it was more valuable to replace her phone, to repair it, or leave it and keep the phone in this state. In this case, the interviewee chose to keep the phone in its current state and accept the fact that her phone will last less long.

Factors that influence expected lifetime

At the moment of purchase, the consumer considers a lot of factors to determine the expected lifetime of their products. It must be stated that the study was conducted on a small scale, and therefore more research is needed to scientifically validate the findings. In this chapter, the factors that were distinguished in this study will be elaborated. First of all, the study revealed that a **warranty** is a good indicator for the consumer to estimate the lifetime of their product. Participants declared that they expect the manufacturer to secure themselves and are therefore have conservative warranty policies.

"I think if the warranty is longer, that you can also assume that the product will last longer because you can, of course, assume that companies never, sort of, insure the full life of a product. But I think if a product has a two-year warranty that I certainly expect that I can use it for 5 years. While when it has a 5-year warranty on something. Then I hope that I can use it for 7 to 10 years or so."

The study shows that the link between warranty and expected lifetime works two ways: People expect the product to last at least the amount of time of warranty, which is positive because people still perceive the product as very valuable when there is still warranty. This counts not only for buying new products but also products on the second-hand market are more valuable when there is still a warranty.

On the other side, there is a risk that people don't expect the product to last much longer than the warranty period. This could be because people expect the company to test the lifetime of a product and determine the warranty based on that. In that case, the amount of warranty would work as a limiting factor of the expected lifetime. However, from this study, the positive effect of warranty seemed to have a stronger effect than the negative effect.

Another indication for the expected lifetime is **past experiences**. This can be past experiences from the consumer themselves or other consumers. People take previous experiences into account of the same product. Some people had the same brand before, or they compare it to another brand. Also, some people compare one product category to other product categories, like the example below. In that case, the participant took his expectations of another product, the smartphone, as an indication of the expected lifetime of his television. In that case, the expectations for his smartphone work as a benchmark for the expectations of his television.

"Actually I based it on telephones, the average telephone usually lasts two years. (...) The technology behind the TVs and software that is on them is also getting bigger (...) As a result, I think it should be something between 4 and 8 years for such a smart TV and I don't know if it is correct, but I have that feeling."

Also, the experience of others is considered, for example by talking about the purchase decision to other people as well as reading reviews about a certain product. In this case, the expected lifetime is influenced less directly, and it indicates whether the product is likely to last long, not specified in numbers.

The third indication mentioned by the participants

is the **average lifetime of products**. Most people think their product will last around the average time. It must be noted that all participants did not know the average lifetime of their products, even though most of them were interested in knowing it. After guessing the average lifetime of products, the participants compared it to their situation. For example, living in a student's house might mean people handle the product less carefully and people feel less responsible for keeping the product clean and maintained. In that case, the product will break earlier than the average lifetime.

This indicates that more knowledge about the average lifetime of products helps estimate the expected lifetime of products and is therefore desired.

"I don't know what the average age of a TV is, but I hope to use this TV for at least 4 to 8 years."

A fourth factor that plays a role in determining the expected lifetime of products is the **expected change in demographics**. This was mentioned by many participants in different situations. For example, graduation would mean the replacement of a smartphone for the following participant:

"When I graduate, I might just want a new phone, so that it just looks good again because it just radiates something to your colleagues and your patient, if you just walk with a phone with a big crack in it."

Other examples given are getting children and moving out of a house.

The last factor that helps to determine the expected lifetime for products is the **purchase price**, although it must be noted that this goes two ways.

It could be that people want a product that lasts long, and therefore select a product that they think lasts the longest. In that case, I assume that a higher price means better quality and therefore longer lifetime. However, in the following example, the participant first determined the purchase price and within that price range, choosing the one that they expected to last the longest.

"Well, in the end, we chose the one within our budget that looks the best with the idea that will last the longest."

Key take-aways

Re-evaluation of lifetime: The interviews showed that the expected lifetime is something that's being re-evaluated multiple times during the lifetime. Triggers for re-evaluation are malfunctioning, new product offers, or demographic changes.

Factors that play a role: The interviews revealed several factors that play a role. First of all, the warranty was mentioned by participants, because they expect the manufacturer to secure themselves and are therefore have conservative warranty policies. Besides that, past experiences were mentioned as a means to compare one product to another product and decide if the current product will last longer or less long. Also, the participants asked about the average lifetime of products, also as a means to compare their product to the average product or situation. However, none of the participants was certain about the average lifetime of their product. At last, the expected change in demographics played a role. This was partly because people expect their own needs to change and also because the way they use their product will change.

To be determined next: These were the general factors as mentioned by the participants in the first part of the interview. In the next part, the participants will react to the list of proposed strategies and tell how they think the strategies will influence the expected lifetime.

3.4.2 The influence of design strategies on expected lifetime

It is important to notice that the expected lifetime is something different from the actual lifetime of a product. Some factors play a role in determining the expected lifetime for products that don't play a role in the physical state of a product (for example, timeless design), and some factors play a very big role in the actual lifetime of product but are not considered when considering the expected lifetime, for example when they prevent the product from breaking without the attention of the consumer.

This study showed that the appearance/state of a product plays a big role in the choice of whether or not to replace a product, even though none of the participants would explain this themselves.

In the following chapter, you can read the answer to the second subquestion:

SQ2: What is the influence of the proposed strategies on the expected lifetime of products?

A summary can be found in figure 19.

Repairable design
Depends on personality of the owner
Positive attitude towards the idea
Action is still needed
Not looked at during purchase

Timeless design
Old-fashioned perceived as older product
Could be both beneficial and detrimental
Depends on the product and design

Extended warranty
Strong indicator for expected lifetime
Works two ways, also limiting
Little action needed

Self-healing materials
Participants not very familiar with the materials
Skepticism about sustainable impact
Prevents only signs of wear and tear

Physical upgradeability
For certain parts or products
No compromise on quality

Durable design
Influences lifetime compared to other products
Depends on the 'bottle neck' of the product

Care and maintenance
People care for newer products
Maintenance still often neglected
Appearance affects expected lifetime

Software updates
Limiting factor to expected lifetime
Perceived to keep the product
Working instead of improving
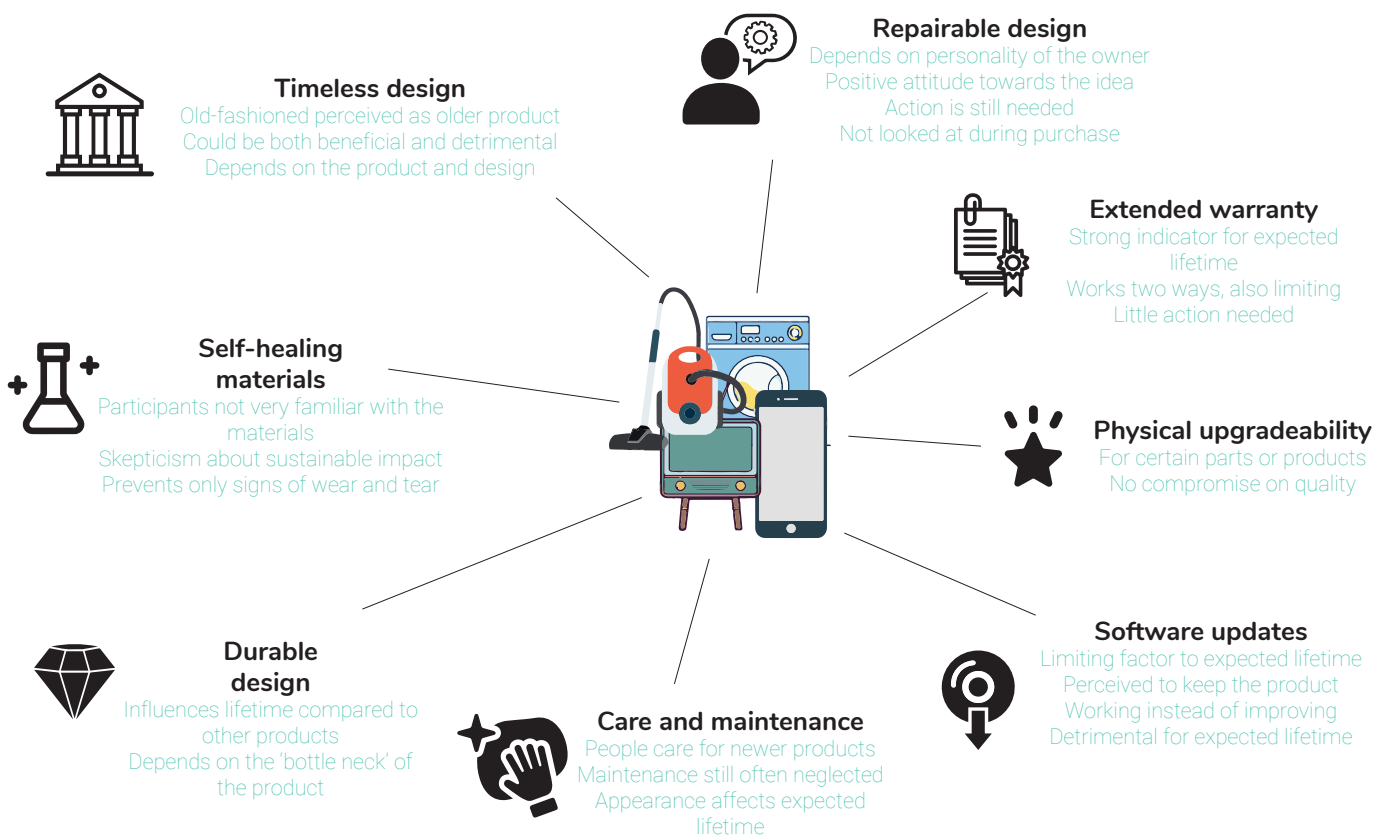Detrimental for expected lifetime

Figure 19: Findings about the proposed strategies

3.4.2.1 Repairable design

The interviews showed that the impact on the expected lifetime of products by repairable design highly depends on the type of consumer. Some consumers perceive themselves as 'handy' and therefore think they can repair their products also without a particular 'repairable design', and other consumers explained they are not so handy, and they don't trust themselves with repairing their own products, even when it has a repairable design. It must be noted that this study only asks about the expectations of the participants, and reality might show something different.

"I would secretly be a bit worried that it would be a bit rickety if I did it myself because I'm not much of a washing machine technician, so I'm also afraid that I will break it instead of repair it. So, I would find that tricky."

On the other hand, the research showed that consumers have a positive attitude towards repairable design in theory. The idea of being able to repair your own product or replace certain parts sounds good. Still, for the participants in this study, all of them didn't expect a repairable design would impact the lifetime of their own product.

"I think I might be more trouble, nowadays you can of course order something new with the click of a button. And if you had to repair it yourself, then that would of course be an effort, and you might also have to delve more into how to do that."

Overall, the participants weren't aware of the repairability of their new products, and it is not something they were aware of during the purchase of their product. Therefore, it can be concluded that the repairability of a product plays a role in extending the actual lifetime of a product, but not so much in the expected lifetime of a product. In other words, when a product breaks, the expected product lifetime does influence whether people will repair their product, but not the other way around.

3.4.2.2 Repair services

It was found that people think repair services, like repairable design, will extend the lifetime of products when something breaks, but the repairability and repairable design is not something that is considered at the purchase and is not something that influences the expected lifetime beforehand. However, when something breaks, the consumers think repair services will help to repair a broken product and therefore extend the actual lifetime of products.

" And, well, it is cool when you can call something and then say, yes, this is broken, I'm going to replace this part now, what should I pay attention to? Or so, that's better, then you feel a bit more confident when you are going to do it."

3.4.2.3 Extended warranty

In contrast to the repairability and repair services, the amount of warranty seems to be a good indicator for the expectations of product lifetimes. Almost all participants related the expectations for their product to the warranty on the product.

However, some of the people regard the amount of warranty as the minimum lifetime for the product, like in the following example:

"I think if the warranty lasts longer, that you also assume the product will last longer. Because you can, of course, presume that companies never insure the entire life of a product."

And others are more skeptical about warranties in general. This means, the amount of warranty is very relevant but works both ways. A longer warranty means a longer expected lifetime, but also a reduced warranty means a reduced expected lifetime. It seems that the participants think that companies test the lifetime of the products and determine the amount of warranty based on that, and therefore it can be seen as a reliable source to determine the expected lifetime. Also, warranty is partly linked to planned obsolescence by some of the participants, who think the product will break right after the warranty expires:

"It depends whether... Yeah, suppose they say you got a five-year warranty, then things always break exactly one day after a warranty expires, you know."

Even though the second life of a product is out of the scope of this study, it is interesting to show that a long warranty also increases the chances for the second life of a product. As explained in the following quote, the participant expects the product to be technologically obsolete (meaning: the product still works but he wants newer technologies) within

the period of warranty. Because at that moment, the product still contains a warranty, it will be easier to sell the product.

"A maximum of eight years with ten years is really nicer. That is a good period, because then you can also sell your TV, or give it another destination with warranty in my case than in my case."

3.4.2.4 Upgradeable hardware

The study showed that upgradeable hardware is perceived as a good option to extend the lifetime of products that go out of date, and therefore extend the expected lifetime for products. Even though the following participant thinks this does not work for all products. Of course, this differs per consumer, whether they think owning the newest technologies matters.

"No, I don't think so because I've never bought another phone because I wanted a better camera."

For other products, like a vacuum cleaner or washing machine, physical upgrades seem to be a great way of extending the expected lifetime of a product. Also, the type of parts that can be upgraded play a role, as the replaced part should be a critical part, and the reason the product would have been replaced.

"I think that you do not necessarily have to compromise on quality as the product gets

older, but that you also do not sell a whole new product, which is, yes again, beneficial, I think because of less production in theory."

3.4.2.5 Upgradeable software

Just like extended warranty, the upgradeable software has shown to be one of the bigger implications for the expected lifetime of products. Meaning, the number of years the software is updated. Even though almost none of the participants is aware of how long the software in their products will be updated, the estimated time for software updates is a good indicator in the expected lifetime. This means, as soon as the manufacturer stops updating the software of a certain product, that is a sign for the owner that the product is obsolete at that moment. Especially when purchasing second-hand products, the remaining software update time was a good indicator of how new the product should be.

"And to be fair, I wanted to buy that iPhone SE 2016 again. Only because Apple will probably no longer provide updates for this next year, I was like, yes, you know, that is just plain worthless, so I better buy a newer model refurbished."

However, unlike the extended warranty that is likely to extend the expected lifetime of products, the software updates mainly work as a restriction to the expected lifetime for products. This counts for products that already contain software updates (TVs and smartphones) as well as for products that don't yet contain software updates (washing machines,

vacuum cleaners).

In the following quote, you can read that this participant is afraid that even though software is not necessarily needed for, for example, a vacuum cleaner, vacuum cleaners would not work anymore without software. In that case, adding software to a product that does not necessarily need software might be detrimental to the expected lifetime of the product.

"If at some point you can no longer buy a vacuum cleaner without software, then... It is not necessary for the basic thing what it has to do (...) so, I would be afraid it cannot work without the software."

This could be because people perceive software updates as something that keeps the product working, instead of improving the product. Therefore, there is a maximum to what level extending the software updates influences the expected lifetime. When the consumer expects the physical product to last for example for three years, the amount of software updates after those three years would not influence the expected lifetime anymore.

"And this is the iPhone SE 2020, so the updates are expected to last 6 years anyway. Well, 6 years is longer than 3 years, so it doesn't really matter, I guess."

3.4.2.6 Product care and maintenance

This study confirmed the careless behavior theory as explained by Belezza et al. (2016) for most of the

interviewees. When a newer product is purchased, people try to keep the product clean and proper as possible with the intention to keep it good for as long as possible. However, as the product gets older, people start neglecting the care and maintenance of the product.

"And I think if you buy a new one, because look, now we just got it new. Now I really intend to use it as economically as possible, because of course, you prefer it to last as long as possible."

Although for many products, it already is easy to carry out maintenance of their products, most participants admitted postponing or neglecting the maintenance for their products, especially when they are cheaper or older. This suggests that just making maintenance or cleaning easier, might not mean people necessarily carry out the maintenance.

"No, but it does have a drum cleaning function, and the manual said, for example, that they recommend you to do that once a month, but I don't. But it also has a drum cleaning function at all positions so, it's actually super easy, and it only takes 15 minutes so, you could do that as easily as that."

However, people do have the intention to clean and maintain their products, because they want to keep their products for as long as possible. Also, most people claimed that the main reason to take care of products is to make the product last longer, and also people give up maintaining products when signs of wear and tear are showing or when the product already looks dirty.

"Yes, I am not a cleaning lady in heart and soul, but I do appreciate it when things stay clean and therefore last longer."

3.4.2.7 Durable design
The interviews indicated that the design of the product plays a big role in the expected lifetime of products, but it depends on the type of product whether this is product specific or category-specific. For example, the vacuum cleaner owners claimed that the looks of their product compared to other vacuum cleaners influence the expected lifetime:

"It looks a bit less sturdy, but it is very nice, and it works well on its own. In appearance, I think the plastic appears a bit cheaper. Well, then I think it might not last as long."

But the phone owners reported that phones, in general, have a less durable design, as the outside mainly exists of glass and the screens break often. This suggests, determining the expected lifetime differs per product category as the different categories have different 'bottle necks' for the lifetime of products.

It must be considered that for many products, durable design means less elegant or luxurious and therefore may be less attractive. This might be detrimental to the expected lifetime of a product as the emotional value of the product might be lower.

3.4.2.8 Self-healing materials

The interviews showed that the majority of consumers are not aware of the existence of self-healing materials. The participants that heard about it, have never seen it nor own a product that contains self-healing materials. Therefore, it is hard to conclude about the impact of self-healing materials. Overall, the participants had a positive attitude towards the idea of self-healing materials:

"I am not familiar with it, but it does sound really nice."
"No, never heard of it, sounds interesting."

However, to the question of whether self-healing materials impact the expected lifetime of products, the participants, they were skeptical, and felt it might be unnecessary as the materials only repair minor scratches.

"No, if there are small scratches on it. Yes, that's just life/use damage. If it doesn't get in the way, I'm not going to replace it."

Besides skepticism about the need for self-healing materials, the question was raised whether it is more sustainable to have products with self-healing materials, or to replace their current parts, as they expect the self-healing materials to be more polluting. As the conflict of what is more sustainable keeps coming back, it is relevant for the implementation of self-healing materials to provide the consumer with clarity about the impact of self-healing materials compared to conventional materials.

"I would have to consider what is worse, whether to replace a screen or the self-healing screen, so that depends on environmental impact. Yes, because of the newly regenerating, self-polluting things versus the double glass screen or something."

3.4.2.9 Timeless design

The results of this study show that timeless design is a good indicator for the expected lifetime of products. Despite some statements from many of the participants that they will only replace products when they become physically obsolete, when a product has an old-fashioned design, people will perceive the product as older, and likely to need replacement soon:

"Yes, in that sense. Suppose that suddenly a mega-development comes into the washing machine world so that it all suddenly looks very high-tech in a while. Then you soon think, if here looks different and a bit old-fashioned, yes, well, yes, it needs to be replaced, even if it is doing well. I think that's how it, how it works."

It could be expected that this is more relevant to products that are highly visible for people, but that was not apparent from the results. While 're-evaluating' products, people compare their product to the current products on the market, and when there is a big discrepancy, this might be detrimental for the 'old' product.

Nevertheless, it depends on the product whether old-fashioned is beneficial or detrimental, as old-fashioned could also be perceived as classic, which is a positive view on old. In that sense, products with a timeless design could be perceived as boring, and products that show their age could be perceived as a showpiece for their age.

"But neat can be in the form of an old-timer or the form of the most modern Tesla. If the screen just isn't cracked, it doesn't matter if you're driving an old-timer Ducati or a Tesla. At least not for me. As long as it just looks neat."

Key take-aways

The results of the second sub-question can be summarized as the following:

Repairable design: Depends on the owner, because action is needed. Also not taken into account while purchasing the product.

Repair service: Most participants were not enthusiastic about repair services and did not understand very well what repair services would add to the expected lifetime of products.

Extended warranty: This was already mentioned by the participants in the first part. Strong indicator and little action from the owner is needed. It has to be considered that this could work two ways, a short warranty could have a negative effect too.

Upgradeable hardware: This could increase the expected lifetime, but it has to be designed smartly. For certain parts, it is more impactful than other parts.

Upgradeable software: Only works as a limiting factor. When the manufacturing stops updating the product, it is perceived to be obsolete. It works as keeping the product functioning, instead of improving the functionality.

Product care and maintenance: People care more for newer products. By keeping the product in a new appearance, you can improve how people maintain their product.

Durable design: Compared to other products, it might work. Regarding the parts, it depends on the 'bottle neck' part of the product.

Self-healing materials: Participants were not aware of these materials and doubted the environmental impact of the material itself. But the fact that it prevents signs of wear and tear showed that it might increase the expected lifetime of the product.

Timeless design: Highly depends on the design, it could work beneficial but could also make the product look boring, and therefore decrease the emotional value of the product.

To be determined next: Besides the effort of the designer to make a product that is perceived to last long, the consumer also plays a big role in the (expected) lifetime of the product. The last part of the qualitative study focuses on the role of the consumers in the expected lifetime of their products.

3.4.3 Consumer responsibility and awareness of longevity

To answer the third research question:

SQ3: How do people view their responsibility on product longevity?'

the participants answered questions such as 'Why did you replace your product?', 'What could you have done to extend the product lifetime?', and 'What is your opinion about the lifetime of your previous product?'. Also, the follow-up questions to other questions contained information about the feeling of responsibility of the consumers. It is important to understand people's attitudes towards actual and expected lifetime, to change the expected lifetime of products and to increase the lifetime of products.

When the consumer does not feel responsible for the lifetime of their products at all, for example, when they think the companies or the government are responsible, a different approach might be necessary to increase the lifetime. For example, increasing the minimum period of warranty and availability of spare parts. While on the other hand, when the consumer is aware of their responsibility, repairability and upgradeability of products help to increase the lifetime of products.

This explorative study gains insights into the consumer perception towards their responsibility in lifetimes, and they cluster into three main parts: Consumer capability, consumer awareness, and consumer attention.

3.4.3.1 Capability
The first cluster that was found is consumer capability. Even if the participant wants to consume as sustainably as possible and they want to increase the lifetime, knowledge and capability are limiting factors. For example, choosing between a longer-lasting product versus a product that is less impactful but also lasts less long. As you can see in the following quote, one of the participants declared the dilemma:

"I study medicine; I do not study environmental sciences or anything. So, I do not know how to figure out okay, what is the impact on the environment if I buy this specific phone second-hand in Iceland compared to if I, for example, would buy a new one in the Netherlands, which was not an option because buying a new one was way too expensive."

Besides knowing what the most sustainable thing is to do and how to extend the lifetime of your products, also the personality of the consumer is very important. One of the people interviewed declared she was very clumsy, and even though she wants her product to last very long, for some people, things happen that decrease the lifetime of products.

"I have to be more economical with my things. But the thing is, even when I try, I'm just really, really clumsy, and you can't suddenly throw 26 years of clumsiness out the window or something. I cannot argue that very well, but I try to pay attention. For example, that I do not put my phone in the same pocket of my bag how where my keys are in, then you can scratch your keys on it and stuff."

3.4.3.2 Awareness

Even though sustainability is a hot topic nowadays, most people found it hard to express the expectations of the lifetimes of their products. Most of the participants even declared that this interview made them more aware of product longevity, even though the interview was only meant to gather information, and not to provide information. This means, people are simply not very aware of the influence of product longevity on the environment, and only making people aware of this might help to increase (expected) lifetimes.

For example, when talking about self-healing materials, the following participant expressed his doubts about the sustainability of the material. On the one hand, it might make the product last longer, but he is not aware of the sustainable impact of the material itself. So, it is hard for a consumer to choose between something that lasts longer and something that has less impact when purchasing the product.

"I don't know if it is very sustainable. On the one hand, it's durable, of course, because it's "self-healing", so you don't have to replace it, so you have fewer production costs in material, but at the same time, something called "self-healing" material sounds like a bunch of toxic substances that are bad for you and the environment"

Besides that, it seems that not all participants they are aware of their role in product longevity, and think the market is responsible for the lifetime of a product. As explained in the following quote, companies might use product failure as a business model. The sooner a product breaks, the sooner you will buy a new product, and also, they can make money on the repair. When a company does this on purpose, it is called 'planned obsolescence' (Guiltinan, 2008).

"It is becoming more and more that producers say, this product will last three years without it breaking and after that, it will probably break and then you must buy a new one. They want to sell more and earn more from it or the repair costs. So, the warranty has become more of a revenue model… But maybe that is my suspicion towards the producer world."

3.4.3.3 Actions

At last, some consumers are environmentally aware, it was also found that the participants are not very consistent in their sustainable behavior. For example, one of the participants explained that she behaves very sustainably regarding clothes and shoes, but she did not take sustainability into account when purchasing her vacuum cleaner. She does not associate vacuum cleaners with sustainable decisions, but she does with clothing.

"With this vacuum cleaner, I did not look at 'What brand is it?' 'What material is it?'. I sometimes do that with other things, but I haven't done that with the vacuum cleaner (…) I often do it with clothes and shoes. And for example, with a telephone but with my vacuum cleaner I did not look at that."

Besides the type of product, it seems that some people don't make the connection to sustainability when discarding a product, even though they do look at sustainability when selecting the new product, as you can read in the following quote. In this case, the participant did look at sustainability when purchasing her new washing machine but did not try to have the old one repaired.

Yes, so in that sense, we looked at the durability of the washing machine we purchased. But we have did not have the guarantee of the durability of the previous product. But yes, we might have been able to have it repaired. If we put a lot of effort and time into finding a technician who could fix the product, we did not do that.

Key take-aways

The following insights into the perception of the consumer towards their responsibility in lifetimes are found:

Capability: Even if the participant wants to consume as sustainably as possible and they want to increase the lifetime, knowledge and capability are limiting factors. Besides knowing what is the most sustainable thing to do, and how to extend the lifetime of your products, also the personality of the consumer is very important.

Awareness: People are simply not very aware of the influence of product longevity on the environment, and only making people aware of this might help to increase (expected) lifetimes. Besides that, it seems that not all participants they are aware of their role in product longevity, and think the market is responsible for the lifetime of a product.

Actions: While some consumers are environmentally aware, it was also found that the participants are not very consistent in their sustainable behavior. Besides the type of product, it seems that some people don't make the connection to sustainability when discarding a product, even though they do look at sustainability when selecting a new product.

To be determined next: The past three sections explain all three parts of the interview. The next chapter will conclude and answer the main research question 'How could the expected lifetime of products be extended?'.

3.5 Conclusion

In the previous paragraphs, the sub-questions were answered. The following chapter gives the conclusions of the subquestions and thereby answers the main research question:

"How can the expected lifetime of products be extended?"

Re-evaluation of lifetime

First of all, this study showed that people re-evaluate the expected lifetime at several moments in the product life. These 'triggers' often harm the expected lifetime, for example when a phone screen breaks, or a washing machine starts to make weird noises. Even though people might repair these minor malfunctioning, it will decrease the consumer's trust in a product and therefore decrease the expectations for the remaining lifetime. Therefore, to design for a longer expected lifetime, it is key to make sure these re-evaluation moments are limited and have as little impact on the expected lifetime as possible. For example, by making the errors seem less severe by making them very easy and cheap to repair, or by producing the product in such a way that it is useful in other contexts as well, for example by making it upgradeable or to give the product a timeless design.

Important factors

Next to that, almost all participants named three factors that they use to determine the expected lifetime of products: Warranty, past experiences, and average lifetime.

First of all, a **warranty** is something very concrete to link to expectations, as the company tested the durability of the product, and they guarantee the product to last that long. Therefore, as expected, an extended warranty is a great opportunity to increase the expected lifetime, and thereby the actual lifetime of a product.

Also, **past experiences** functioned as indicators of the expected lifetime. However, it is hardly possible to design past experiences, it is important to take this context into account. For example, service models such as pay-per-use, where a product can use the same product for a longer period. In that case, the product might not last longer, but it would make the consumer experience the same product for a longer period.

Also, many participants in the study asked me what the **average lifetime** for this type of product is, to estimate their expected lifetime. Therefore, promoting the average lifetime for these products might make a difference in the expected lifetime. This could also benefit the seller of the product as they could use the average lifetime as a promotion.

Then the last factor named by the participants is **expected change in demographics.** For example, one of the participants wanted to keep this phone at least during her studies, but then replace it because at her real job, she needed to have a representative phone. In this case, making the product upgradeable and durable will increase the expected lifetime. Upgradeability could make sure the product is usable in different contexts and could be used throughout different stages of the user's life.

The bottleneck of the product

Another insight from the interviews is that the bottleneck of products differs per product category. Therefore, this should be considered when designing for products with a longer expected lifetime. For example, products that contain software and need software updates, might benefit from a longer period of software updates,whereas other products might benefit from having a service model that makes it easier to replace parts.
A washing machine might benefit from a service model that helps to maintain the machine from the inside, or vacuum cleaners with a service that periodically sends new filters.

Products that get carried around a lot will benefit from self-healing materials that will remove the signs of wear and tear, whereas a television might benefit from software updates to keep it up to date with newer models.

Potentially best strategies

From the interviews, it can be concluded that there is no single best strategy for increasing the expected lifetime of products. It depends on the type of product, the type of consumer, and the execution of the strategy whether it will increase the lifetime of products.

However, the extended warranty and care and maintenance seem to be promising strategies that can be applied to all product categories and will probably work for most consumer segments. Because the amount of **warranty** is expressed in years, this is a very concrete indicator for the expected lifetime. This is established by the manufacturer and therefore a credible source for the

participant. The downside of this is that it could also work as a limitation, as people could think a product with an expired warranty hard made its money worth and can therefore be replaced.

Care and maintenance will probably also work well, because of the careless behavior theory from Belezza et al. (2017). When it is made easier for the consumers to maintain their product, they will perceive it as new for a longer period and they are more involved with the product. Products that look older will also be neglected more, and this would become a vicious circle and end up in earlier product replacement.

Strategies that depend on the product category are upgradeable software and hardware and durable design. **Upgradeable software** will probably not extend the (expected) lifetime of a product, but it will probably work as a limiting factor. In case the software is the first feature that will be obsolete, this can be a reason to replace the product.

Upgradeable hardware is a strategy that could increase the expected lifetime for products. However, it depends on the type of product and which part is upgradeable. For example, a vacuum cleaner that contains a lot of parts that could potentially be upgraded, such as the hose, filters, and attachments might benefit from hardware updates. On the other hand, for televisions, it might be harder to increase the expected lifetime, as televisions are more likely to be replaced when the owner wants a bigger television or a more innovative television.

Another strategy that could potentially extend the

expected lifetime is **durable design**. Especially when the design conceals signs of wear and tear, the owner will perceive the product as a better state, and this increases the expected lifetime. It must be noted that durable design could negatively influence the aesthetics of the product, which might decrease the consumer's attachment to the product, therefore an optimum should be found between durability and aesthetics.

Self-healing materials can be seen as a way of making the product more durable without surrendering to aesthetics.

Even though participants found it hard to admit at first, **timeless design** is likely to influence the expected lifetime of products. However, this l harder to measure as timeless design is subjective and it will always influence the aesthetics of the product. At the same time, participants declared that when their product looked more outdated, they were more likely to replace the product sooner.

And finally, **repairable design** is one strategy with a lot of potentials but is also difficult at the same time. When a product gets a defect, repairability could increase the expected lifetime at the moment of malfunctioning. However, almost none of the participants was aware of how repairable their currently owned product is (meaning, how to repair certain parts of the product), and therefore it would not increase the expected lifetime at the moment of a functioning product. Also, repairability requires consumer behavior: They must take action to repair the product. Therefore, both motivation, ability, and triggers must be taken into account when designing for repairability.

Consumer participation

As a final note, the interviews showed that the participants are not consciously aware of the expected lifetime of a product. This means, they have the product, and they have expectations, but when asked about the number of years, they found it hard to answer. Also, many participants explained that they would only replace products when they are broken beyond repair. However, during most of the interviews, later it became clear that their replaced product was not broken beyond repair. This shows that more awareness about the lifetime of the product might also increase the expected lifetime of products. When people are more aware of the process, they might consciously counteract this process, and realize that longevity is almost always the more sustainable option than replacing their product for another new -yet sustainable- product.

3.6 Limitations

It must be noted that this study was performed on a small scale. The information was not saturated and can therefore not be used to generalize the findings. However, this study aimed to get an overall impression on the topic and to identify relevant factors that play a role in the expected lifetime for products.

Also, it has turned out to be harder than expected to interview people about sustainability. Especially because many people are not aware of longevity when it comes to sustainability, and it was noticed that sometimes people give a desired answer when asked about this topic. It was tried to prevent this from happening by asking about sustainability at the end of the research and openly asked questions.

Besides that, only the proposed list of strategies was covered in the interviews explicitly. I only asked the participants about this list of strategies to be able to have a guided interview and talk about the same topics with all participants. The interview started with questions about replacement behavior in general, and the sustainability questions at the end of the interviews, to find more strategies. When the participant brought up something new, follow-up questions were asked but most information was gathered about this list.

3.7 Next step

In this part, the expected lifetime of products was studied in an explorative way. Eight interviews were conducted to learn more about the way people determine the expected lifetime of products. However, because of the small number of participants, no hard conclusions can be drawn from this number of interviews. Therefore, more quantitative research is needed to compare the different strategies.

In the next chapter, study 2 will be treated. In this part, the influence of the design strategies will be explored quantitatively. This will be done by performing conjoint study combined with a cluster analysis, to find out which strategy is the most effective and seek clusters to see if there are specific strategies that might work better for certain groups. Therefore, the following research question will be covered:

RQ2: What is the best way to increase the expected lifetime of products?

To find an answer to this question, three sub-questions were formulated:

SQ1: What are the most effective strategies to increase the expected lifetime of products?
This question will be answered using a conjoint analysis.

SQ2: Is there a correlation between the personality of the consumer and the relative importance of the design strategies?
This question will be answered using a correlation analysis

SQ3: What are the consumer clusters when it comes to the effectiveness of design strategies?
This question will be answered using a cluster analysis
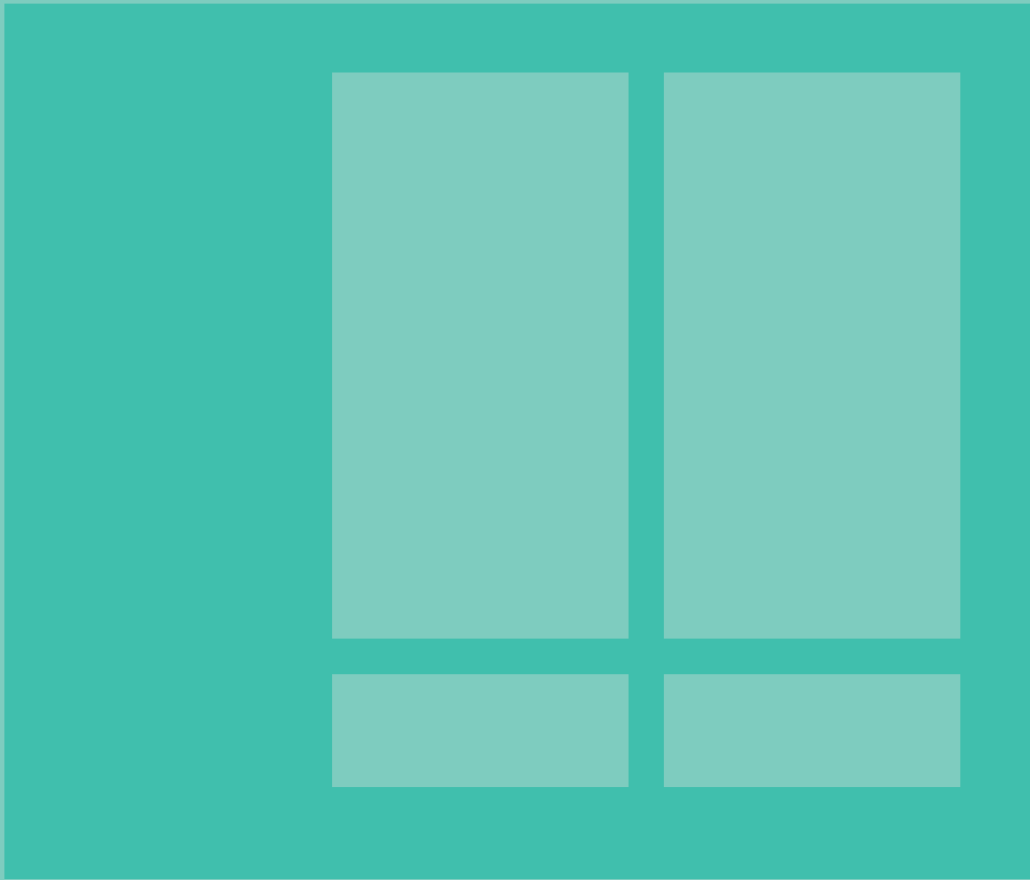
PART 4: STUDY 2 - QUANTITATIVE STUDY

In the following chapter, the quantitative study will be explained. This study aimed to quantify the influence of the proposed strategies on the expected lifetime of vacuum cleaners. Based on the previous findings, and to keep the study within limits, the scope for this study was narrowed down. The method that was chosen is conjoint analysis was combined with cluster analysis. First, the most important strategies will be quantified and after that consumer segments will be identified that have their own specific most important attributes.

4.1 Updated scope

Before moving to the quantitative study of the project, the scope needed to be narrowed down first. This is because if we take all strategies into account, and all product categories, the questionnaire would become too long, and too many participants would be needed to be able to get significant results.

Stick vacuum cleaner
It was chosen to focus on the stick vacuum cleaner only from now on. The stick vacuum cleaner was chosen as this is a versatile product. It tends to show signs of wear and tear, there is a big variety in types of stick vacuum cleaners, so there is not one standardized design. Also, it is possible for consumers to repair a broken vacuum cleaner and to replace parts. This is beneficial because that makes repairability relevant to test.

I chose the stick vacuum cleaner because they suit all of the conditions above, and robot vacuum cleaners are different from stick vacuum cleaners. They are not touched by the owner, will show fewer signs of wear and tear, and because they are very compact, also harder to repair. Even though the stick vacuum is more like a 'regular' vacuum cleaner, I think the stick vacuum cleaners will be more commonly used than the current regular vacuum cleaners. In the end, I expected the stick vacuum cleaner to apply to most of the strategies and therefore chose to pursue that.

Selected attributes
Because of the choice for conjoint analysis (for more information, see chapter 4.2.1), the number of attributes needed to be narrowed down. According to Hair (1995), a conjoint study preferably contains a maximum of 6-7 attributes. This because otherwise, it would become too complicated for the participants to weigh all attributes to choose the best option. Therefore, the list of strategies was revised to fit the vacuum cleaners and the study best. I chose to include 7 attributes in the pre-test, and see if it is

possible to eliminate one extra attribute.

Repair services and repairable design were combined. Vacuum cleaners are simple products, so it is relatively easy to repair a vacuum cleaner yourself. Because the purchase price is relatively low, in case the vacuum cleaner cannot be repaired by the consumer, it is likely to be replaced instead of repaired using repair services.

The strategies that were left out for the rest of this study are upgradeable hardware, upgradeable software, and timeless design.
Upgradeable hardware because in essence, a vacuum cleaner is simple and the effect of upgrades in the hardware would be minor. It is already easy to replace filters and to change the attachments and replacing the motor would be too expensive. Upgradeable software was left out because stick vacuum cleaners do not contain software now, and we did not see the benefits of smart vacuum cleaners for now.

At last, the timeless design was left out. This is because we expect timeless design to be a study in itself. When changing the timelessness of the vacuum cleaner, you are changing the entire design, and then you have the risk that people choose the vacuum cleaner that they think is the most aesthetically pleasing, even though that is not part of this study.

Finally, I included brand and price in the following study. Even though they were not considered before, brand and price could influence the expected lifetime of products.
First of all, the reputation of the brand could play a role, as well as own experiences with a brand. I assume that consumers perceive a more expensive product to be of higher quality and therefore have a longer lifetime, but that needs to be tested. Also, they could influence peoples' choices when they have to choose between options in the conjoint analysis.

4.2 Method

For the second study of this project, a quantitative approach was chosen. This study aims to quantify the relative impact of the proposed design strategies. Because a high number of strategies needs to be compared, a conjoint analysis (CA) was chosen.

CA is often used in marketing research, helping to find out how people value separate components of a product and searching for the most desirable option. For this study, conjoint analysis is used to find out the relative impact of the design strategies. Instead of asking for the most preferred option, the participants choose which option has the highest expected lifetime.

In addition to conjoint analysis, cluster analysis was executed. Cluster analysis is a method that helps to identify clusters within a study of homogeneous groups of consumers. The cluster analysis aims to identify the most optimal design feature for extending the expected lifetime of vacuum cleaners. To find these clusters, general survey questions were asked after the CA. The survey questions can be found in appendix 4.

Also, a correlation analysis was performed. The Pearson correlation analysis helps to identify correlations between the strategies and also between the strategies and the additional research scales.

4.2.1 Choice-Based Conjoint Analysis

For the quantitative research, it was chosen to perform a Choice-Based Conjoint Analysis. This method is usually used in marketing research to find the optimal combination of product features. The participant must select the most suitable option out of two or three combinations. This analysis forces the participants to make trade-offs between options, by which the real preferences of the participants become clear (Green and Srinivasan, 1978; 1990). This makes the study more like in real settings, as they cannot value all attributes of the same importance like they can do when asking about it directly (Garver, 2005; Garver et al., 2010). Also, CA is a suitable method to do segmentation studies, because you can rate the participants based on their logistical needs (utility scores) (Garvet et al, 2008; 2010, Collin et al., 2009; Mentzer et al., 2001; Sharma and Lamberts, 1990).

This method is suitable for this study because it forces the participants to choose. This way, even though this is not a real purchase setting, you can force the participant to choose between two options. Then, the participant is not able to give all attributes the same rating. Also, there is less difference between the participants' benchmarks (for example, some people would also give 3 points as average, and other people would always give 7 points as average). An example of a conjoint choice task is shown in figure 20.

Figure 20: Example conjoint analysis task

However, there are some limitations to CA. First, the design of CA is quite complex. For example, you have to make sure all relevant attributes are in the study, and they are all equally important, otherwise the study would not make sense to the participant. Also, the participant must make the trade-off between all attributes, and this can be quite exhausting for the participant, running the risk of respondent fatigue, which would mess up the results. Therefore, the maximum number of attributes that can be tested is six to seven attributes. Also, many participants are needed to be able to make sure all attributes are tested well enough and to make sure that participants do not have to evaluate too many choices to avoid respondent fatigue.

Also, a pre-test is needed to make sure you are testing what you want to test. First to select out some of the attributes and also to test the importance and desirability of the attributes.

4.3 Stimuli and attributes

A pre-test was executed to determine the right attributes and level. In the following chapter, you can find how the pre-test was executed and how the attributes and levels were selected.

4.3.1 Pre-test

As explained above, for CA it is necessary to do a pre-test before. The goal of the pre-test is to make sure the attributes are roughly equally important for determining the expected lifetime of the vacuum cleaner. Also, the pre-test is there to make sure all levels are equally desirable, or at least, none of them should be perceived to be unacceptable by most of the participants. When some of the levels or attributes stand out from the rest, they will skew the results of the study and that will result in less accurate data.

Therefore, a 5-point Likert scale of Product Importance (1 = not at all important; 5 = very important) to test the attributes of the survey. To test the desirability of the levels, a 5-point Likert scale of Product Desirability was used (1 = very undesirable; 5 = very desirable).

The survey was distributed via social media and a total of 35 people participated in the pre-test. The tables and means can be found in appendix 5. In the following chapter, the chosen attributes and levels will be explained.

4.3.2 Attribute and level selection

With the help of the results of the pre-test, the final attributes and levels were selected. First of all, the importance of the attributes. When looking at the importance of the attributes, none of the attributes must be perceived to be 'not at all important' or 'very important', because in that case, the CA would only measure that attribute and not the influence of the levels.

Also, all attributes should be important in general, because if people would think they are not important, then it makes no sense to test them at all.

To analyze the outcomes of the pre-test, I looked at the distribution of the answers as shown in figure

22. Also, the answers were imported into SPSS to create the means and standard deviation table (see figure 21). The 7-point scale was entered as 1=Not at all important and 7=Very important.

As you can see in figure 21, all mean values of the importance of the attributes are between 4.3 and 5.7 on a scale from 1 to 7. Because none of the attributes stood out, it was chosen to include all attributes in the real survey. Also, because all attributes only consist of two levels, which makes the number of options (and therefore the number of required participants) smaller.

Then I looked at the separate levels of the attributes. For attributes, none of the levels must be unacceptable or only desirable. In that case, that level is more likely to 'win' only because people prefer that option (or prefer everything except that option).

Descriptive Statistics

	N	Mean	Std. Deviation
Brand	35	5.2571	1.46213
Price	35	5.6000	.84714
Warranty	35	5.3714	1.45695
WearTear	35	5.4571	1.44187
Durable	35	5.7429	1.17180
Spareparts	35	4.3429	1.78132
Maintenance	35	4.8000	1.38903
Valid N (listwise)	35		

Figure 21: Results of the attibute importance test

Please indicate for the following attributes how important they are for the 'expected lifetime' of a vacuum cleaner.
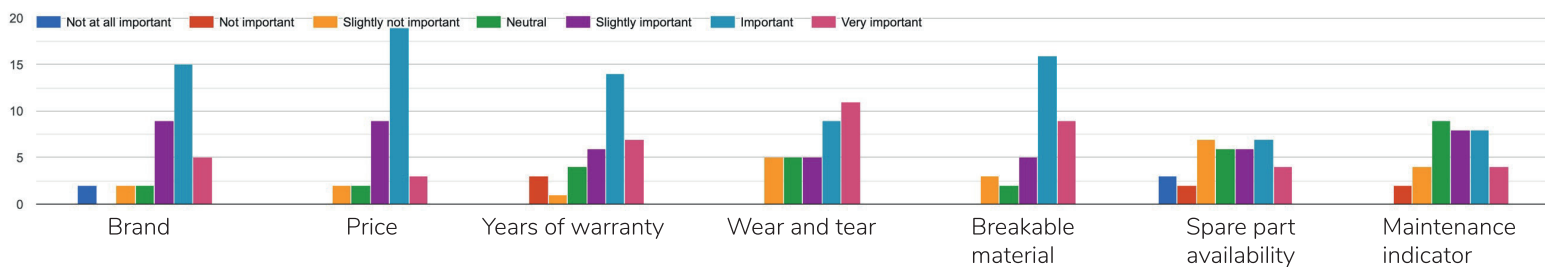
Figure 22: Results of the attibute importance test

4.3.2.1 Repairability

To test the repairability of vacuum cleaners in this survey, we chose to test the number of years that the spare parts are available. We chose this because it is very common for a vacuum cleaner to be easy to take apart. Also, this is would affect all possible failures of a vacuum cleaner (e.g. if you expect the motor to break first, being able to repair the hose would not make sense, and the other way around). At last, spare part availability is expressed in years, and therefore we can easily see what the availability does for the expected lifetime, whether it has any effect or not.

As you can see in figure 23, for spare parts, 2 years is most unacceptable and was therefore left out. In the end, 5 and 10 years were chosen, because, in my opinion, 5 and 7 years were too close to each other.

4.3.2.2 Warranty

The warranty will be tested in the number of years of warranty. This is also expressed in years, so interesting to see how much influence warranty has on the expected lifetime.

Then follows the maximum years of warranty (figure 24). Here you can see that 2 years is mostly unacceptable, and 7 years is mostly desirable. Therefore, it was chosen to continue with 3 years and 5 years.
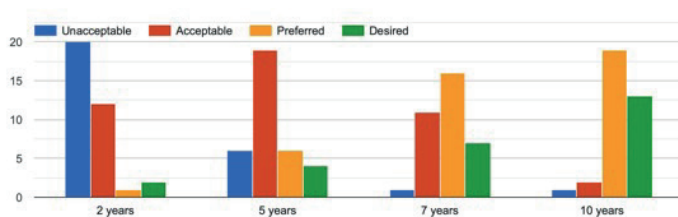
Figure 23a: Desirability spare parts
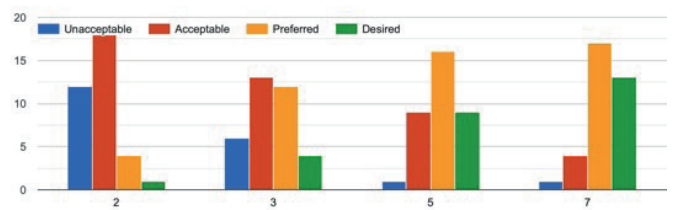
Figure 24a: Desirability warranty

Descriptive Statistics

	N	Mean	Std. Deviation
Spare2	35	1.5714	.81478
Spare5	35	2.2286	.87735
Spare7	35	2.8286	.78537
Spare10	35	3.2571	.70054
Valid N (listwise)	35		

Figure 23b: Mean table esirability spare parts

Descriptive Statistics

	N	Mean	Std. Deviation
Warranty2	35	1.8286	.74698
Warranty3	35	2.4000	.91394
Warranty5	35	2.9429	.80231
Warranty7	35	3.2000	.75926
Valid N (listwise)	35		

Figure 24b: Mean table desirability warranty

4.3.2.3 Care and maintenance

Furthermore, care and maintenance was tested in the form of maintenance indicator light or sound. The qualitative study indicated that people want to maintain their product as good as possible when it is still new, but later start to neglect maintenance. Therefore, indicators could be used as a reminder to maintain the vacuum cleaner. For example, a light could pop up when it is time to replace the filters or clear the dust collection.

For care and maintenance, the right maintenance indicator had to be selected (figure 25). In the study, sound and light indicators were tested and lights turned out to be more acceptable.

It must be noted that no maintenance indicator received many 'unacceptables', but it was still chosen to include this because this would still test whether people think these indicators influence the expected lifetime of products. Also, many vacuum cleaners don't contain maintenance indicators so it is still a realistic scenario.

4.3.2.4 Durability

In the pre-test, durability was tested based on the material of the stick (figure 26). In the qualitative study, a vacuum cleaner owner declared that she thought the stick would last less long because the vacuum cleaner was plastic, whereas her previous vacuum cleaner was a metal one.

However, in consultation with my coaches, we decided to change the material of the stick for the suction power of the motor. This because material we realized most of the vacuum cleaners are metal, or at least look metal. Also, it hardly happens that a vacuum cleaner stick breaks, at most the connecting pieces but that is harder to test.

Besides that, the suction power of a vacuum cleaner is directly linked to the lifetime of a product. The more suction power, the more it can wear out before it makes the product obsolete.

With the help of the web shops to see what is in confirmity with the market, we chose to include 120 Watt and 220 Watt.

Figure 25a: Desirability indicators
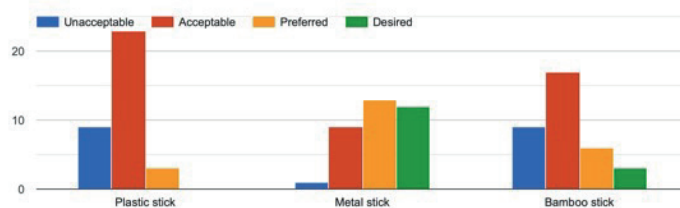
Figure 26a: Desirability material

	N	Mean	Std. Deviation
CMLight	35	3.2000	.83314
CMNo	35	1.6571	.59125
CMSound	35	1.9714	.92309
Valid N (listwise)	35		

Figure 25b: Mean table desirability indicators

	N	Mean	Std. Deviation
MatPlastic	35	1.8286	.56806
MatMetal	35	3.0286	.85700
MatBamboo	35	2.0857	.88688
Valid N (listwise)	35		

Figure 26b: Mean table desirability material

4.3.2.5 Graceful aging

Also, self-healing materials were kept in this study. This is because signs of wear and tear are the most important causes of premature obsolescence of vacuum cleaners (Harmer et al., 2019). Also, most vacuum cleaners are used throughout the entire house and bump into furniture.

For graceful aging (figure 27), it was chosen to add bamboo as an option. Even though these options might not be too realistic, it would make the participants rate three options and therefore increase the reliability of the other two outcomes. For graceful aging, self-healing coating and regular coating were acceptable and preferred, and therefore passed the pre-test and will be included in the survey.

4.3.2.6 Brands

The brands were selected with the help of webshops (bol.com, Coolblue, and Mediamarkt). For the pre-test, Bosch, Miele, Philips, and AEG were included.

The first one was brand (figure 28). Here you can see that AEG was mostly acceptable, and therefore included in the study. Also, Miele was included in the study because of its reputation of being long-lasting.
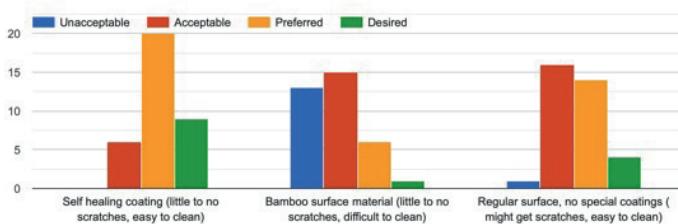
Figure 27a: Desirability coating
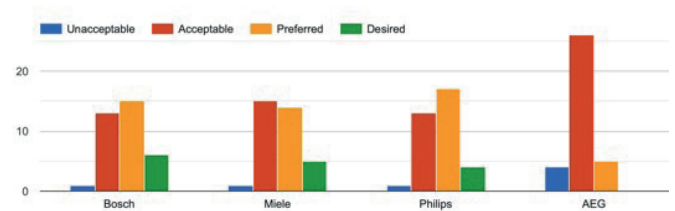
Figure 28a: Desirability brands

	N	Mean	Std. Deviation
AgingRegular	35	2.6000	.73565
AgingBamboo	35	1.8571	.80961
AgingHealing	35	3.0857	.65849
Valid N (listwise)	35		

Figure 27b: Mean table desirability coating

	N	Mean	Std. Deviation
BrandBosch	35	2.7429	.78000
BrandMiele	35	2.6571	.76477
BrandAEG	35	2.6857	.71831
BrandPhilips	35	2.0286	.51368
Valid N (listwise)	35		

Figure 28b: Mean table desirability brands

4.3.2.7 Price

Then the price for the vacuum cleaner (figure 29). Here, the prices were also chosen based on the market prices. However, as most of the participants thought €399,- and €499,- were unacceptable, it was chosen to continue with €199,- and €299,-.

4.3.2.8 Conjoint in Qualtrics

Including all of the attributes and levels, the conjoint analysis was entered in Qualtrics and looked like the following (figure 30):

Figure 30: Conjoint analysis design

Figure 29a: Desirability price

	N	Mean	Std. Deviation
Price199	35	3.2286	.84316
Price299	35	2.2286	.91026
Price399	35	1.3429	.59125
Price499	35	1.0857	.37349
Valid N (listwise)	35		

Figure 29b: Mean table desirability price

4.3.3 Additional research scales

Besides the conjoint analysis, four research scales were included in the survey. These research scales aimed to find significance and being able to tell more about the clusters that can be generated from the conjoint studies. Therefore, four scales were selected that were expected to correlate with the conjoint analysis. In appendix 4, the scales can be found.

The first scale used was the care scale, created by Ackermann, Schoormans, and Mugge (2021, to be published). This scale was added, hoping to be able to tell whether the people that think care and maintenance have a high influence on the expected lifetime of products, also perceive themselves to take good care of their products. This way, you can also give character to the people in the clusters, instead of only tell how they perceive the influence of the strategies.

The second scale was the Environmental Concern (EC) scale by Thogersen et al. (2010). This scale was added to see whether there is a difference in environmental concern and the differences between the strategies. For example, whether a warranty would be more important for people with lower environmental concern, and durability for higher environmental concern.

The third scale was the Repair scale as used by van den Berge et al. (2021, to be published). This one was added to see if there is a relation between this scale and the influence of the availability of spare parts.

The last scale is the technological innovativeness scale by Mathwick, Wagner, and Unni (2010). Also, this is where the attention check was placed. When the respondent would not carefully read the questions they fill in the wrong answer and will be excluded from the study. The technological innovativeness was added because we expected that people with higher technological innovativeness might replace their product for other reasons (because of the need for novelty instead of malfunctioning, etc.)

Finally, demographics were asked of the respondents. This is to be able to check whether the respondents are equally distributed and this is also important to report.

4.3.4 Survey design

In figure 31, an overview is shown of the selected attributes, levels, and additional questions. The combinations for the conjoint analysis tasks are created by Qualtrics, using a conjoint analysis extension. The other questions are asked to all participants in the same order. In appendix 4, screenshots of the entire survey can be found.

SURVEY DESIGN

Conjoint study

Attribute	Level 1	Level 2
Brand	AEG	Miele
Warranty	3 years	5 years
Suction power	120 Watt	220 Watt
Self-healing coating	Yes	No
Spare part availability	5 years	10 years
Maintenance indicator	Yes	No
Price	€199	€299

Additional research scales

Care scale (Ackermann, Schoormans and Mugge, 2021)

Environmental Concern scale (Thogersen et al., 2010)

Repair scale (van den Berge, 2021)

Technological Innovativeness (Mathwick, Wagner and Unni, 2010)

Demographics

Gender	Education	Age

Figure 31: Overview survey questions

4.4 Participants

The goal was to find at least 250 participants for the study. This is calculated by Qualtrics, and this is needed to get enough responses to properly perform the conjoint analysis. If there are fewer participants, not all combinations can be tested and therefore the outcomes would be less valid. The amount of participants is dependent on the number of attributes, as well as the number of levels, and also the number of options shown to the participants. The more levels and attributes, the more participants would be needed.

For this study, it was chosen to show the participants four combinations, so they would not get tired of choosing. For shorted conjoint analysis, this could be more, but because there already were 7 attributes to compare, the number of combinations was limited to four.

The participants for this study were recruited on a platform called Prolific (see figure 32). On this platform, a small fee is paid to participants who fill in the survey. An advantage is that a high quantity of people can be reached in a short amount of time, and also a variety of people can be reached, contradictory to convenience sampling when you only ask friends and family members that are likely to have a similar mindset.

To make sure the participants read all of the questions thoroughly, an attention check was included:

Figure 32: Screenshot of the survey as shown on Prolific

4.5 Analysis

The survey was sent out on Prolific on the 11th of June and was completed by 255 people on the 13th of June. A total of 82 people did not finish the survey and were left out, as well as the six people who failed the attention check. Therefore, 249 responses were taken to the analysis.

Of these 249 participants, 59% were male (147), 40,5% was female (101) and 0,5% was non-binary/third gender (1). All participants were aged between 23 and 75, the average age was 33,4 and the age distribution can be seen in figure 33.

And even though all education levels are covered in the participants, most of the participants were higher educated, as can be seen in figure 34.

As explained before, the study contains three parts: Conjoint analysis, correlation analysis, and cluster analysis. The outcomes for the conjoint analysis (Feature importance, Utility scores, and Preference shares) can be seen directly in Qualtrics.

To use the outcomes of the conjoint analysis for the correlation and cluster analysis, the datasets were exported separately and then combined in SPSS. This was done with the consult of one of the PhD candidates who helped me to combine the datasets using coding, and an instruction manual can be found in appendix 6.

Then, a Pearson's correlation analysis was performed. After that, a Hierarchical cluster analysis was performed as well as a Two-Step cluster analysis to determine the number of clusters. After that, K-means analysis was used to create the clusters. Thereafter, univariate analysis was performed on all attributes to find out whether the results are significant.
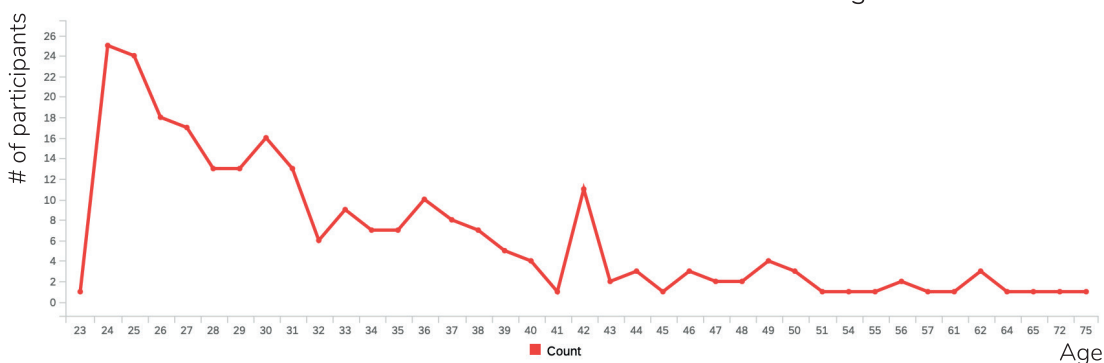
Figure 33: Age distribution
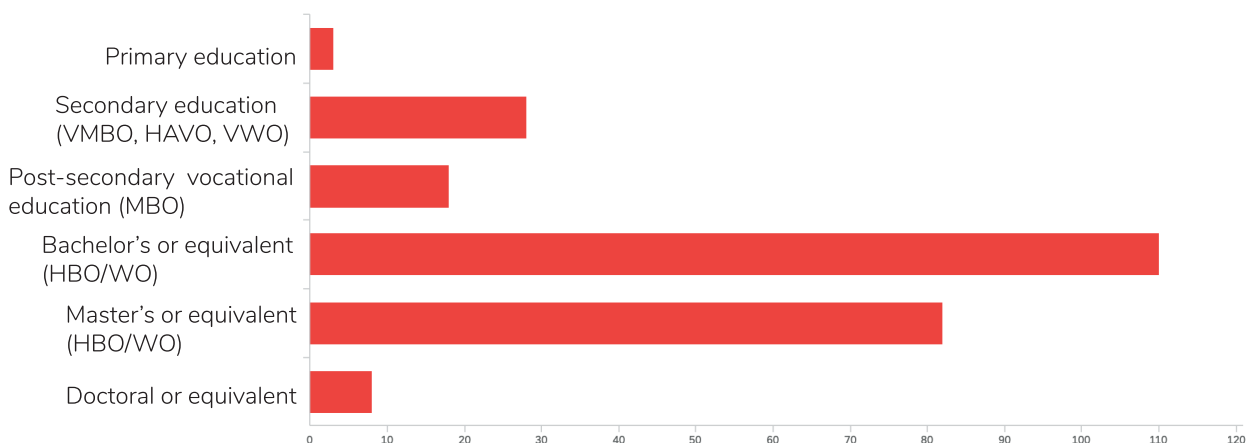
Figure 34: Education distribution

4.6 Results

In the following chapter, the results for the conjoint, correlation, and cluster analysis will be discussed. The research question:

"What is the best way to increase the expected lifetime of products?

will be answered by answering the three subquestions:

SQ1: What are the most effective strategies to increase the expected lifetime of products?"

SQ2: Is there a correlation between the personality of the consumer and the relative importance of the design strategies?

SQ3: What are the consumer clusters when it comes to the effectiveness of design strategies?

4.6.1 Relative impact of different strategies
To answer the first subquestion,

SQ1: What are the most effective strategies to increase the expected lifetime of products?"

the results of the conjoint study will be explained. First, the relative impact of the proposed strategies will be explained. Also, the impact of the levels will be explained using part-worth utilities and the preference share.

Figure 35 shows the utility importance for each attribute, and the average utility values for each attribute level can be found in figure 36. A bigger figure, as well as the graphs for the average utility values for each attribute, can be found in appendix 7. The utility importance means, how important was this attribute relative to the others. As can be seen in figure 34, the levels of each attribute are always the same but negative to each other. This is because there are only 2 levels for each attribute. In case there are more than two levels for an attribute, this

would give the relation between these values. When this value is negative, it means it is avoided by the participant, and when it is positive, it is preferred by the participant. When the value is high, it means it is strongly preferred or avoided and when the value is low, it is weakly preferred or avoided. In the following section, the positive value is always given.

As you can see in the figures, the amount of warranty is an important attribute in the expected lifetime for products, contributing to 24,7% of the overall utility attributes. As expected, the participants preferred the longer warranty with an average utility level of 6,1.

A slightly more important attribute was the availability of spare parts with a relative importance of 28,1%. Again, as expected, the participants preferred the longer availability of spare parts with an average utility level of 6,9.

The third important attribute is the self-healing coating of the products, which contributed 14,9% to the overall utility. And as expected, the vacuum cleaner that contained a self-healing coating was preferred with an average utility level of 3,5.

Then, almost equal to self-healing coating was the maintenance indicator. The relative importance of the maintenance indicator was 14,4% with an average utility level of 3,6 for the vacuum cleaner that contained maintenance indicators.

Then the three least significant attributes follow. Suction power only contributed for 7,3% and surprisingly, brand (6,1%) and price (4,5%) were the least important attributes when looking at the expected lifetime of products.

The participants perceived Miele (1,3) to be longer-lasting than AEG (-1,3). However, the cheaper vacuum cleaners were chosen more often than

the more expensive vacuum cleaners (with an average utility of 0,3), which is very interesting. An explanation could be that when people could not decide or did not think it would affect the expected lifetime, preferred the cheaper one.
From this, it can be concluded that warranty and the availability of spare parts are the most important strategies to increase the expected lifetime as established using a conjoint study.

The least important strategies seem to be the brand and price. This is interesting because from literature you would expect that these are very important. This will be further discussed in chapter 4.7. The strategies that are in between are the strategies self-healing coating and the amount of suction power.

Furthermore, all average utility values are as expected, except for the price. There the cheaper one had a higher expected lifetime, which was unexpected. This will also be discussed in chapter 4.7. In the next chapter, you will find the results of the correlation analysis.
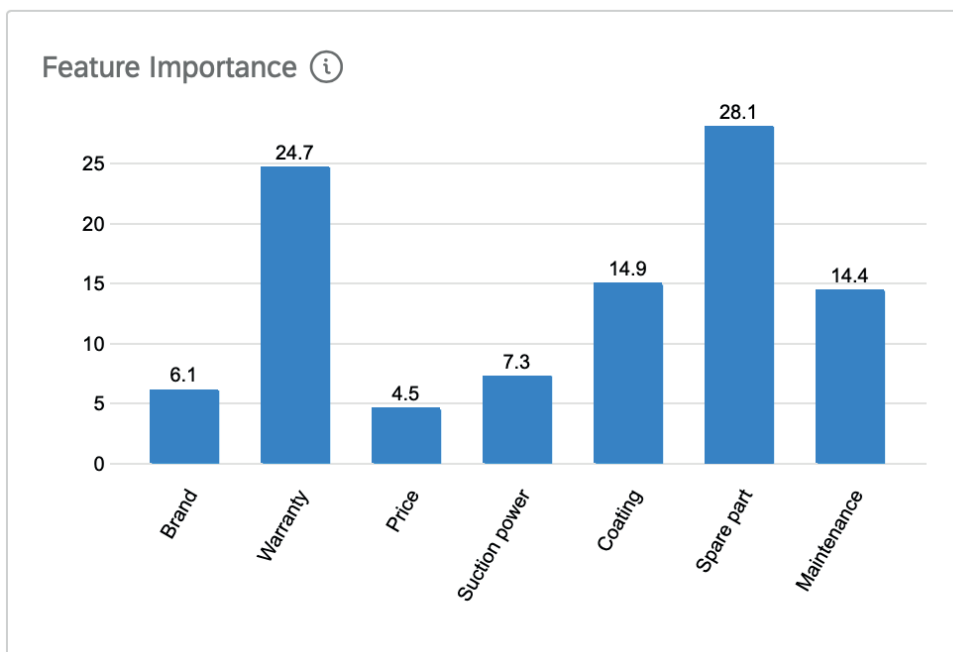
Figure 35: Average utility importance of each attribute

Average utility values for attribute levels	
3 years (Warranty)	-6,1
5 years (Warranty)	6,1
AEG (Brand)	-1,3
Miele (Brand)	1,3
€199 (Price)	0,3
€299 (Price)	-0,3
120 W (Power)	-1,8
220 W (Power)	1,8
Self-healing (Coating)	3,5
No self-healing (Coating)	-3,5
5 years (Spare parts)	-6,9
10 years (Spare parts)	6,9
Maintenance indicator	3,6
No maintenance indicator	-3,6
Average importance of attributes (%)	
Warranty	6,1
Brand	24,7
Price	4,5
Power	7,3
Coating	14,9
Spare parts	28,1
Indicator	14,4

Figure 36: Average utility values

Key take-aways

Relative importance of attributes: It can be concluded that warranty and the availability of spare parts are the most important strategies to increase the expected lifetime. The least important strategies seem to be the brand and price. The strategies that are in between are the strategies self-healing coating and the amount of suction power.

To be determined next: This paragraph showed the outcomes of the conjoint study in Qualtrics. The next study will show if there are correlations between the different attributes and the additional research scales.

4.6.2 Correlation analysis

A correlation analysis was performed to answer the second sub-question:

SQ2: Is there a correlation between the personality of the consumer and the relative importance of the design strategies?

After analyzing the results of the conjoint study in Qualtrics, the data was imported into SPSS and analyzed. First, a correlation analysis was performed, to see if there are correlations between the strategies and the additional research scales. The correlation matrix can be found in figure 37. When 2 strategies are positively correlated, this means they strengthen each other, and if they are negatively correlated, they counteract each other. Also, this strategy is helpful to see whether people with, for example, high environmental concern, also score on certain strategies, to see if these strategies work especially for certain people.

To analyze the results, a two-tailed Pearson's correlation analysis was performed. When all data was entered, a giant table was the outcome. To keep the results accessible, only the first levels of the strategies were entered. This means, below you will see the outcomes for only one option of the strategy, and if you want to know the other level of the strategy, the outcome is always negative. For example, below you see the outcomes for the brand AEG correlated to the price of €199 (r=-.647). If you take the brand Miele against the price of €199, it would be (r=.647). If it would be Miele against the price of €299, it would be (r=-.647). The big table with all levels can be found in appendix 7.

4.6.2.1 Strategy correlations

Brand (AEG) negatively correlates to the strategy price (r=-.647, p<0.01). It positively correlates to the strategies suction power (r=.309, p<0.01),

self-healing materials (r=.192, p<0.01), spare parts availability (r=.469, p<0.01) and care and maintenance indicator (r=.234, p<0.01).
Also, brand negatively correlates to the Repair Experience scale (r=-.169, p<0.01).
For Miele, this would be negative.

Warranty (3 years) positively correlates to the strategies suction power (r=.352, p<0.01), self-healing materials (r=.724, p<0.01), spare parts availability (r=.338, p<0.01), and care and maintenance indicators (r=.770, p<0.01).
For 5 years of warranty, this would be negative.

Price (€199) negatively correlates to the strategies brand (r=-.647, p<0.01), spare parts availability (r=-.501, p<0.01) and care and maintenance indicator (r=-.180, p<0.01).
Price positively correlates to the Repair Experience scale (r=.157, p<0.05) and the Care scale (r=.137, p<0.05).
For €299, this would be positive. Note that for price the values are reversed. This is because for price, level 2 was perceived longer lifetime than level 1, unlike all other attributes.

Power (120 Watt) positively correlates to the strategies brand (r=.309, p<0.01), warranty (r=.352, p<0.01), self-healing materials (r=.242, p<0.01), spare parts availability (r=.212, p<0.01) and care and maintenance indicator (r=.359, p<0.01).
For 220 Watt, this would be negative.

Self-healing materials (Yes) positively correlates to the strategies brand (r=.192, p<0.001), warranty (r=.724, p<0.001), suction power (r=.242, p<0.001), spare parts availability (r=.240, p<0.001) and care and maintenance indicator (r=.442, p<0.001).
For no self-healing materials, this would be negative.

Spare parts availability (5 years) correlates to all strategies except for care and maintenance indicator. Brand: (r=.469, p<0.01), warranty: (r=.338, p<0.01), price: (r=-.501, p<0.01), power: (r=.212, p<0.01), self-healing materials: (r=.240, p<0.001). For 10 years of spare parts availability, this would be negative.

Care and maintenance (Yes) indicator correlates to all strategies except for spare parts availability. Brand: (r=.234, p<0.01), warranty: (r=.770, p<0.01), price: (r=.137, p<0.05), power: (r=.359, p<0.01), self-healing materials: (r=.442, p<0.001). For no care and maintenance indicator, this would be negative.

4.6.2.2 Scales correlations
The **Care scale** correlates to the strategy price (r=.137, p<0.05).
Also, Care correlates to the Repair Experience scale (r=.602, p<0.01) and the Innovativeness scale (r=.291, p<0.01).

The **Environmental Concern** scale only correlates to the RepairExperience scale (r=.152, p<0.05).

Repair Experience scale correlates to the strategies of brand (r=-.169, p<0.01) and price (r=.157, p<0.05).
Also, Repair Experience correlates to all of the other scales. Care: (r=.602, p<0.01), Environmental Concern: (r=.152, p<0.05) and Innovativeness: (r=.465, p<0.01).

Correlations

		Brand_1	Warranty_1	Prijs_1	Power_1	Healing_1	Spare_1	Care_1	Care	Environment alConcern	RepairExperi ence	Innovativenes s
Brand_1	Pearson Correlation	1	.099	-.647**	.309**	.192**	.469**	.234**	-.115	-.057	-.169**	-.089
	Sig. (2-tailed)		.121	.000	.000	.002	.000	.000	.071	.372	.007	.160
	N	249	249	249	249	249	249	249	249	249	249	249
Warranty_1	Pearson Correlation	.099	1	.003	.352**	.724**	.338**	.770**	.062	.005	-.059	.008
	Sig. (2-tailed)	.121		.966	.000	.000	.000	.000	.333	.934	.355	.902
	N	249	249	249	249	249	249	249	249	249	249	249
Prijs_1	Pearson Correlation	-.647**	.003	1	-.109	-.091	-.501**	-.180**	.137*	.025	.157*	.071
	Sig. (2-tailed)	.000	.966		.086	.152	.000	.004	.030	.691	.013	.266
	N	249	249	249	249	249	249	249	249	249	249	249
Power_1	Pearson Correlation	.309**	.352**	-.109	1	.242**	.212**	.359**	.010	-.101	-.073	-.003
	Sig. (2-tailed)	.000	.000	.086		.000	.001	.000	.877	.113	.251	.966
	N	249	249	249	249	249	249	249	249	249	249	249
Healing_1	Pearson Correlation	.192**	.724**	-.091	.242**	1	.240**	.442**	.051	.031	-.095	-.045
	Sig. (2-tailed)	.002	.000	.152	.000		.000	.000	.427	.626	.133	.481
	N	249	249	249	249	249	249	249	249	249	249	249
Spare_1	Pearson Correlation	.469**	.338**	-.501**	.212**	.240**	1	.108	-.104	-.048	-.090	.050
	Sig. (2-tailed)	.000	.000	.000	.001	.000		.089	.100	.451	.155	.432
	N	249	249	249	249	249	249	249	249	249	249	249
Care_1	Pearson Correlation	.234**	.770**	-.180**	.359**	.442**	.108	1	.015	-.003	-.046	-.032
	Sig. (2-tailed)	.000	.000	.004	.000	.000	.089		.819	.962	.473	.618
	N	249	249	249	249	249	249	249	249	249	249	249
Care	Pearson Correlation	-.115	.062	.137*	.010	.051	-.104	.015	1	.115	.602**	.291**
	Sig. (2-tailed)	.071	.333	.030	.877	.427	.100	.819		.071	.000	.000
	N	249	249	249	249	249	249	249	249	249	249	249
EnvironmentalConcern	Pearson Correlation	-.057	.005	.025	-.101	.031	-.048	-.003	.115	1	.153*	.042
	Sig. (2-tailed)	.372	.934	.691	.113	.626	.451	.962	.071		.016	.512
	N	249	249	249	249	249	249	249	249	249	249	249
RepairExperience	Pearson Correlation	-.169**	-.059	.157*	-.073	-.095	-.090	-.046	.602**	.153*	1	.465**
	Sig. (2-tailed)	.007	.355	.013	.251	.133	.155	.473	.000	.016		.000
	N	249	249	249	249	249	249	249	249	249	249	249
Innovativeness	Pearson Correlation	-.089	-.008	.071	-.003	-.045	.050	-.032	.291**	.042	.465**	1
	Sig. (2-tailed)	.160	.902	.266	.966	.481	.432	.618	.000	.512	.000	
	N	249	249	249	249	249	249	249	249	249	249	249

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Figure 37: Correlation matrix, the green boxes show significant correlations between all variables

Innovativeness correlates to the Care scale (r=.291, p<0.01) and the Repair Experience scale (r=.465, p<0.01).

4.6.2.3 Conclusion correlation analysis
In figure 37, the correlation matrix is shown. The green blocks are the significant correlations, and the green line separates the design strategies from the research scales. As you can see, the strategies strongly correlate with each other, and also the research scales strongly correlate with each other. On the other hand, the strategies have fewer correlations with the research scales.

The fact that the strategies strongly correlate mutually, means that it is important to combine the strategies in order to increase the expected lifetime. This means, the strategies build upon each other, and the more strategies are implemented in a product, the longer the expected lifetime.

As you can see in the figure, there are fewer correlations between the strategies and the research scales. There are three correlations, but they are not very strong (between r=.137 and r=.169), so there is a possibility that this is a coincidence.

If you look at the correlations that are there, you see that brand is negatively correlated to repair experience. This means that people who have much repair experience, think the brand is less important. This could be, because these participants are creative and could therefore think they can always repair the product themselves, regardless of the brand of the product.

When looking at the price strategy, this one correlates to the care scale and the repair experience. This could mean that the people who like to take care of their product and also people that have much experience with repairing their products, also think the price is an important attribute for the lifetime of their product. This could mean, that these people think it is important to increase the lifetime of their products to save money. This could be used by companies as a way of marketing.

Key take-aways
Strategy correlations: Most strategies mutually correlate. This means, the strategies build upon each other when it comes to increasing the expected lifetime of a product. For companies, it is important to implement a combination of strategies to increase the expected lifetime of products.
Scales correlations: There are three correlations between the research scale and the strategies. Brand and repair experience negatively correlate. Also, price correlates positively to repair experience and care.
To be determined next: In this part, we looked at the correlation between the strategies to see what strategies build upon each other. In the next part, consumer clusters will be distinguished, to see whether certain strategies can be used for specific target groups.

4.6.3 The different consumer segments

After looking at the correlations, a cluster analysis was performed to answer the third sub-question:

SQ3: What are the consumer clusters when it comes to the effectiveness of design strategies?

The aim of this cluster analysis is to see whether more consumer groups can be identified. This important for companies because they can either target specific people, or make sure more people are targeted at once.

To find the clusters, Hierarchical Cluster analysis was performed. The aim of the clusters is to see if there are certain groups of people that can be targeted with certain strategies. In this case, several strategies can be combined in a smart way, or applied to certain products.
The number of clusters was decided with the help

of Hierarchical Cluster Analysis (see Dendrogram in figure 38) and Two-Step cluster analysis (see figure 39. From these two analyses, it was clear that the number of clusters should be two, three, or five. Then the K-means analysis was performed, and the clusters were compared on the mean levels.

When looking at the means tables, the dendrogram, and the two-step cluster analysis, it was concluded that two clusters would be the best option. For three clusters, there would be two clusters that were much alike, and 5 clusters would not give evenly divided clusters.

After clustering, univariate tests were done to see if there were significant relations between the clusters and the general question scales, but unfortunately, no significant relation could be found. The results for the univariate tests can be found in appendix 7.

It must be noted, that in this study, only the expected lifetime was tested. Therefore, no conclusions can be drawn on the personality of the consumer segments. The only input for the clusters is what they think is most important for determining the expected lifetime.
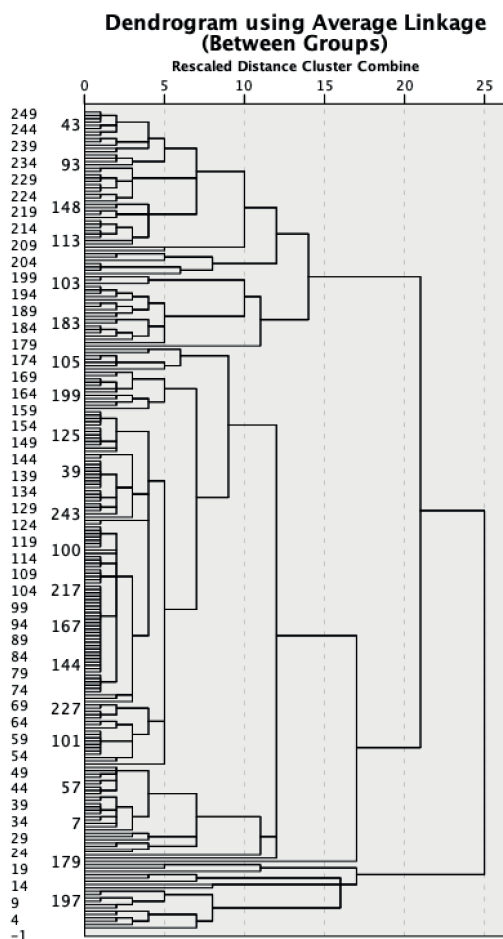
Figure 38: Cluster dendrogram, each horizontal line represents a potential cluster.

Size of Smallest Cluster	93 (37.3%)
Size of Largest Cluster	156 (62.7%)
Ratio of Sizes: Largest Cluster to Smallest Cluster	1.68
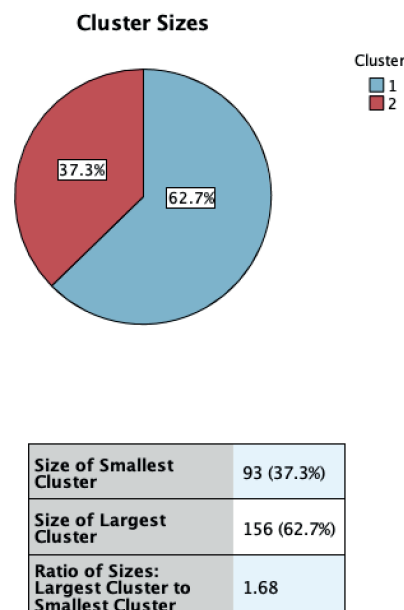
Figure 39: Two-step cluster analysis

Cluster 1: Consumer participation needed

Cluster 1 covers 37,3% (93) of the participants. From the means table (figure 37), it can be concluded that these participants perceive **Self-Healing materials** to be the most important attribute when thinking about the expected lifetime of products. The average utility score for this segment is 5.7.

Next to that, the presence of the care and **maintenance indicator** was important to the first cluster. This had an average utility score of 4.5. Also, with an average utility score of 4.1, the amount of years that **spare parts** are available is quite important to this segment. And at last, this segment values care and maintenance indicators (average utility score of 4.8).

From this, it can be concluded that this segment thinks, for the expected lifetime, it is important that the consumer is able to prevent the product from breaking and are able to actively engage in keeping the product in a good state. Therefore, self-healing materials are perceived to be important as they prevent the product from showing signs of wear and tear. Also, think it is important for the expected lifetime that the consumer gets help with taking care of the product when needed, and in case of a part malfunctions, they think consumers should be able to repair the product.

What is interesting about this cluster, is that the overall results of the conjoint study (see paragraph 4.6.1) is matching the results for cluster 2. Apparently, there are two completely different clusters and since cluster 2 is the bigger cluster, this is also what the overall scores look like. However, if we would only listen to and consider the results of the overall conjoint, you would leave out about two-thirds of the participants.

Cluster 1	
Brand:	.7377291
Warranty:	3.0096394
Price:	.2894241
Power:	1.6436821
Healing:	**5.7113954**
Spare:	**4.0922218**
Care:	**4.5249688**

Cluster 2: Company's involvement needed

Cluster 2 covers 62,7% (156) of the participants and is thereby the biggest cluster. This group mostly valued the long warranty and availability of spare parts when looking at the expected lifetime of vacuum cleaners.

The availability of spare parts has the highest average utility score, which is 8.3. After that comes the lifetime of the warranty, which has an average utility score of 7.6

From this, it can be concluded that this segment thinks it is more important that the company keeps being involved with the product. Either this means that they think, as long as the company is involved with the product, the product lasts longer. Or, they use the lifetime of the warranty and the availability as a benchmark to determine the expected lifetime of their product. This could be because they think the company did research about the lifetime of the product and establish the warranty and availability of spare parts according to the expected lifetime as the company expects.

Cluster 2	
Brand:	1.5758680
Warranty:	**7.6050246**
Price:	.5064899
Power:	1.9170676
Healing:	2.4784287
Spare:	**8.2865249**
Care:	3.1915207

Key take-aways

Cluster analysis: This study defined two clusters, the first cluster focuses on the participation of consumers and the second cluster on the involvement of the company.

Consumer participation needed: Exists of about one-third of the participants, and this group perceives the presence of self-healing materials, availability of spare parts, and care and maintenance indication to be most important. All of these attributes help the consumer to increase the lifetime of their product. Therefore, to increase the expected lifetime of products for these people, the design should help the consumer to improve or maintain the state of the product.

Company's involvement needed: Exists of the other two-thirds of the participants, and they think warranty and the availability of spare parts are the most important. To increase the expected lifetime of products for this group of people, extended involvement of the company is needed.

To be determined next: In the next chapter, the conclusion of the entire quantitative study will be given.

4.7 Conclusion

In the previous paragraphs, various analyses have been performed to answer the second research question:

What is the best way to increase the expected lifetime of products?

For this study, the scope was narrowed down and in this study, questions were asked about vacuum cleaners only.

Conjoint analysis

First, conjoint analysis was performed to answer the first subquestion:

What are the most effective strategies to increase the expected lifetime of products?

From this study, it was concluded that out of the 7 attributes that were tested, the amount of warranty and the availability of spare parts were the most effective strategies to increase the expected lifetime of vacuum cleaners.

According to the conjoint analysis, brand and price were the least effective strategies to increase the expected lifetime of vacuum, and the amount of suction power (durability), self-healing materials, and the presence of care and maintenance indicators were in the middle.

Correlation analysis

After the conjoint analysis, a correlation analysis was performed to answer the second research question:

Is there a correlation between the personality of the consumer and the relative importance of the design strategies?

According to the correlation analysis, there is limited correlation between the listed strategies and the individual variables. Brand is negatively

correlated to the Repair Experience variable, and price is positively correlated to both Care and Repair Experience. However, these correlations are not very strong, so further research is needed to be able to know what conclusions can be drawn from this.

Also, it was noticed that almost all strategies correlate positively, and therefore it is concluded that the strategies build upon each other. Therefore, to increase the lifetime of products, companies should implement a combination of strategies to get better results.

Cluster analysis

At last, a cluster analysis was performed to answer the third research question:

What are the consumer clusters when it comes to the effectiveness of design strategies?

This study identified two clusters: For the first cluster, consumer participation is needed to increase the expected lifetime of products, and for the second cluster, the company's involvement is needed to increase the expected lifetime of products.

According to the first cluster, self-healing materials, care and maintenance indicators and the availability of spare parts were the best strategies to increase the expected lifetime. And according to the second cluster, the amount of warranty and availability of spare parts were the most important strategies to increase the expected lifetime of products.

From this, it can be concluded that not only warranty and availability of spare parts (as concluded from the conjoint analysis) should be implemented, but also the care and maintenance indicators and self-healing materials should be implemented, to work for both clusters.

4.8 Discussion

According to the conjoint analysis, warranty and spare part availability have the highest attribute importance. However, these two are also the only two attributes that contain a number of years. This could mean that people have used this only because of the number of years which could give a bias. Nonetheless, it does prove that these indicators for lifetimes help to determine the expected lifetime, but it is something to take into account. Also, warranty is the factor that came out best for all studies, so there is little doubt whether warranty is very influential for the expected lifetime of products.

In fact, what is even more interesting, are the results for brand and price. From the conjoint study, it seems that these are the least important attributes, while traditionally, brand and price are used as the main proxies for quality and durability. There is a possibility that the difference between the levels was not enough to make a difference. In practice, the prices differences are more extreme and also there is more variation in brands. The way the pre-test was performed, also let the people compare the prices, and therefore, the selected levels could have been less effective.

Not to mention, that the results for price were unexpected. It seems that the consumers perceived the cheaper product to last longer than the more expensive product. One reason could be, is that people did not consider the price when determining the expected lifetime, but then chose the cheapest option when they couldn't choose. Another reason could be that, as suggested above, that the difference in levels was not high enough. Therefore people did not consider the price difference at all, and this result came out like this by accident.

After that, in the correlation and the cluster analysis, little to no correlation was found between the individual variables and the strategies. This could be because there is not a difference between the consumer's personality and the effectiveness of the strategies. Also, it could be because the wrong scale items were chosen. As seen in the correlation matrix, the individual variables showed much correlation, and therefore they could have been too alike. All research scales were indirectly environmental concern, and maybe other variables could have been tried. For example, the level of experience with this specific product type.

Furthermore, the attributes and levels that were selected for the conjoint analysis were very concrete examples of the strategies. However, many more interpretations are possible for these strategies, and the results could be different for other interpretations. One example is repairability. In this study, the availability of spare parts was chosen to test the repairability of the design, because many people have difficulty with that. However, there are many more sides to repairability, for example, the amount of tools needed to disassemble, how easy it is to disassemble and the price of spare parts are important factors to the repairability of a product.

PART 5: IMPLEMENTATION

In the previous chapter, research was conducted about the expected lifetime of products. The outcomes are a list of design strategies that should increase the expected lifetime. Also, clusters of different consumer segments were identified with consumers that determine the expected lifetime in a different way.
In the following chapter, the design strategies that work best for the different consumer segments are illustrated in showcase examples.
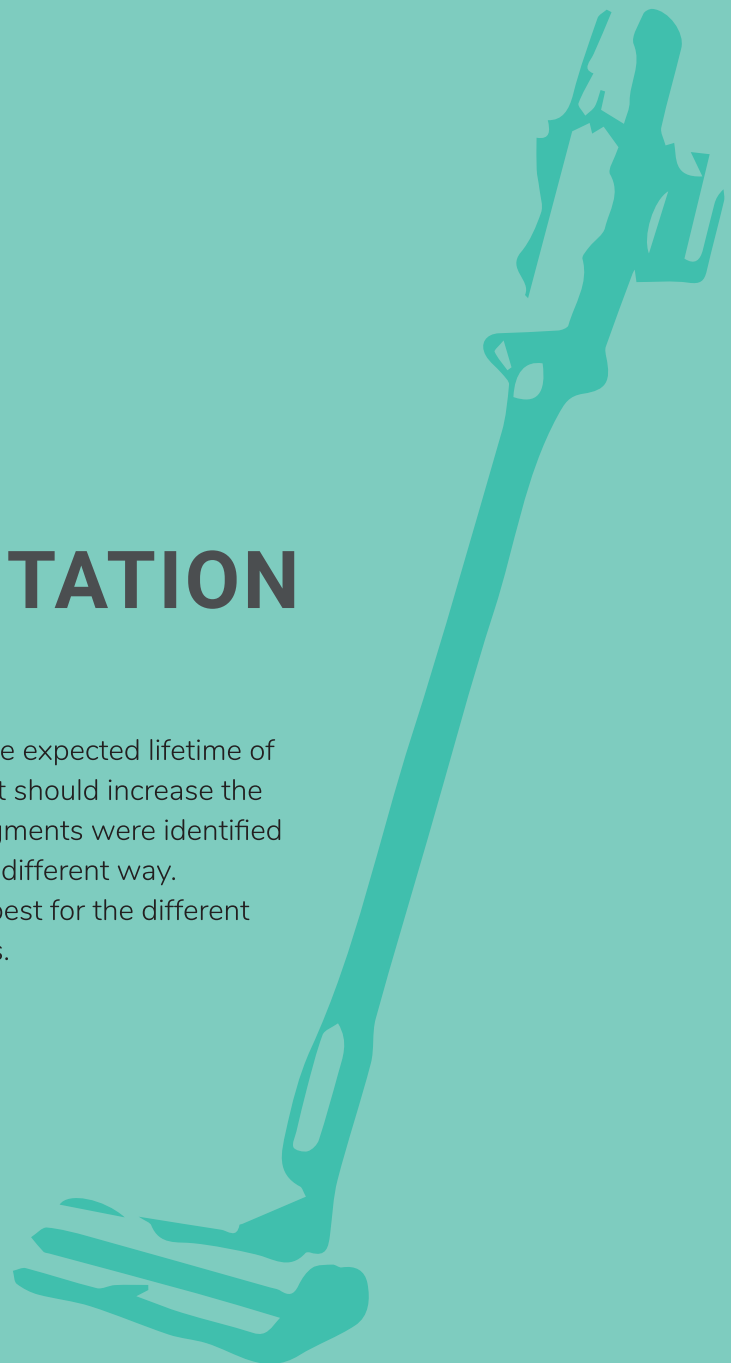
5.1 Implementation example

In the following chapter, the learnings from the previous studies will be integrated into a case example. The example will be in the form of a vacuum cleaner, as the quantitative study was also about a vacuum cleaner. However, the idea is that the insights gained in the studies can also be applied to other products.

From the qualitative study, it was concluded that the expected lifetime is determined at several moments throughout the lifetime of a product. During these evaluation moments, the expected lifetime is mostly trimmed down. Therefore, it is important to decrease the number of re-evaluation moments and decrease the impact of these re-evaluation moments. Also, knowledge about the lifetime of products helps the consumer to determine the expected lifetime, and therefore this could be used to increase the expected lifetime of products.

From the quantitative study, it was concluded that both warranty and the availability of spare parts are the most important design features to determine the expected lifetime, therefore they should be included. Also, two clusters were formed, that should both be included in this example. The first cluster found it most important to enable the consumer to improve the product and therefore the example should show how people can help to maintain their product and also to repair it when broken. The second cluster perceived warranty and the availability of spare parts to be most important, which is similar to the outcomes of the entire study. Because this cluster thought the strategies that require the involvement of the company were most important, the example should also involve the company throughout the lifetime of the product.

Replacing parts

To keep the impact of malfunctioning on the re-evaluation as low as possible, repairment has to be fun, low effort, and fun to do. Therefore, there are several features on the vacuum cleaner to help with the repair of the product.

First, there should be maintenance indicators on the vacuum cleaner, and the type of indication also teaches you about the type of failure (see figure 40). This will help with the diagnosis of the failure. For a vacuum cleaner, this will most often be when there is something stuck in the stick, when the storage is full, or when the battery is almost empty. On the vacuum cleaner, there is a sticker that tells you what indicators mean which failure. For example, flashing light and solid light, and a certain number of beeps might tell you more about the failure of the product. These failures should be solved very intuitively, so the consumer can maintain their product without putting in a lot of effort or being very technical. This feature especially increases the expected lifetime for people in cluster 1, for whom it was important that people could maintain the product to increase the expected lifetime of products.

Also, to prevent the product from showing signs of wear and tear, and failure, the company should actively push people to perform maintenance. For example, periodically send new filters (this could be linked to an app, that registers when the filters are (almost) full, and then restock them, as a reminder for people to replace their filter. These service models help both clusters to increase the expected lifetime.

	Flashing light	Solid light
One beep	Stick is stuck	Low battery
Two beeps	Wheel is stuck	Storage not installed
Three beeps	Fan is overloaded	Storage full

Figure 40: Example of intuitive diagnosis

As shown on the storyboard in figure 41, when a physical product breaks or needs to be replaced, action is required from the consumer, and not all consumers know where to find spare parts of their vacuum cleaner. Therefore, a QR code on the vacuum cleaner is recommended. When this QR code is scanned, the consumer is directed to a camera that contains AR, and when the consumer points at the broken part, the AR should recognize that part and redirect you to the page where you can order that specific part.

Reversed warranty

The idea of reversed warranty is that the longer you own the product, the cheaper the spare parts get. This means, in the beginning, it is relatively expensive to purchase spare parts, but the older the product, the cheaper they are.

This feature aims to promote the consumers to handle their product carefully by saving for discount. This feature is especially helpful for people from cluster 2. These people perceived the efforts from a company to be most important for the expected lifetime, and also, this system will give people a target for the lifetime of products.

It is possible to have spare parts available for a long period because of 3D printing. This way, the parts don't have to be in stock at all times but can be made on request. This way, it is also cheap to make the spare parts at a low price. After several years, the trade-in system as explained in the next paragraph will

Trade-in system

Also, when the consumer has used the product for a long period, the company could introduce a trade-in system. For example, when the product is purchased, it's registered and after 10 years, the

consumer gets the opportunity to trade in their product for a discount.

This system would have several advantages. First of all, you give the people a goal for the expected lifetime. Instead of giving a warranty or having the spare parts available for a certain amount of time, you give the consumer a goal, and potentially shift how long a vacuum cleaner should last in the minds of the consumer. Next to that, you promote the consumer to maintain their product, and keep it in a good state for a longer, because there is a goal at the end of the lifetime of the vacuum cleaner.

Even though this might sound like promoting the premature obsolescence of vacuum cleaners, the opposite is true. Because at the end of the lifetime, the product is traded in, and therefore sent back to the company. This means, the old product can be used again by the company, for example, to refurbish and remanufacture the product. Also, the parts can be recycled to be used for the new products. But the biggest goal of this system is to increase the initial lifetime. If the current average lifetime is 5 years, the trade-in system might start at 7 years, or even 10 years, and this could also increase over time.

Another advantage of this system is to decrease the number of re-evaluation moments. As learned in the qualitative study of the project, people re-evaluate the expected lifetime at several moments. One of them is when the product starts to malfunction or when it starts to show signs of wear and tear. By promoting the consumer to take better care of their product, the product is also less likely to break and will show fewer signs of wear and tear. Therefore, the number of re-evaluation moments can be brought down, and also the impact of the diminished book value can be decreased.

Consumer happily uses the vacuum cleaner

Vacuum cleaner starts to malfunction

Consumer takes out their phone and scan QR
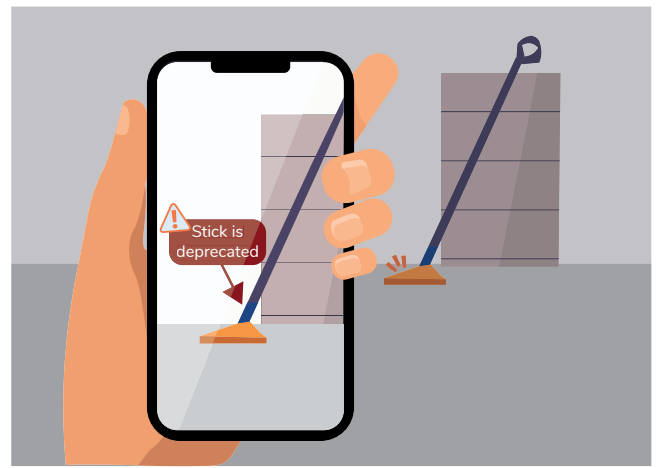
AR camera opens, and detects the broken part

App immediately shows where to purchase and how to install the part

The broken part is brought to consumers' house

Figure 41: Story board of the AR intuitive part replacement

Advertisement

The two features above are ways to increase the expected lifetime of products, but if the consumer is not aware of them, it will not make a difference. Even though it did not show in the quantitative study, from the qualitative and literature study, the brand of a product is important for the expected lifetimes. Therefore, it is suggested to advertise with longevity, and also include numbers. For example: 'our vacuum cleaners last 15 years on average'.

When the market advertises with longevity, it also makes longevity more important in the minds of the consumer. This will make consumers more aware of longevity in combination with sustainability and might help them unconsciously extend the lifetime of their product. For example, see figure 42.
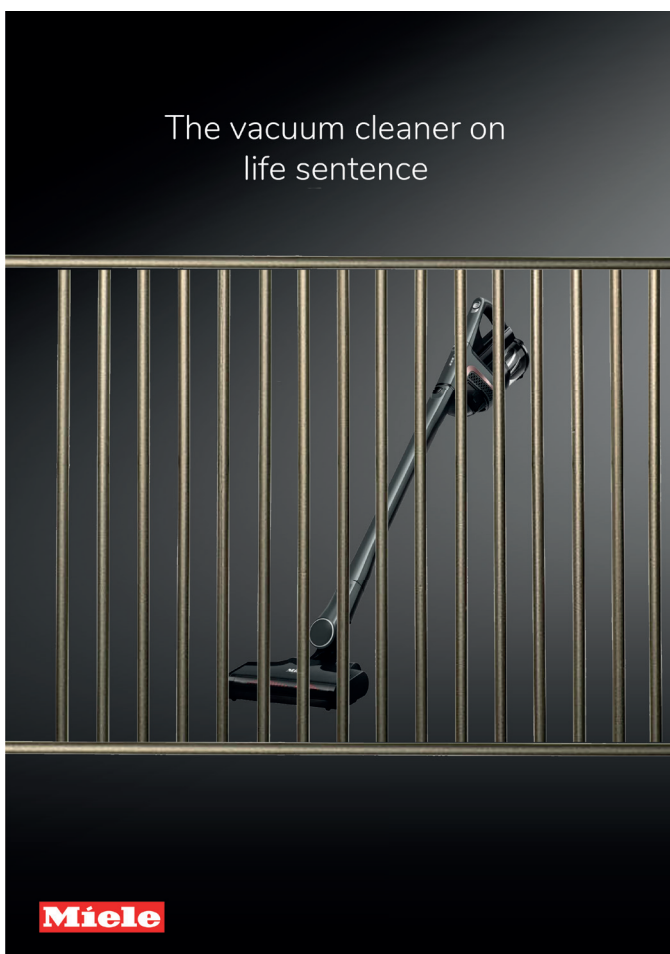
Figure 42: Two example advertisements, advertise longevity

5.2 Advice for PROMPT

The learnings from the studies can be used by PROMPT in several ways. First of all, PROMPT currently focuses on the actual lifetime of products. But, in the end, it is up to the consumer how long the product lasts. Therefore, it is important to take into account consumer behavior and decision-making.

From this study, it became clear that the expected lifetime is very important for the actual lifetime, and should therefore be taken into account in the testing program. This means, companies should not only make the product very long-lasting, but they should also help the consumer to increase the lifetime of their products.

As learned in the qualitative study, not many consumers are aware of their role in longevity and of the impact of longevity on the environment. Therefore, more awareness should be created, and more importantly, consumers should work towards owning and using their products for a longer period.

In the future, PROMPT could implement the expected lifetime in their testing program using a three-step system: Low, medium, and high standard. Because in this study, the actual lifetime of products was not considered, no exact data is included and should be determined by the PROMPT consortium, but in figure 43, the proposal can be found. The best way to implement these criteria should be considered per product.

The low standard could be by considering the amount of warranty. Warranty was the result of all studies to be very important to determine the expected lifetime of products and is also very easy to measure. Therefore, this can easily be implemented in a testing program, and is also easy for companies to improve.

For the medium standard, the extended availability of spare parts can be introduced. This also came from the quantitative study as being very influential. Also, maintenance indication should be present for a product with an increased expected lifetime. And finally, to achieve a medium standard, the company should also promote a longer life for this product.

To reach a high standard, companies should do everything they can to increase the expected lifetime of their products. First of all, a reversed warranty as shown in the example of chapter 5.1 should be implemented. Besides having maintenance indicators, these companies should also actively assist in increasing the lifetime of a product. For example, by adding a maintenance service that pushes people to maintain the product when needed (example: Senseo sends people a descaler when it is time to descale the coffee machine to make sure people do it). And also, for a high standard, people should be proud of their long-lasting product and products should contain the latest technology to increase the expected lifetime. For example, where possible, implement self-healing materials in the products.

Low ★	Medium ★★	High ★★★
Extra warranty	More warranty	Reversed warranty
	Maintenance indicator	Actively push maintenance
	Advertise longer lifetime	Lifetime increasing tech

Figure 43: Three testing criteria

PART 6: CONCLUSION

In the following chapter, the quantitative study will be explained. The aim of this study was to quantify the influence of the proposed strategies on the expected lifetime of vacuum cleaners. Based on the previous findings, and to keep the study within limits, the scope for this study was narrowed down. The method that was chosen is conjoined analysis was combined with cluster analysis. First, the most important strategies will be quantified and after that consumer segments will be identified that have their own specific most important attributes.

6.1 General conclusion

From the literature review of this project, it was concluded that, in order to increase the lifetime of products, the expected lifetime of products should be increased too. Consumers make the final replacement decision and therefore the consumer behavior is important to consider when trying to increase the lifetime of products.

In the first study, the qualitative study, the following research question was answered: "How could the expected lifetime of products be extended?". It turned out that people determine the expected lifetime at several moments throughout the lifetime of the product. Therefore it is not only important that the expected lifetime is increased at the moment of purchase, but it is maintained throughout the lifetime of the product.

Also, from the qualitative study, it was found that consumers take previous experiences, as well as the average lifetime of the product and the amount of warranty into account when determining the expected lifetime of products. Also, the expected change in demographics is taken into account by consumers to consider how long they will keep their current product.

After that, the entire list of strategies was reviewed by the participants. It seemed to differ per product and consumer what strategy would increase the expected lifetime. The type of consumer was different because some people were very involved with their product and liked to repair their product, whereas other people did not care at all. Also, the expected reason to replace the product mattered because when a consumer expects to replace their product because they want to stay up to date with the latest technology, it does not matter how repairable the product is, and the other way around.

Furthermore, the qualitative study concluded that many consumers are not aware of the importance of longevity for the environment. Many people did not have a specific number of years in mind when thinking of the expected lifetime of products. Also, people said they want to purchase a sustainable product, but never considered keeping their current product.

In the second study, the quantitative study, the following question was answered: "What is the best way to increase the expected lifetime of products?" For this study, the research scope was narrowed down to vacuum cleaners only, and the list of strategies was simplified to concrete design features.

It was concluded that warranty and the availability of spare parts were the most important features for determining the expected lifetime of products. On the other hand, brand and price turned out to be the least important strategies to increase the expected lifetime of products. And somewhere in the middle, the self-healing materials, care, and maintenance indicators, and suction power turned up in the middle.

Additionally, from the cluster analysis, it was concluded that 2 clusters could be distinguished. One cluster indeed had warranty and the availability of spare parts as the most important strategies to increase the expected lifetime of products. On the other hand, about one-third of the participants were classified in the second cluster. This cluster mainly looked at the self-healing materials, care and maintenance indicators, and the availability of spare parts. This means, to approach not only the first but also the second cluster, almost all strategies should be integrated into a product to increase the overall expected lifetime.

This also shows in the correlation analysis, from which it was concluded that the strategies build upon each other when increasing the expected lifetime of products. Also shown from the correlation analysis, there was little correlation between the strategies and the individual variables.

6.2 General discussion

At the beginning of this project, it was assumed that for a more sustainable future, it is necessary to increase the lifetime of products. This makes sense, as this would lower the throughput of resources, decrease the amount of waste, and would mean less pollution to the environment. However, in this study, the rebound effect was not considered. This means, when people would use their current product for longer, they also have more money left to spend on other products, which would counteract the attempts of increasing product lifetimes. In this case, service models might be effective. Also, the purchase prices of products should increase in the first place. This might sound less beneficial for the consumer, but it also increases the emotional attachment of the consumer with the product.

Also, this study, and especially the second, qualitative study, mainly focuses on incremental change. This means small improvements to the current products. However, it could be stated that to change people's view on the expected lifetime of products, radical change is needed. Maybe we should completely turn around the way people think about the ownership of products. For example, step away from ownership at all, and have service models that go beyond warranty or repair services.

This study was performed in an academic setting, and the experiment was not performed in a real-time setting. To get as close to reality as possible, the method of conjoint analysis was chosen, but still, people could make different choices in real life.

Besides that, in this study, questions were asked about which product people expect to last the longest. This does not mean people will also purchase this option. In this study, we did not test the desirability of the options, only the expected lifetime. Further research could explore whether people value durability in a product, and how to make sure people consider durability when purchasing a new product.

6.3 Recommendations

It must be noted that literature about the expected lifetime of products is very limited. There is some knowledge about the actual lifetime, but the role of the expected lifetime is not considered a lot. Therefore, further research on this topic is recommended. This project mainly aimed at getting a good impression on the topic and finding recommendations for the market. However, further research could dive even deeper into, for example, grouping the strategies into categories. For example, strategies that require action from the consumer (care and maintenance, repair) and strategies that increase the expected lifetime without any action required (durable design, timeless design, self-healing materials).

Furthermore, in the second study of this project, the scope was narrowed down to vacuum cleaners. Therefore, the findings cannot be directly generalized to other product categories. Further research is needed to see whether these strategies also work the best for other categories.

Also, different ways of executing the strategies should be studied. In this study, from each strategy, only one type of execution was tested. For every product and product category, it differs what strategies are effective. Therefore, more research about each strategy and the different ways of executing them could be performed.

6.4 Personal reflection

For my graduation project, I wanted to tackle a problem that would improve something. With the topic of increasing product lifetimes, I am proud to have added some new knowledge to the world about the expected lifetime, and hopefully, I made people more aware of the importance of increasing the lifetime of your product. I hope, in the future, I can use my skills and knowledge to continue improving the world by making people more aware of what they can do to decrease their footprint on the environment.

This journey was a long and hard but interesting ride. There were many times where I got stuck or got insecure. But during this project, I also learned to keep going, even when I did not know where it was going. I learned to ask for help from my friends or my supervisors, which was sometimes a challenge when working on my own at home. In the end, especially with all of the COVID measures, I am proud of what I accomplished within the given time.

Besides learning a lot about the topic, I learned to manage a project on my own. Sometimes I was looking for the right balance, as it is also an individual project, and there was no company involved. But I learned that an individual project does not mean you have to do everything by yourself, it is okay to ask for help and feedback.

In my project brief, I defined three personal learning goals. First of all, I wanted to learn more about academic writing. This is something I sometimes missed during my studies, because IDE is mostly visual, and I noticed a threshold to start writing. Therefore, I wanted to take the chance to practice this one last time in my project. My key learning about writing is: Just start writing. I learned that there was such a threshold, but when I just started with the intention of writing a draft, I noticed that it was very easy to keep going.

Also, I wanted to find out whether I want to continue researching as a job. I must say that I enjoyed doing this project, but I also learned that I am more of a team player. I felt lost sometimes because of the lack of direction. I have my own opinion but found it hard that there is no one interested in my work, and I think in a team it is easier to spar with people and that boosts my drive to work.

My second personal learning goal was to deep dive into one topic. I am really happy that I chose to do a project for the TU Delft and not for a company because I got to focus on learning more on this specific topic. I also learned that I am passionate about (sustainable) consumer behavior and this is something I will take with me to the career market. Besides that, I learned that if I want to, I can dive into a subject. Before this, I was the type of person that would say 'I don't know enough about that', but during this project, I learned that I can learn and make myself acquainted with a new topic.

The last personal learning goal, improving my self-confidence, was probably the hardest. But when I look back at my work, I am very proud of what I accomplished and I am confident that I can execute an entire project on my own. I created a routine to keep myself on track, I found a nice group of people around me that were always there to support me when needed and I also took the time to relax now and then.

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PART 8: APPENDIX

Appendix 0: Approved project brief

DESIGN FOR our future

TUDelft

IDE Master Graduation
Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

❗ USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT
Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME
Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 ! ❗

family name	Koek	4766
initials	S	given name	Simone
student number	▮▮▮▮▮	
street & no.	▮▮▮▮▮	
zipcode & city	▮▮▮▮▮	
country	▮▮▮▮▮	
phone	▮▮▮▮▮	
email	▮▮▮▮▮	

Your master programme (only select the options that apply to you):

IDE master(s): ( ) IPD ( ) DfI (✓) SPD

2nd non-IDE master: _____

individual programme: ___ - ___ - ___ (give date of approval)

honours programme: ( ) Honours Programme Master

specialisation / annotation: ( ) Medisign

( ) Tech. in Sustainable Design

( ) Entrepeneurship

SUPERVISORY TEAM **
Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair	R. Mugge	dept. / section: DOS/MCR
** mentor	L. Magnier	dept. / section: DOS/MCR
2nd mentor	_____	
	organisation: _____	
	city: _____	country: _____

comments (optional)
Ruth Mugge will coach mainly about the product design. Lise Magnier will coach mainly about marketing. Both angles are essential to fully understand premature obsolescence and learn how to fight it.

❗ Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

❗ Second mentor only applies in case the assignment is hosted by an external organisation.

❗ Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

APPROVAL PROJECT BRIEF
To be filled in by the chair of the supervisory team.

chair ___R. Mugge_____ date __26__ - __02__ - __2021__ signature

Ruth Mugge

Digitally signed by Ruth Mugge Date: 2021.02.26 11:51:58 +01'00'

CHECK STUDY PROGRESS
To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: ___30___ EC

Of which, taking the conditional requirements
into account, can be part of the exam programme ___30___ EC

List of electives obtained before the third
semester without approval of the BoE

( ) YES   all 1st year master courses passed

( ) NO   missing 1st year master courses are:

name ___J. J. de Bruin_____ date __02__ - __03__ - __2021__ signature

J. J. de Bruin, SPA

Digitally signed by J. J. de Bruin, SPA Date: 2021.03.02 11:27:29 +01'00'

FORMAL APPROVAL GRADUATION PROJECT
To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks?
- Does the composition of the supervisory team comply with the regulations and fit the assignment?

Content: (|) APPROVED   ( ) NOT APPROVED

Procedure: (|) APPROVED   ( ) NOT APPROVED

comments

name ___Monique von Morgen_____ date __16__ - __03__ - __2021__ signature

Premature obsolescence: Design guidelines to increase product lifetimes   project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date   15 - 02 - 2021   09 - 07 - 2021   end date

INTRODUCTION **
Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

On the journey towards a more sustainable society, the high throughput of resources is a growing problem. According to Koehler (2012), industrial design engineers have a great influence on the demand of materials and products, and should therefore take their responsibility in sustainable material management. One strategy to decrease the high material throughput is to design products with a long lifetime. Especially e-waste (electronic waste), which currently increases three times faster than regular waste and is hard to collect and recycle (The World Bank, 2021), is an increasing concern and an opportunity for improvement. In the existing literature, a lot of emphasis has been put on reducing the throughput of resources. However, the role of product longevity is rarely mentioned (Cooper, 2015). Consumers fail to see the connection between longevity and sustainable consumption (Echegaray, 2016). It has been shown by research that many electronic household products are being replaced for other reasons than being broken beyond repair (31% of washing machines, 66% of vacuum cleaners, 56% of TV's and 69% of smartphones) (Wieser & Troger, 2018; Harmer et al., 2019; Hennies & Stamminger, 2016). This means other factors than just physical durability influence the replacement behavior of consumers.

To reduce the amount of e-waste, I will look at the consumer's replacement behavior. In the existing literature, the role of the consumer has mainly been related to their responsibilities for waste disposal and recycling, yet, the consumers' ability to leverage product durability remains underdeveloped (Evans & Cooper, 2010). According to Echegaray, the expected product lifetime highly influences psychological and symbolic obsolescence. At the time of purchase, the customer has expectations about the lifetime of a product. As it turns out, these expectations have a large impact on the actual lifetime of products. In the survey from Echerary (2016), one-third of the participants acknowledged replacing products prematurely because the product reached their expected lifetime. To illustrate how this works, the framework of figure 1 is shown. This framework shows the psychological process of product replacement. According to van den Berge et al. (2020), there is a value trade-off between the mental book value of the currently owned book value and the expected value and costs of the new product. When a product has reached the expected lifetime, the speed at which the mental book value decreases accelerates, and the chance of premature disposal increases.

In this project, I will contribute to the European research project PROMPT. PROMPT (Premature Obsolescence Multi-stakeholder Product Testing) is a program aiming to boost durability by creating an independent testing program to tackle premature obsolescence. They already listed criteria that are expected to result in an extended lifetime:
- Product design (quality and durable materials, timeless and robust design)
- Maintenance (clear explanation, easy to carry out)
- Repair (easy to repair, help available)
- Upgradeability (upgrades are easy and add value to the product)
- Brand policy (brand promotes sustainable behavior)

However, there is no scientific evidence that these criteria affect product lifetime yet. In this project, I will take the criteria determined by PROMPT as a starting point to investigate what design features affect the expected product lifetime of products from a consumer perspective.

*The reference list can be found in figure 2.

space available for images / figures on next page

introduction (continued): space for images

OWNED PRODUCT · NEW PRODUCT

Strategies to support the owned product value
- Stimulate Product Attachment
- Sustain Product Aesthetics
- Stimulate Product Care / Maintenance
- Enable Upgradebility

RELATIVE VALUES
Functional
Emotional
Social
Epistemic
Conditional

Strategies to support the new product value
- Development of new technologies
- Marketing Efforts

Repeated use/ Satiation

Mental Book Value Currently Owned Product

TRADE-OFF

Expected Value and Costs New Product

Trade-in Promotions

RETENTION · REPLACEMENT

image / figure 1:   Psychological process of product replacement (van den Berge et al., 2020)

Reference list

Van den Berge, R. B. R., Magnier, L., & Mugge, R. (2020). Too good to go? Consumers' replacement behaviour and potential strategies for stimulating product retention. Current opinion in psychology.

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image / figure 2:   Reference list

PROBLEM DEFINITION **
Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

The problem that is going to be faced in this project is premature obsolescence. As about half of the products are discarded prematurely (so before they are physically obsolete), there is a big opportunity to tackle the problem of material scarcity and moving towards a circular economy.

As stated by Wieser et al. (2015), the expectation about the product lifetime influences their decision whether to replace or repair a product. For example, when a washing machine breaks, the consumer has to decide whether it is worth it to repair the washing machine, or whether it is more convenient to replace it with a new one. This could be solved by improving the repairability of the product.
Also, Echegaray (2016) found out that 66.7% of the participants in his survey feel an urge to replace products after a certain period, regardless of whether this is based on psychological obsolescence or technical failure. On top of that, 31.6% of the participants anticipate product replacement because of social value and modernity issues.

At this moment, PROMPT is working on a test program to assess the lifetime of products, but research showed that the physical state of a product is not the only reason to discard a product. To measure the lifetime of a product, it is also important to take consumer behavior into account. At this moment, it is still unclear what factors influence the expected lifetime of products, and what design features or business models can increase the expected product lifetime.

ASSIGNMENT **
State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

Generate design guidelines that help to improve the expected product lifetime and illustrate this on a case example. This will be done by researching the factors that influence the expected product lifetime of consumer durables.

The deliverables of this project consist of 2 parts:
- A set of design guidelines that help to improve the expected product lifetime of consumer durables. These guidelines will be scientifically substantiated.
- A case study that explains the design guidelines. I deliberately chose not to involve a company from the start so I could choose the best example after diving into the topic. At this stage, I want to pick a specific product to redesign and - if possible- present it to a particular party that best suits the designed strategy.

Personal Project Brief - IDE Master Graduation

**PLANNING AND APPROACH **
Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date ___15__ - _2_ - __2021___   __9__ - _7_ - __2021___ end date

Calender week	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Project week			1	2	3	4	5	6	7	8	9	10	-	11	12	13	14	15	16	17	18	19	20
Kick-off meeting																							
Finalize project brief																							
Literature research																							
QL research																							
QNT research																							
Midterm																							
Generating design guidelines																							
Example case study																							
Green light																							
Write conclusion / Implement feedback																							
Improve/finalize report and presentation																							
Graduation																							

Legend: Process, Deadline, Holidays, Officials, Meetings

As I wanted to do a research project, the focus of the project is research.
Also, I calculated one week of holidays after the midterm presentation, but the date is not fixed yet.

The project consists of 4 phases
1. The research part
This is the biggest part, consisting of a literature review, brief qualitative research (about five interviews), and an extensive quantitative research phase. At the midterm presentation, I can present the results from the literature results and the qualitative research. At this point, I can discuss the quantitative part, but there will not be results yet.
2. Generating design guidelines
The results will be combined into the guidelines for product longevity. These will be the main conclusions from the research.
3. Case study: Applying research in practice
During this 4-week phase, I will apply the research to practice, and illustrate the conclusions from research into an existing product. This will help me to communicate and make the findings tangible.
4. Reporting
During the last month, I planned the reporting phase. Improvements can still be made but it is time to tie the knots and take the time to finish the report and presentation.

Initials & Name __S_____Koek_____ _4766___   Student number _4356489_____

Title of Project __Premature obsolescence: Design guidelines to increase product lifetimes_____

MOTIVATION AND PERSONAL AMBITIONS
Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

Motivation
The reason I decided to go for this assignment is that I have always been interested in the consumer behavior side of sustainability. Why do people behave the way they do and how can you 'nudge' people to behaving more sustainably. Personally, I believe designing new (sustainable) products is not always the right way to go, and in order to accomplish a circular economy, I think shifting towards slow consumption and the reduction of waste is a crucial step.
By choosing a project that does not serve a particular company, I can let go of the commercial interests of the business and independently do research. Then, at a later stage, I can see which party is the most suitable to reduce the waste-economy and how it can be best applied in practice.

Personal ambitions
- Academic research and writing: During this project, I would like to learn more about doing research and academic writing. I really liked doing the SPD Research course and during my graduation, I want to find out if I want to continue doing research after graduation (either for a university or a company). During my past experiences I found out I have the most difficulties with writing so this is something I will have to put extra emphasis on during graduation. To do this, I will start writing the report from day one, so I can practice, iterate and get much feedback.
- Deep dive into a topic: I see this project as an opportunity to dive deep into one topic - sustainable consumer behavior. This is a field that I have always had an interest in and I want to take this final half a year to specialize in this topic and thereby differentiate myself from other IDE students.
- Self-confidence: Realizing this is one of the few individual 'courses' of the entire IDE program, I need to build more confidence working alone, be less afraid to make mistakes, and move forward. I noticed I have the tendency to doubt too much about myself and therefore stagnate in the process. By doing weekly (short) reflections I will keep track of my personal growth, and keep moving forward in the project. Especially during the corona lockdowns, it might sometimes be hard to stay on track, so by putting extra attention to this I hope to notice quickly when it is time to ask for help.

FINAL COMMENTS
In case your project brief needs final comments, please add any information you think is relevant.

Initials & Name   S_____ Koek_____ 4766____   Student number   4356489_____

Title of Project   Premature obsolescence: Design guidelines to increase product lifetimes_____

Appendix 1a: Interview guide (Dutch)

Interview opzet

Doel van het kwalitatief onderzoek:
- Erachter komen welke design-features of businessmodellen de verwachte levensduur van WM, SM, VC en tv's kunnen verlengen

Onderzoeksvragen
- Hoe kan de verwachte levensduur voor WM, SM, VC en TV worden verlengd?
  - o Hoe bepalen mensen de verwachte levensduur van producten?
  - o Wat is de invloed van onderstaande strategieën op de verwachte levensduur?
  - o Hoe zien mensen hun verantwoordelijkheid voor een lang leven?

Deelnemers
- 2 personen per productcategorie - dus 8 in totaal
- Nederlandse mensen
- Mensen die hun WM/SM/VC of TV hebben vervangen gedurende de 6 maanden, dus de feitelijke vervangingssituatie is nog vers en ze kunnen zich nog hun motieven herinneren om dit product te kopen.

Extra
- Ik wil het hebben over hun nieuwe product omdat ze zojuist hun verwachte levensduur van het nieuwe product hebben besloten en niet van het oude product

Introductie
- Welkom bij dit interview, bedankt voor je hulp. Zoals je wellicht (niet) weet, ben ik bezig met mijn afstudeerproject. Dit project gaat over het voortijdig verouderen van producten en het verlengen van de levensduur van producten vanuit consumentenperspectief.
- Het doel van dit interview is om meer te weten te komen over de levensduur van producten en hoe u enkele van de strategieën ziet om de levensduur van producten te verlengen.
- Ik wil benadrukken dat ik u niet zal beoordelen op uw antwoorden, er zijn geen foute antwoorden. Ik wil meer weten over uw mening en ervaringen.
- Dit interview wordt anoniem en vertrouwelijk gedocumenteerd, als u zich wilt terugtrekken uit het interview is dat op elk moment mogelijk.
- Voel je vrij om me op elk moment te onderbreken.
- Is het oké als ik deze sessie opneem? Ik zal het alleen gebruiken om het interview te transcriberen en daarna zal ik het verwijderen.
- Heeft u nog vragen voordat we beginnen?

De vervanging
1. Kun je me vertellen over de laatste keer dat je je 'X' hebt vervangen?
    a. Wanneer heb je het vervangen?
2. Wat waren de redenen voor vervanging? Meerdere antwoorden zijn mogelijk
Doel: de verschillende redenen voor vervanging begrijpen
    a. Kunt u voor elke reden uitleggen waarom dit tot vervanging leidde?
    b. Wat was de rol van de uitvoering en het uiterlijk van de oude 'X' bij uw beslissing om deze te vervangen?
    c. Was er een moment voordat u het product moest vervangen dat u eraan dacht het product te vervangen?
        i. Waarom heb je het op dat moment niet vervangen?

Mogelijkheid om te repareren
3. Functioneerde het product nog helemaal goed toen u besloot het te vervangen?
Doel: Inzicht krijgen in de redenen om het product (niet) te laten repareren
    a. Indien nee:
        i. Heeft u de mogelijkheid overwogen om de oude 'X' te repareren? Waarom (niet)?
        ii. Wat waren de redenen om te kiezen voor vervanging in plaats van reparatie? Meerdere antwoorden zijn mogelijk
4. Zou u een reparatie overwegen als het nieuwe product defect zou raken?
Doel: de redenen begrijpen om het product (niet) te laten repareren
    a. Waarom of waarom niet? Er zijn meerdere redenen mogelijk

Verwachte levensduur
5. Hoe lang heb je de oude 'X' gebruikt?
Doel: inzicht in de verwachte levensduur van het product van de deelnemer
    a. Was je tevreden met het leven?
    b. Had je verwacht dat het product zo lang meegaat? Waarom?
    c. Kun je factoren bedenken die de levensduur hadden kunnen verlengen?
6. Hoelang verwacht u de nieuwe 'X' te gebruiken?
Doel: inzicht in de verwachte levensduur van het product van de deelnemer
    a. Waarom denk je dat het zo lang zal duren?
    b. Zou je kunnen evalueren wat je daarvan vindt?

Levenslange verlengingsmogelijkheden
Doel: Inzicht krijgen in gedachten over mogelijke ontwerpoplossingen en bedrijfsmodellen voor het verlengen van de verwachte levensduur
- Ik zal nu verschillende mogelijke oplossingen in het ontwerp of de gerelateerde diensten uitleggen die de verwachte levensduur van producten kunnen beïnvloeden. Elke oplossing wordt tijdens het interview kort uitgelegd op een dia / kaart

12. Als uw nieuwe product een verlengde garantie had, zou dit dan van invloed zijn op de tijd die u verwacht het te gebruiken?
    a. Kunt u op welke manier uitleggen?
    b. Wat is het voordeel van een verlengde garantie? Licht uw antwoord toe
    c. Wat is het negatief van een verlengde garantie? Licht uw antwoord toe

[Upgradebaar ontwerp - fysiek]

Een upgrade bestaat erin de prestaties van een product naar een hoger niveau te tillen door fysieke componenten aan het product toe te voegen of te vervangen.

13. Heeft uw nieuwe 'X' een ontwerp dat kan worden geüpgraded? [toon dia / kaart met definitie]

Geef indien nodig voorbeelden van onderdelen die geüpgraded kunnen worden (bijv. Betere luidsprekers voor tv, betere camera voor smartphone, toevoeging van een waterfilter om verkalking te voorkomen en verlaging van de hoeveelheid wasmiddel wasmachine en verbeterd filter voor stofzuiger let op: dit zijn slechts voorbeelden en andere modules zijn mogelijk)
    a. Zo ja: was dit iets waar u bewust naar op zoek was bij de aankoop van dit product?

14. Als uw nieuwe product een upgradebaar ontwerp had, zou dit dan van invloed zijn op de tijd die u verwacht het te gebruiken?
    a. Kunt u op welke manier uitleggen?
    b. Wat is positief aan een upgradebaar ontwerp? Licht uw antwoord toe
    c. Wat is het negatieve van een upgradebaar ontwerp? Licht uw antwoord toe

[Upgradebaar ontwerp - Software]

Een software-update bestaat uit het verbeteren van de prestaties van een product door de software in het product te verbeteren.

15. Heeft uw nieuwe 'X' software-updates? [toon dia / kaart met definitie]

Geef indien nodig voorbeelden van software-updates (bijv. Nieuwe software voor betere prestaties van tv, nieuw besturingssysteem voor smartphone, nieuwe software voor betere wasprogramma's voor wasmachine en nieuwe software voor betere vuilcontrole in stofzuiger - houd er rekening mee dat dit slechts voorbeelden en andere updates zijn mogelijk)
    a. Zo ja: was dit iets waar u rekening mee heeft gehouden bij de aankoop van dit product?
    b. Kun je dat toelichten?

16. Als uw nieuwe product een software-update had, zou dit dan van invloed zijn op de tijd die u verwacht het te gebruiken?
    a. Kunt u op welke manier uitleggen?
    b. Wat is positief aan een software-update? Licht uw antwoord toe
    c. Wat is het negatieve van een software-update? Licht uw antwoord toe
17. Hoelang verwacht je dat jouw telefoon software updates blijft doen?
    a. Was dit iets waar je bewust mee bezig was tijdens de aankoop?
    b. Als dit langer of korter zou zijn, zou dat invloed hebben op hoelang jij verwacht dat je het product zou gebruiken?

[Herstelbaar ontwerp]

Productreparatie omvat werkzaamheden om defecte onderdelen te vervangen. Een herstelbaar ontwerp is eenvoudig te demonteren, kritieke onderdelen kunnen eenvoudig worden vervangen en reserveonderdelen zijn online of in winkels tegen een redelijke prijs verkrijgbaar.

7. Heeft uw nieuwe 'X' een herstelbaar ontwerp? [toon dia / kaart met definitie]
Geef indien nodig voorbeelden van herstelbare ontwerpen (smartphone / tv die gemakkelijk kan worden opengeschroefd om onderdelen te vervangen, kritieke onderdelen in een wasmachine die gemakkelijk kunnen worden vervangen)
   a. Zo ja: was dit iets waar u bewust naar op zoek was bij de aankoop van dit product?
8. Als uw nieuwe product een beter te repareren ontwerp had, zou dit dan de tijd beïnvloeden die u verwacht het te gebruiken?
   a. Kunt u op welke manier uitleggen?
   b. Wat is positief aan een herstelbaar ontwerp? Licht uw antwoord toe
   c. Wat is het negatief van een herstelbaar ontwerp? Licht uw antwoord toe

[Reparatieservices]

Reparatiediensten helpen u bij het repareren van uw product, bijvoorbeeld een handleiding voor het repareren van een product, een servicenummer dat u kunt bellen om reparatieondersteuning te vragen, enz.

9. Heeft u toegang tot reparatieservices voor uw nieuwe 'X'? [toon dia / kaart met definitie]
   a. Zo ja:
      i. Wat voor soort reparatiediensten?
      ii. Was dit iets waar je bewust naar op zoek was bij de aankoop van dit product?
10. Als uw nieuwe product een reparatiedienst had, zou dit dan van invloed zijn op de tijd die u verwacht het te gebruiken?
   a. Kunt u op welke manier uitleggen?
   b. Wat is positief aan reparatiediensten? Licht uw antwoord toe
   c. Wat is het negatief van reparatiediensten? Licht uw antwoord toe

[Verlengde garantie]

Een verlengde garantie, ook wel een serviceovereenkomst, een servicecontract of een onderhoudsovereenkomst genoemd, is een verlengde garantie die aan consumenten wordt aangeboden naast de standaardgarantie op nieuwe artikelen.

11. Heeft uw nieuwe 'X' een verlengde garantie? [toon dia / kaart met definitie]
   a. Zo ja:
      i. Wat betekent dit voor uw product?
      ii. Was dit iets waar je bewust naar op zoek was bij de aankoop van dit product?
   b. Zo nee: was dit een optie?
      i. Waarom koos u niet voor verlengde garantie?

[Productzorg]

Productverzorging omvat zorg- en onderhoudsactiviteiten en andere beschermende maatregelen die het product voor een langere tijd in goede staat kunnen houden.

18. Helpt uw nieuwe 'X' u bij het uitvoeren van de productverzorgings- en onderhoudsactiviteiten? [toon dia / kaart met definitie]

Geef indien nodig voorbeelden van productonderhoud (bijv. Herinneringen voor wasbeurten van 90 graden voor de wasmachine, herinnering om te ontkalken; een stofzuiger die aangeeft wanneer een filter moet worden vervangen, een telefoon die aangeeft wanneer het klaar is met opladen om de levensduur van de batterij te optimaliseren, een tv die aangeeft wanneer stof het koelsysteem blokkeert)

   a.   Zo ja: was dit iets waar u bewust naar op zoek was bij de aankoop van dit product?

19. Als het product je zou helpen/aanmoedigen het product te onderhouden, zou dit dan van invloed zijn op de tijd die u verwacht het te gebruiken?

   a. Kunt u uitleggen hoe?
   b. Wat is er positief aan een product dat zorg en onderhoud aanmoedigt? Licht uw antwoord toe
   c. Wat is het negatieve van een product dat zorg en onderhoud aanmoedigt? Licht uw antwoord toe

[Duurzaam ontwerp]

Een duurzaam ontwerp bestaat uit materialen en componenten die robuuster zijn en minder snel kapotgaan of tekenen van slijtage vertonen.

20. Heeft uw nieuwe 'X' een duurzaam ontwerp? [toon dia / kaart met definitie]

Geef indien nodig voorbeelden van duurzame ontwerpen (bijv. Een telefoon die valbestendig is, een tv met een hoogwaardig moederbord, een stofzuiger met een stevige slang en mondstuk of een wasmachine met trommellagers van hoge kwaliteit)

   a.   Zo ja: was dit iets waar u bewust naar op zoek was bij de aankoop van dit product?

21. Als uw nieuwe product een duurzaam ontwerp had, zou dit dan van invloed zijn op de tijd die u verwacht het te gebruiken?

   a. Kunt u op welke manier uitleggen?
   b. Wat is positief aan een duurzaam ontwerp? Licht uw antwoord toe
   c. Wat is het negatief van een duurzaam ontwerp? Licht uw antwoord toe

[Tijdloos design]

Een tijdloos design (ook wel klassiek design genoemd) volgt niet de laatste modestijlen en zal voor langere tijd aantrekkelijk blijven

22. Heeft uw nieuwe 'X' een tijdloos ontwerp? [toon dia / kaart met definitie]
Geef indien nodig voorbeelden van tijdloze dessins (bijv. Kleding die langer in de mode blijft vs. die maar een seizoen mooi is; dus een telefoon of tv die simpel en subtiel is qua design, het design van een wasmachine of stofzuiger) reiniger die vooral gericht is op functionaliteit, in plaats van op mode)

 a. Zo ja: was dit iets waar u bewust naar op zoek was bij de aankoop van dit product?

23. Als uw nieuwe product een tijdloos ontwerp had, zou dit dan van invloed zijn op de tijd die u verwacht het te gebruiken?

 a. Kunt u op welke manier uitleggen?
 b. Wat is positief aan een tijdloos ontwerp? Licht uw antwoord toe
 c. Wat is het negatief van een tijdloos ontwerp? Licht uw antwoord toe

[Zelfherstellende materialen]

Zelfherstellende materialen hebben een ingebouwde mogelijkheid om automatisch schade aan het materiaaloppervlak te herstellen, zoals slijtage of krassen.

24. . Heeft uw nieuwe 'X' zelfherstellende materialen? [toon dia / kaart met definitie]
Geef indien nodig voorbeelden van ontwerpen voor zelfherstellende materialen (bijv. Gebroken of krassen op het telefoon- of tv-scherm dat zichzelf herstelt, oppervlak van stofzuigers en wasmachines die zichzelf reinigen)

 a. Zo ja: was dit iets waar u bewust naar op zoek was bij de aankoop van dit product?

25. Als uw nieuwe product zelfherstellende materialen had, zou dit dan van invloed zijn op de tijd die u verwacht het te gebruiken?

 a. Kunt u op welke manier uitleggen?
 b. Wat is positief aan zelfherstellende materialen? Licht uw antwoord toe
 c. Wat is negatief over zelfherstellende materialen? Licht uw antwoord toe

Duurzaamheid

 a. Hoe speelde duurzaamheid een rol in het vervangen van je oude telefoon?
 b. Hoe speelde duurzaamheid een rol in de keuze voor deze telefoon?
 c. Denk je dat je iets had kunnen doen om het vervangen uit te stellen?
  a. Waarom en hoe?

Het einde

26. Is er iets dat ik tijdens dit interview niet heb gevraagd dat ik had moeten vragen?

Einde

Bedankt voor je medewerking!

Appendix 1b: Interview guide (English)

Interview set-up

Aim of the qualitative research:
- To find out which design features or business models can extend the expected lifetime of WM, SM, VC and TV's

Research questions
- How can the expected lifetime for WM, SM, VC and TV be extended?
  - o How do people determine the expected lifetime of products?
  - o What is the influence of the strategies listed underneath on expected lifetime?
  - o How do people perceive their responsibility towards longevity?

Participants
- 2 people per product category – so 8 in total
- Dutch people
- People who have replaced their WM/SM/VC or TV during the 6 months, so the actual replacement situation is still fresh, and they can still remember their motives for purchasing this product.

Extra
- I want to talk about their new product because they just decided their expected lifetime of the new product and not of the old product

Introduction
- Welcome to this interview, thank you for helping me. As you may (not) know, I am working on my graduation project. This project is about premature obsolescence of products and how to increase the lifetimes of products from a consumer perspective.
- The aim of this interview is to learn more about the lifetimes of products and how you perceive some of the strategies to increase product lifetimes.
- I want to emphasize that I will not judge you on your answers, there are no wrong answers. I want to find out more about your opinions and experiences.
- This interview will be documented anonymously and confidentially, if you want to withdraw from the interview that is possible at any moment.
- Feel free to interrupt me at any time.
- Is it okay if I record this session? I will use it only to transcribe the interview and I will delete it afterwards.
- Do you have any questions before we start?

The replacement
1. Can you tell me about the last time you replaced your 'X'?
    a. When did you replace it?
2. What were the reasons for replacement? Multiple answers are possible

Goal: Understanding the different reasons for replacement
    a. Can you explain for each reason why this triggered replacement?
    b. What was the role of the performance and appearance of the old 'X' in your decision to replace it?
    c. Was there a moment before replacing the product when you thought of replacing the product?
        i. Why did you not replace it at that moment?

Possibility to repair
3. Was the product still functioning completely well when you decided to replace it?

Goal: Understanding of the reasons to (not) have the product repaired
    a. If not:
        i. Did you consider the possibility to repair the old 'X'? Why (not)?
        ii. What were the reasons for choosing for replacement over repair? Multiple answers are possible
4. If the new product would malfunction, would you consider repair?

Goal: Understand of the reasons to (not) have the product repaired
    a. Why or why not? Multiple reasons are possible

Expected lifetime
5. How long did you use the old 'X'?

Goal: Understanding of participant's expected product lifetime
    a. Were you satisfied with the lifetime?
    b. Did you expect the product to last this long? Why?
    c. Can you think of factors that could have extended the lifetime?
6. How long do you expect to use the new 'X'?

Goal: Understanding of participant's expected product lifetime
    a. Why do you think it will last this long?
    b. Do you think that is long for an 'X' and why?

Lifetime extension possibilities
Goal: Understanding thoughts on potential design solutions and business models on lengthening the expected lifetime
- I will now explain several possible solutions in either the design or the related services that may influence the expected lifetime of products. Each solution is briefly explained on a slide/card during the interview

[Repairable design]

Product repair consists of activities to replace malfunctioning parts. A repairable design is easy to disassemble, critical parts are changed easily, and spare parts are available online or in stores at a reasonable price.

7. Does your new 'X' have a repairable design? [show slide/card with definition]

If needed, give examples of repairable designs (Smartphone /TV that can be screwed open easily to replace parts, critical parts in a washing machine that can be replaced easily)

    a. If yes: Was this something you consciously looked for when purchasing this product?

8. If your new product had more repairable design, would it influence the time you expect to use it?

    a. Can you explain in what way?
    b. What is positive of a repairable design? Please explain your answer
    c. What is negative of a repairable design? Please explain your answer

[Repair services]

Repair services are assisting you in repairing your product, for example a guide on how to repair a product, a service number you can call to ask for repair support etc.

9. Do you have access to repair services for your new 'X'? [show slide/card with definition]

    a. If yes:
        i. What kind of repair services?
        ii. Was this something you consciously looked for when purchasing this product?

10. If your new product had repair services, would it influence the time you expect to use it?

    a. Can you explain in what way?
    b. What is positive of repair services? Please explain your answer
    c. What is negative of repair services? Please explain your answer

[Extended warranty]

An extended warranty, sometimes called a service agreement, a service contract, or a maintenance agreement, is a prolonged warranty offered to consumers in addition to the standard warranty on new items

11. Does your new 'X' have extended warranty? [show slide/card with definition]

    a. If yes:
        i. What does this mean for your product?
        ii. Was this something you consciously looked for when purchasing this product?
    b. If no: Was this an option?
        i. Why did you not choose for extended warranty?

12. If your new product had extended warranty, would it influence the time you expect to use it?

a. Can you explain in what way?
b. What is positive of an extended warranty? Please explain your answer
c. What is negative of an extended warranty? Please explain your answer

[Upgradeable design- physical]
An upgrade consists in raising a product's performance to a higher standard by adding or replacing physical components in the product.

13. Does your new 'X' have an upgradeable design? [show slide/card with definition]
If needed, give examples of upgradeable parts (e.g., better speakers for TV, better camera for smartphone, adding a water filter to prevent calcifications and lower the amount of washing detergent washing machine and improved filter for vacuum cleaner please note that these are only examples and other modules are possible)
      a. If yes: Was this something you consciously looked for when purchasing this product?

14. If your new product had upgradeable design, would it influence the time you expect to use it?
      a. Can you explain in what way?
      b. What is positive of an upgradeable design? Please explain your answer
      c. What is negative of an upgradeable design? Please explain your answer

[Upgradeable design - Software]
A software update consists in raising a product's performance by improving the software in the product.

15. Does your new 'X' have software updates? [show slide/card with definition]
If needed, give examples of software updates (e.g., new software for better performance of TV, new OS for smartphone, new software for better washing programs for washing machine and new software for better dirt control in vacuum cleaner – please note that these are only examples and other updates are possible)
      a. If yes: Was this something you took into account while purchasing this product?
      b. Can you elaborate?

16. If your new product had a software update, would it influence the time you expect to use it?
      a. Can you explain in what way?
      b. What is positive of a software update? Please explain your answer
      c. What is negative of a software update? Please explain your answer

17. How long do you expect your phone to keep updating software?
      a. Was this something you were consciously working on during the purchase?
      b. If this were longer or shorter, would it affect how long you expect to use the product?

[Product care]
Product care consists of activities of care and maintenance as well as other protective measures that can keep the product in a proper working condition for a longer period of time

18. Does your new 'X' help you to perform the product care and maintenance activities? [show slide/card with definition]

If needed, give examples of product care (e.g., reminders for 90-degree washes for washing machine, reminder to decalcify; a vacuum cleaner indicating when a filter needs to be replaced, a phone indicating when it is done charging to optimize the battery lifetime, a TV indicating when dust is blocking its cooling system)

    a. If yes: Was this something you consciously looked for when purchasing this product?

19. Do you think having the product encourage you to perform product care and maintenance lengthens the time you will use the product?

    a. Can you explain in how?

    b. What is positive of a product that encourages care and maintenance? Please explain your answer

    c. What is negative of a product that encourages care and maintenance? Please explain your answer

[Durable design]

A 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.

20. Does your new 'X' have a durable design? [show slide/card with definition]

If needed, give examples of durable designs (e.g., a phone that is drop-resistant, a TV that has a high-quality mainboard, a vacuum cleaner with a solid hose and nozzle, or a washing machine with high quality drum bearings)

    a. If yes: Was this something you consciously looked for when purchasing this product?

21. If your new product had durable design, would it influence the time you expect to use it?

    a. Can you explain in what way?

    b. What is positive of a durable design? Please explain your answer

    c. What is negative of a durable design? Please explain your answer

[Timeless design]

A timeless design (aka classic design) does not follow the latest fashion styles and will remain attractive for a longer period of time

22. Does your new 'X' have a timeless design? [show slide/card with definition]

If needed, give examples of timeless designs (e.g., clothing that stays longer in fashion vs. that is only nice for a season; so, a phone or TV that is simple and subtle in its design, the design of a washing machine or vacuum cleaner that is mainly focused on its functionality, rather than fashion style)

    a. If yes: Was this something you consciously looked for when purchasing this product?

23. If your new product had timeless design, would it influence the time you expect to use it?
    a. Can you explain in what way?
    b. What is positive of a timeless design? Please explain your answer
    c. What is negative of a timeless design? Please explain your answer

[Self-healing materials]
Self-healing materials have a built-in ability to automatically repair damages to the material surface, such as wear and tear or scratches.

24. Does your new 'X' have self-healing materials? [show slide/card with definition]
If needed, give examples of self-healing materials designs (e.g., broken or scratches on phone or TV screen that repairs itself, surface of vacuum cleaners and washing machines that clean itself)
    a. If yes: Was this something you consciously looked for when purchasing this product?

25. If your new product had self-healing materials, would it influence the time you expect to use it?
    a. Can you explain in what way?
    b. What is positive of self-healing materials? Please explain your answer
    c. What is negative of self-healing materials? Please explain your answer

Durability
a. How did sustainability play a role in replacing your old phone?
b. How did sustainability play a role in choosing this phone?
c. Do you think you could have done something to delay the replacement?
a. Why and how?

The end
26. Is there anything I did not ask during this interview that I should have asked?

End
Thank you for your cooperation!

Appendix 2: Slideshow interviews

Repair services

- Repair services are assisting you in repairing your product, for example a guide on how to repair a product, a service number you can call to ask for repair support etc.

Repairable design

- Product repair consists of activities to replace malfunctioning parts. A repairable design is easy to disassemble, critical parts are changed easily, and spare parts are available online or in stores at a reasonable price.

Upgradeable design – software

- A software update consists in raising a product's performance by improving the software in the product.

Upgradeable design -physical

- An upgrade consists in raising a product's performance to a higher standard by adding or replacing physical components in the product.

Product care

- Product care consists of activities of care and maintenance as well as other protective measures that can keep the product in a proper working condition for a longer period of time.

Extended warranty

- An extended warranty, sometimes called a service agreement, a service contract, or a maintenance agreement, is a prolonged warranty offered to consumers in addition to the standard warranty on new items.

Durable design

- A 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.

Timeless design

- A timeless design (aka classic design) does not follow the latest fashion styles and will remain attractive for a longer period of time.

Self-healing materials

- A 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.

Appendix 3: Clusters

Appearance

Product in sight

Cleaning

Replacing filters

Quality

Increasing value

Instruction

Confidence to repair

Combination of methods

Average lifetime

Changing demographics

Expected use time

Opinion product lifetime

Expected events

Formulatig expecte lifetime

Predicting own behaviour

Reviews

Past experiences

Price

Brand/model

Sustainability

Lifetime

Effort

Improper use

Wear and tear

Cheap looking

Decreasing value

Technological development

Planned obsolescence

New versus old

Money

Urgency

Good for transport

Waiting on the phone

Trusting the quality

Longer lifetime

Durable/robust design

Flexibility of the product

Annoying

Repair service

Decreasing value of the product

Profitable for the company

Expensive

Ugly design

Sustainability

- Refurbished
- Fairphone
- In decision-making
- Eco-mode
- Other products
- Repairability

Consumer personality

- Action when product breaks
- Repair action - software
- Repair behaviour
- Ignorance/indifference
- Repair awareness
- Repairability knowledge
- Lifetime not important
- Own precautions
- Own responsibility
- Type of consumer
- Self-reflection

Trade-off

- Sustainability/money
- Sustainability/effort
- Sustainability/effort
- Sustainability/lifetime

Purchasing decision

- Wireless product
- Real life versus online shopping
- Throwaway society
- Ergonomics
- Size
- Water resistant
- Second-hand
- Value new product
- Ease of use
- Compared to other products
- Social

Care and maintenance

- Apple care
- Feeling stupid for not doing it
- Procastinate
- Increas the lifetime
- Helpful
- Effort
- Annoying reminder
- Indifference

Unfamiliar

Luxurious

Functional?

Self-healing materials

Price

What is more sustainable?

Extending the lifetime

Features are worse

Technological development

Timeless design

Boring

Old-fashioned

It's a safe choice

Easy choice

"Funny to have"

Establishing lifetime by warranty

Price of warranty

Warranty versus insurance

Extended warranty

"I've lost faith in humanity"

Faith in warranty

Reliability of theproduct

Minimum warranty needed

Results

When do you stop upgrading

Little to no influence on lifetime

Unnecessary upgrades

Physical upgradeability

Increasing the lifetime

Increasing value of the product

Self-repair by update

Increasing lifetime

Taken for granted

Automatic updates

Confusing

Annoying

Software updates

Improve the function?

Little impact

Unnecessary

Expectations

Appendix 4: Survey questions

Thank you for taking part in my research.

I am a Strategic Product Design graduate student, conducting a study about the expected lifetime of vacuum cleaners. For this, I value your input on some questions that I have. Filling in this questionnaire takes about 8 minutes. Please remember that you can quit this questionnaire at any moment that you feel uncomfortable or do not want to continue. Your answers will be kept anonymous, and will only be used for research purposes.

In case of questions, please don't hesitate to send an email to: S.Koek@student.tudelft.nl

Please note that it is not possible to participate in this survey on a mobile device, only on desktop of laptop.

Informed Consent Form:

1. Taking part in the study
I have read and understood the study information. I have been able to ask questions about the study and my questions have been answered to my satisfaction.

I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.

I understand that taking part in the study involves filling in this survey.

2. Use of the information in the study
I understand that information I provide will be used for research purposes and scientific publications.

I have read the above statements and I understand the purpose of this research. I agree to voluntarily take part in this research.

Yes
No

Prolific ID:

[   ]

>>

Please make sure to read the following text carefully, it is not possible to move back afterwards.

The following section is about **stick vacuum cleaners** (see figure below).
Next, you will see two options for vacuum cleaners. The assignment is to go through the specifications and determine which of the two vacuum cleaners has the **longest expected use lifetime before replacement**.
In other words, which stick vacuum cleaner would you probably use longer before you would replace the vacuum cleaner?

Below, you will find a definition of the attributes proposed on the cards:
Brand: The brand of the vacuum cleaner
Warranty: Legal obligation for the seller to repair or replace a product if it is malfunctioning within a specified period of time (including battery)
Suction power: How much suction power the vacuum cleaner delivers
Case coating: Selfhealing coatings have a built-in ability to repair damages without human intervention. For example cracks or scratches will disappear automatically.
Maintenance indicator: Maintenance indicators show when it is time to perform maintenance on the vacuum cleaner. For example, when it is time to replace the filters or to empty the dust collection bag.
Price: The price of the vacuum cleaner

NB. In order to ensure that you have enough time to evaluate the described situation, you will be able to go to the next page after 30 seconds

Timing

These page timer metrics will not be displayed to the recipient.

First Click	0 seconds
Last Click	0 seconds
Page Submit	0 seconds
Click Count	0 clicks

The first page contains the informed consent and the Prolofic ID of the respondent. The Prolific ID is needed to be able to pay the respondent after the survey.

Because it is not possible to move back when the conjoint analysis starts, a timer was added to make sure the respondent carefully read the introduction with the explanation of all attributes.

(1/4) Which option has the *longest expected use lifetime* before replacement?

Option 1		Option 2	
Brand	AEG	Brand	Miele
Warranty	3 years	Warranty	5 years
Suction power	220 W	Suction power	220 W
Coating	Self-healing	Coating	Not self-healing
Spare part	5 years availability	Spare part	5 years availability
Maintenance	Without indicator	Maintenance	With indicator
Price	€299.00	Price	€199.00

>>

Please indicate to what extent the following statements apply to you personally:

	Strongly disagree						Strongly agree
I am experienced in looking after my vacuum cleaner.	○	○	○	○	○	○	○
I can look after my vacuum cleaner well.	○	○	○	○	○	○	○
I have the necessary equipment for care activities on my vacuum cleaner.	○	○	○	○	○	○	○

Please indicate to what extent the following statements apply to you personally:

	Strongly disagree						Strongly agree
It is important for me to take care of my vacuum cleaner.	○	○	○	○	○	○	○
I look after my vacuum cleaner.	○	○	○	○	○	○	○
I try to prevent my vacuum cleaner from failure.	○	○	○	○	○	○	○
I clean my vacuum cleaner.	○	○	○	○	○	○	○

Please indicate to what extent the following statements apply to you personally:

	Strongly disagree						Strongly agree
Taking care of my vacuum cleaner gives me a good feeling.	○	○	○	○	○	○	○
It makes me proud that I am able to take care of my vacuum cleaner.	○	○	○	○	○	○	○
In general, looking after my vacuum cleaner is a positive experience.	○	○	○	○	○	○	○

>>

Then, the real conjoint analysis started. The profiles were automatically created by Qualtrics, so all respondents got different combinations.

The first scale used was the care scale, created by Ackermann, Schoormans and Mugge (2021, to be published).
The scales were added, hoping to find a relation between these and the clusters, to learn more about the consumer segments in the clusters.

Please indicate to what extent the following statements apply to you personally:

	Strongly disagree						Strongly agree
I am concerned about the development of the global environment.	O	O	O	O	O	O	O
I feel it is a moral obligation to use environment-friendly products.	O	O	O	O	O	O	O
It concerns me that people do not care enough for the environment.	O	O	O	O	O	O	O
I have changed from one brand to another for the sake of the environment.	O	O	O	O	O	O	O
I often buy eco-labeled products for the sake of the environment.	O	O	O	O	O	O	O

Please indicate to what extent the following statements apply to you personally:

	Strongly disagree						Strongly agree
I undertake repair actions often.	O	O	O	O	O	O	O
Repairing things is part of my identity.	O	O	O	O	O	O	O
I am interested in repair actions.	O	O	O	O	O	O	O

When it comes to repairing products you...

	Strongly disagree						Strongly agree
are knowledgeable.	O	O	O	O	O	O	O
are an expert.	O	O	O	O	O	O	O
know more than most people.	O	O	O	O	O	O	O

<< >>

Please indicate to what extent the following statements apply to you personally:

	Strongly disagree						Strongly agree
Other people come to me for advice on new technologies.	O	O	O	O	O	O	O
It seems I am learning more about the newest technologies than my friends are.	O	O	O	O	O	O	O
In general, I am among the first in my circle of friends to acquire new technology when it appears.	O	O	O	O	O	O	O
I feel confident that machines will follow through with what I instruct them to do.	O	O	O	O	O	O	O
If you really read this, choose strongly agree.	O	O	O	O	O	O	O
I keep up with the latest technological developments in my areas of interest.	O	O	O	O	O	O	O
I enjoy the challenge of figuring out high-tech gadgets.	O	O	O	O	O	O	O
I find I have fewer problems than other people in making technology work for me.	O	O	O	O	O	O	O

<< >>

The second scale was the Environmental Concern (EC) scale by Thogersen et al. (2010).
The third scale was the Repair scale as used by van den Berge et al. (2021, to be published).

The last scale is the technological innovativeness scale by Mathwick, Wagner and Unni (2010).
Also, this is where the attention check was placed. When the respondent would not carefully read the questions they fill in the wrong answer and will be excluded from the study.

Gender

Male

Female

Non-binary / third gender

Prefer not to say

What is the highest level of school you have completed or the highest degree you have received?

Primary education

Secondary education (VMBO, HAVO, VWO)

Post-secondary vocational education (MBO)

Bachelor's or equivalent (HBO/WO)

Master's or equivalent (HBO/WO)

Doctoral or equivalent

Age (in years)

<<   >>

Finally, the demographics were asked from the respondents. This is in order to be able to check whether the respondents are about equally distributed and this is also important to report.

Appendix 5: Outcomes Pre-test

Attribute importance

	Brand	Price	Warranty	Wear and tear	Breakable	Spare parts	Maintenance
Very important	5	3	7	11	9	4	4
Slightly important	9	9	6	5	5	6	8
Important	15	19	14	9	16	7	8
Slightly not important	2	2	1	5	3	7	4
Not at all important	2	0	0	0	0	3	0

Level desirability

Price levels

	€199	€299	€399	€499
Desired	18	3	0	0
Preferred	9	10	2	1
Acceptable	9	14	8	1
Unacceptable	0	9	26	34

Material levels

	Plastic stick	Metal stick	Bamboo stick
Desired	0	12	3
Preferred	3	14	6
Acceptable	24	9	18
Unacceptable	9	1	9

Warranty levels

	2 years warranty	3 years warranty	5 years warranty	7 years warranty
Desired	1	4	9	13
Preferred	4	13	17	18
Acceptable	19	13	9	4
Unacceptable	12	6	1	1

Spare part levels

	2 years spare	5 years spare	7 years spare	10 years spare
Desired	2	4	7	14
Preferred	1	6	16	19
Acceptable	12	19	12	2
Unacceptable	21	7	1	1

Coating levels

	Self-healing	Bamboo	No coating
Desired	9	1	4
Preferred	21	6	14
Acceptable	6	16	17
Unacceptable	0	13	1

Maintenance levels

	Light indicator	No indicator	Sound indicator
Desired	16	0	2
Preferred	11	2	8
Acceptable	9	20	13
Unacceptable	0	14	13

Appendix 6: Instruction manual coding

Instruction manual

Combining two datasets to perform a combination of cluster analysis and conjoint analysis

First tip: Buy SPSS from 'Surfspot', it costs €10,- per year but saves you hours of time trying to get the free SPSS from Brightspace. Definitely worth it.

1. First, delete all faulty answers from Qualtrics:
   a. Unfinished surveys
   b. Failed the attention check
   c. Export the Dataset ('data') and the Conjoint Analysis Utility Scores CSV-files
   d. Turn CSV-files into SAV-files
      i. Open it in SPSS
      ii. 'Save as' and then select SAV as the extension
      iii. If this isn't shown, just save it in 'save as' and it probably turns into SAV
2. Open Syntax in SPSS (File -> Open -> Syntax…)
3. Merge the two data sets using following code in SPSS syntax:

```
CD '/Users/simonekoek/Documents/Graduation/QNT/SPSS'.
GET FILE = IndividualUtilities.sav.
SORT CASE BY ResponseID.
SAVE OUTFILE = merge1.sav.

GET FILE = SurveyData.sav.
SORT CASE BY ResponseID.
SAVE OUTFILE = merge2.sav.

MATCH FILES
/FILE=merge1.sav
/FILE=merge2.sav
/BY ResponseId.

SAVE OUTFILE = combinedData.sav.
```

   a. */Users/simonekoek/Documents/Graduation/QNT/SPSS* → This should be replaced by the pathname of the folder you are working in (where you can find the files you exported before)
      i. Lifehack: To find the right path in mac, right click on the file/folder and press 'alt', then it shows 'Copy xx as pathname'
   b. IndividualUtilities.sav → should match the name of the individual utilities file
   c. ResponseID → this should match automatically because this row is produced by Qualtrics
   d. SurveyData.sav → Should match the exported dataset
   e. Check if the combinedData.sav actually is the two files combined, if not:
      i. Check whether the ResponseID in both files are both 'string' and the width is '17', if one of the two is '50', turn that into '17' and run it again, it probably solves the problem.
4. Now the files should be merged!

5. To complete the analysis, I performed Hierarchical Cluster Analysis and Two-Step cluster analysis to determine the amount of clusters. K-means Cluster analysis to make the clusters. Then compared the means by making a means table. Finally I did univariate to seek significant relations

Theresa Wallner explained me how to merge the two data sets so I could analyze them together. I decided to make an instruction manual so other people can use these steps too.

Appendix 7: SPSS output quantitative study

Utility scores of each level of each attribute

Price

Relative Utility Value ⓘ

Level	Value
€199.00	2.2
€299.00	-2.2

Average Level Utility ⓘ

€199.00: 0.3
€299.00: -0.3

Suction power

Relative Utility Value ⓘ

Level	Value
120 W	-3.5
220 W	3.5

Average Level Utility ⓘ

120 W: -1.6
220 W: 1.6

Coating

Relative Utility Value ⓘ

Level	Value
Self-healing	7.5
Not self-healing	-7.5

Average Level Utility ⓘ

Self-healing: 3.3
Not self-healing: -3.3

Spare part

Relative Utility Value ⓘ

Level	Value
5 years availability	-14.2
10 years availability	14.2

Average Level Utility ⓘ

5 years availability: -6.4
10 years availability: 6.4

Maintenance

Relative Utility Value ⓘ

With indicator	7.1
Without indicator	-7.1

-5　　　0　　　5

Average Level Utility ⓘ

With indicator: 3.3
Without indicator: -3.3

2
0
-2

Warranty

Relative Utility Value ⓘ

3 years	-12.5
5 years	12.5

-10　　-5　　0　　5　　10

Average Level Utility ⓘ

3 years: -5.7
5 years: 5.7

4
2
0
-2
-4

Brand

Relative Utility Value ⓘ

AEG	-2.9
Miele	2.9

-2　　　0　　　2

Average Level Utility ⓘ

AEG: -1.1
Miele: 1.1

1
0.5
0
-0.5
-1

Hierarchical Cluster Analysis

K-means for 3 clusters

Dendrogram using Average Linkage (Between Groups)
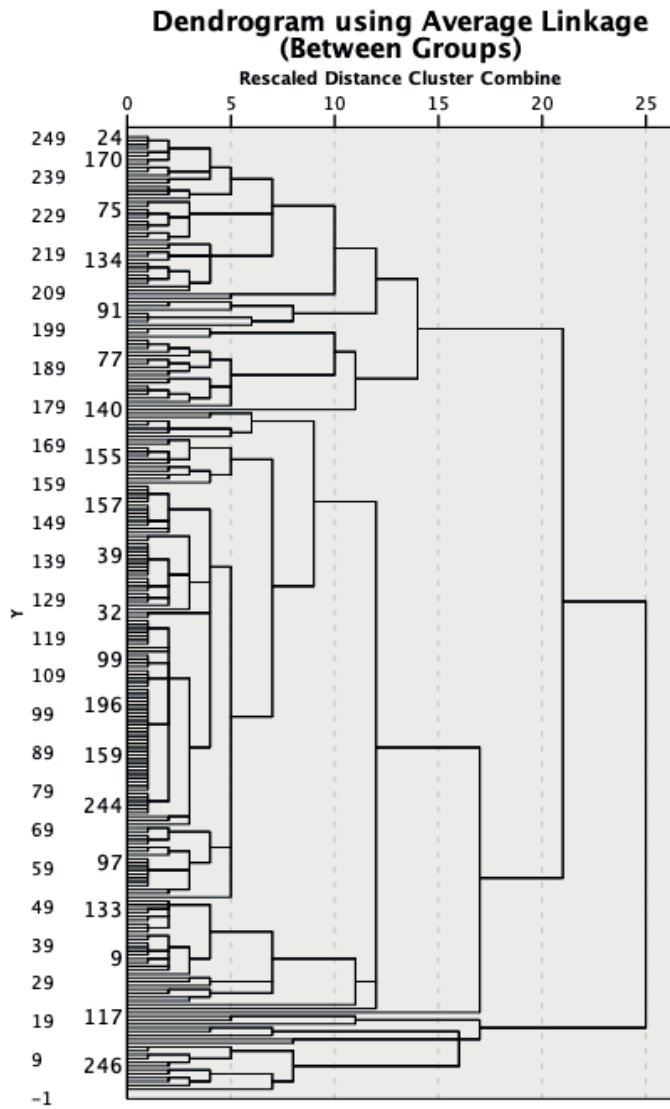
Number of Cases in each Cluster

Cluster	1	69.000
	2	30.000
	3	150.000
Valid		249.000
Missing		.000

Two-Step Cluster Analysis:
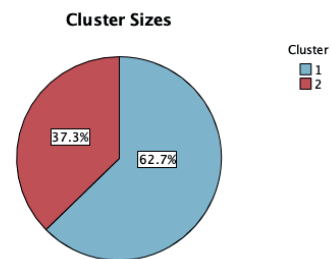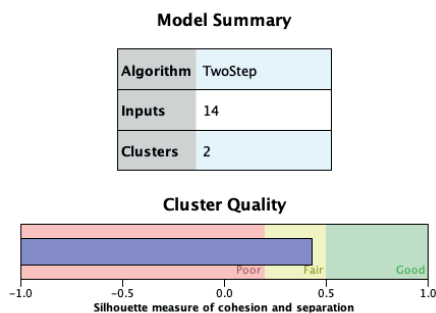
Model Summary

Algorithm	TwoStep
Inputs	14
Clusters	2

Cluster Quality

Silhouette measure of cohesion and separation

Cluster Sizes

Size of Smallest Cluster	93 (37.3%)
Size of Largest Cluster	156 (62.7%)
Ratio of Sizes: Largest Cluster to Smallest Cluster	1.68

Correlations

		Brand_1	Warranty_1	Prijs_1	Power_1
Brand_1	Pearson Correlation	1	.099	-.647**	.309**
	Sig. (2-tailed)		.121	.000	.000
	N	249	249	249	249
Warranty_1	Pearson Correlation	.099	1	.003	.352**
	Sig. (2-tailed)	.121		.966	.000
	N	249	249	249	249
Prijs_1	Pearson Correlation	-.647**	.003	1	-.109
	Sig. (2-tailed)	.000	.966		.086
	N	249	249	249	249
Power_1	Pearson Correlation	.309**	.352**	-.109	1
	Sig. (2-tailed)	.000	.000	.086	
	N	249	249	249	249
Healing_1	Pearson Correlation	.192**	.724**	-.091	.242**
	Sig. (2-tailed)	.002	.000	.152	.000
	N	249	249	249	249
Spare_1	Pearson Correlation	.469**	.338**	-.501**	.212**
	Sig. (2-tailed)	.000	.000	.000	.001
	N	249	249	249	249
Care_1	Pearson Correlation	.234**	.770**	-.180**	.359**
	Sig. (2-tailed)	.000	.000	.004	.000
	N	249	249	249	249
Care	Pearson Correlation	-.115	.062	.137*	.010
	Sig. (2-tailed)	.071	.333	.030	.877
	N	249	249	249	249
EnvironmentalConcern	Pearson Correlation	-.057	.005	.025	-.101
	Sig. (2-tailed)	.372	.934	.691	.113
	N	249	249	249	249
RepairExperience	Pearson Correlation	-.169**	-.059	.157*	-.073
	Sig. (2-tailed)	.007	.355	.013	.251
	N	249	249	249	249
Innovativeness	Pearson Correlation	-.089	.008	.071	-.003
	Sig. (2-tailed)	.160	.902	.266	.966
	N	249	249	249	249

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Healing_1	Spare_1	Care_1	Care	EnvironmentalConcern	RepairExperience	Innovativeness
.192**	.469**	.234**	−.115	−.057	−.169**	−.089
.002	.000	.000	.071	.372	.007	.160
249	249	249	249	249	249	249
.724**	.338**	.770**	.062	.005	−.059	.008
.000	.000	.000	.333	.934	.355	.902
249	249	249	249	249	249	249
−.091	−.501**	−.180**	.137*	.025	.157*	.071
.152	.000	.004	.030	.691	.013	.266
249	249	249	249	249	249	249
.242**	.212**	.359**	.010	−.101	−.073	−.003
.000	.001	.000	.877	.113	.251	.966
249	249	249	249	249	249	249
1	.240**	.442**	.051	.031	−.095	−.045
	.000	.000	.427	.626	.133	.481
249	249	249	249	249	249	249
.240**	1	.108	−.104	−.048	−.090	.050
.000		.089	.100	.451	.155	.432
249	249	249	249	249	249	249
.442**	.108	1	.015	−.003	−.046	−.032
.000	.089		.819	.962	.473	.618
249	249	249	249	249	249	249
.051	−.104	.015	1	.115	.602**	.291**
.427	.100	.819		.071	.000	.000
249	249	249	249	249	249	249
.031	−.048	−.003	.115	1	.153*	.042
.626	.451	.962	.071		.016	.512
249	249	249	249	249	249	249
−.095	−.090	−.046	.602**	.153*	1	.465**
.133	.155	.473	.000	.016		.000
249	249	249	249	249	249	249
−.045	.050	−.032	.291**	.042	.465**	1
.481	.432	.618	.000	.512	.000	
249	249	249	249	249	249	249

Means table for 3 clusters:

Report

Cluster Number of Case		Brand_1	Brand_2	Warranty_1	Warranty_2	Prijs_1	Prijs_2	Power_1	Power_2
1	Mean	-.9180726	.9180726	-2.4465978	2.4465978	.0357562	-.0357562	-1.6171883	1.6171883
	N	69	69	69	69	69	69	69	69
	Std. Deviation	1.33722087	1.33722087	2.00474438	2.00474438	1.49323110	1.49323110	.51029630	.51029630
2	Mean	-.2909790	.2909790	-7.5562687	7.5562687	-1.0580010	1.0580010	-1.8614840	1.8614840
	N	30	30	30	30	30	30	30	30
	Std. Deviation	1.57396030	1.57396030	2.18016102	2.18016102	1.78719381	1.78719381	.54670996	.54670996
3	Mean	-1.6884349	1.6884349	-7.5367799	7.5367799	.6114381	-.6114381	-1.9203232	1.9203232
	N	150	150	150	150	150	150	150	150
	Std. Deviation	1.01002449	1.01002449	1.65905876	1.65905876	1.14408616	1.14408616	.30982800	.30982800
Total	Mean	-1.3065929	1.3065929	-6.1285956	6.1285956	.2507746	-.2507746	-1.8292329	1.8292329
	N	249	249	249	249	249	249	249	249
	Std. Deviation	1.28369171	1.28369171	2.92051026	2.92051026	1.43876304	1.43876304	.42623869	.42623869

Means table for 4 clusters:

Report

Cluster Number of Case		Brand_1	Brand_2	Warranty_1	Warranty_2	Prijs_1	Prijs_2	Power_1	Power_2
1	Mean	-1.2505750	1.2505750	-9.4220470	9.4220470	.0058223	-.0058223	-2.0062725	2.0062725
	N	56	56	56	56	56	56	56	56
	Std. Deviation	1.07859475	1.07859475	1.13972519	1.13972519	1.17398052	1.17398052	.38799167	.38799167
2	Mean	-.8579379	.8579379	-2.0859821	2.0859821	.0618011	-.0618011	-1.5922921	1.5922921
	N	56	56	56	56	56	56	56	56
	Std. Deviation	1.28742641	1.28742641	2.00233928	2.00233928	1.48120024	1.48120024	.53040025	.53040025
3	Mean	-1.7775574	1.7775574	-6.5785592	6.5785592	.7682458	-.7682458	-1.8726562	1.8726562
	N	117	117	117	117	117	117	117	117
	Std. Deviation	1.04326121	1.04326121	1.34913679	1.34913679	1.12852376	1.12852376	.29205943	.29205943
4	Mean	.0354655	-.0354655	-5.5939620	5.5939620	-1.5614400	1.5614400	-1.7429300	1.7429300
	N	20	20	20	20	20	20	20	20
	Std. Deviation	1.68349413	1.68349413	1.77953561	1.77953561	1.87495573	1.87495573	.56850500	.56850500
Total	Mean	-1.3065929	1.3065929	-6.1285956	6.1285956	.2507746	-.2507746	-1.8292329	1.8292329
	N	249	249	249	249	249	249	249	249
	Std. Deviation	1.28369171	1.28369171	2.92051026	2.92051026	1.43876304	1.43876304	.42623869	.42623869

Means table for 2 clusters:

Report

Cluster Number of Case		Brand_1	Brand_2	Warranty_1	Warranty_2	Prijs_1	Prijs_2	Power_1	Power_2
1	Mean	-.7377491	.7377491	-3.0096394	3.0096394	-.2894241	.2894241	-1.6436821	1.6436821
	N	80	80	80	80	80	80	80	80
	Std. Deviation	1.42104009	1.42104009	2.35723096	2.35723096	1.69898277	1.69898277	.53173739	.53173739
2	Mean	-1.5758680	1.5758680	-7.6050246	7.6050246	.5064899	-.5064899	-1.9170676	1.9170676
	N	169	169	169	169	169	169	169	169
	Std. Deviation	1.12069451	1.12069451	1.77565445	1.77565445	1.22215827	1.22215827	.33328737	.33328737
Total	Mean	-1.3065929	1.3065929	-6.1285956	6.1285956	.2507746	-.2507746	-1.8292329	1.8292329
	N	249	249	249	249	249	249	249	249
	Std. Deviation	1.28369171	1.28369171	2.92051026	2.92051026	1.43876304	1.43876304	.42623869	.42623869

Healing_1	Healing_2	Spare_1	Spare_2	Care_1	Care_2	Care	Environment alConcern	RepairExperi ence	Innovativenes s
6.1456839	−6.1456839	−5.0541081	5.0541081	4.8781842	−4.8781842	4.0750	4.7920	3.4928	4.7717
69	69	69	69	69	69	69	69	69	69
1.73226679	1.73226679	2.54482625	2.54482625	1.04656239	1.04656239	1.28692	1.27474	1.41694	1.09644
1.7656783	−1.7656783	−2.4600310	2.4600310	2.7393067	−2.7393067	3.5733	4.5333	3.3222	4.9113
30	30	30	30	30	30	30	30	30	30
2.66638832	2.66638832	2.87892195	2.87892195	1.17918044	1.17918044	1.42899	.96036	1.72259	1.16997
2.6582903	−2.6582903	−8.7017737	8.7017737	3.2172705	−3.2172705	4.0567	4.8933	3.8000	4.7275
150	150	150	150	150	150	150	150	150	150
1.69277651	1.69277651	1.44998653	1.44998653	.93559146	.93559146	1.25326	1.34886	1.53519	1.20950
3.5171329	−3.5171329	−6.9389576	6.9389576	3.6199377	−3.6199377	4.0035	4.8219	3.6573	4.7619
249	249	249	249	249	249	249	249	249	249
2.47291632	2.47291632	3.05004412	3.05004412	1.27325780	1.27325780	1.28921	1.28838	1.53196	1.17135

Healing_1	Healing_2	Spare_1	Spare_2	Care_1	Care_2	Care	Environment alConcern	RepairExperi ence	Innovativenes s
.9690150	−.9690150	−6.8507846	6.8507846	2.4053377	−2.4053377	3.9607	4.8786	3.5446	4.7589
56	56	56	56	56	56	56	56	56	56
1.83647022	1.83647022	1.84395357	1.84395357	1.00455476	1.00455476	1.17112	1.23328	1.47350	1.06597
6.3386496	−6.3386496	−4.8879627	4.8879627	4.9600807	−4.9600807	4.0584	4.7866	3.3988	4.7835
56	56	56	56	56	56	56	56	56	56
1.72186537	1.72186537	2.20842729	2.20842729	1.06454891	1.06454891	1.29057	1.30435	1.44868	1.04759
3.3926204	−3.3926204	−9.0335283	9.0335283	3.6150864	−3.6150864	4.0667	4.8496	3.8405	4.7126
117	117	117	117	117	117	117	117	117	117
1.43853727	1.43853727	1.31068048	1.31068048	.73693697	.73693697	1.29555	1.37738	1.55432	1.28792
3.4800135	−3.4800135	−.6753890	.6753890	3.2967975	−3.2967975	3.6000	4.6000	3.6250	4.9982
20	20	20	20	20	20	20	20	20	20
2.47866580	2.47866580	2.49847040	2.49847040	1.37544376	1.37544376	1.56373	.82844	1.75542	1.11385
3.5171329	−3.5171329	−6.9389576	6.9389576	3.6199377	−3.6199377	4.0035	4.8219	3.6573	4.7619
249	249	249	249	249	249	249	249	249	249
2.47291632	2.47291632	3.05004412	3.05004412	1.27325780	1.27325780	1.28921	1.28838	1.53196	1.17135

Healing_1	Healing_2	Spare_1	Spare_2	Care_1	Care_2	Care	Environment alConcern	RepairExperi ence	Innovativenes s
5.7113954	−5.7113954	−4.0922218	4.0922218	4.5249688	−4.5249688	3.9709	4.7406	3.4479	4.7813
80	80	80	80	80	80	80	80	80	80
2.12229543	2.12229543	3.05648673	3.05648673	1.33446495	1.33446495	1.33070	1.21186	1.49415	1.08363
2.4784287	−2.4784287	−8.2865249	8.2865249	3.1915207	−3.1915207	4.0189	4.8604	3.7564	4.7527
169	169	169	169	169	169	169	169	169	169
1.87916687	1.87916687	1.91151606	1.91151606	.99050882	.99050882	1.27284	1.32482	1.54400	1.21366
3.5171329	−3.5171329	−6.9389576	6.9389576	3.6199377	−3.6199377	4.0035	4.8219	3.6573	4.7619
249	249	249	249	249	249	249	249	249	249
2.47291632	2.47291632	3.05004412	3.05004412	1.27325780	1.27325780	1.28921	1.28838	1.53196	1.17135

Care scale:

Tests of Between-Subjects Effects

Dependent Variable: Care

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	6.328[a]	2	3.164	1.918	.149
Intercept	2514.207	1	2514.207	1523.887	.000
QCL_3	6.328	2	3.164	1.918	.149
Error	405.867	246	1.650		
Total	4403.175	249			
Corrected Total	412.194	248			

a. R Squared = ,015 (Adjusted R Squared = ,007)

Multiple Comparisons

Dependent Variable: Care
Bonferroni

(I) Cluster Number of Case	(J) Cluster Number of Case	Mean Difference (I–J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	.5016	.28090	.226	-.1755	1.1787
	3	.0183	.18684	1.000	-.4321	.4687
2	1	-.5016	.28090	.226	-1.1787	.1755
	3	-.4833	.25689	.183	-1.1026	.1359
3	1	-.0183	.18684	1.000	-.4687	.4321
	2	.4833	.25689	.183	-.1359	1.1026

Based on observed means.
The error term is Mean Square(Error) = 1,650.

Environmental concern scale:

Tests of Between-Subjects Effects

Dependent Variable: EnvironmentalConcern

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.325[a]	2	1.663	1.002	.369
Intercept	3710.059	1	3710.059	2235.095	.000
QCL_3	3.325	2	1.663	1.002	.369
Error	408.338	246	1.660		
Total	6201.062	249			
Corrected Total	411.663	248			

a. R Squared = ,008 (Adjusted R Squared = ,000)

Multiple Comparisons

Dependent Variable: EnvironmentalConcern
Bonferroni

(I) Cluster Number of Case	(J) Cluster Number of Case	Mean Difference (I–J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	.2587	.28176	1.000	-.4205	.9379
	3	-.1013	.18741	1.000	-.5531	.3504
2	1	-.2587	.28176	1.000	-.9379	.4205
	3	-.3600	.25768	.491	-.9811	.2611
3	1	.1013	.18741	1.000	-.3504	.5531
	2	.3600	.25768	.491	-.2611	.9811

Based on observed means.
The error term is Mean Square(Error) = 1,660.

Repair experience scale:

Tests of Between–Subjects Effects

Dependent Variable: RepairExperience

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8.291[a]	2	4.146	1.777	.171
Intercept	2067.756	1	2067.756	886.579	.000
QCL_3	8.291	2	4.146	1.777	.171
Error	573.743	246	2.332		
Total	3912.611	249			
Corrected Total	582.034	248			

a. R Squared = ,014 (Adjusted R Squared = ,006)

Multiple Comparisons

Dependent Variable: RepairExperience

Bonferroni

(I) Cluster Number of Case	(J) Cluster Number of Case	Mean Difference (I–J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	.1705	.33398	1.000	−.6345	.9756
	3	−.3072	.22215	.504	−.8427	.2282
2	1	−.1705	.33398	1.000	−.9756	.6345
	3	−.4778	.30544	.357	−1.2140	.2585
3	1	.3072	.22215	.504	−.2282	.8427
	2	.4778	.30544	.357	−.2585	1.2140

Based on observed means.
 The error term is Mean Square(Error) = 2,332.

Environmental concern scale:

Tests of Between–Subjects Effects

Dependent Variable: Innovativeness

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.854[a]	2	.427	.309	.734
Intercept	3810.854	1	3810.854	2762.012	.000
QCL_3	.854	2	.427	.309	.734
Error	339.416	246	1.380		
Total	5986.528	249			
Corrected Total	340.270	248			

a. R Squared = ,003 (Adjusted R Squared = -,006)

Multiple Comparisons

Dependent Variable: Innovativeness

Bonferroni

(I) Cluster Number of Case	(J) Cluster Number of Case	Mean Difference (I–J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	−.1396	.25688	1.000	−.7588	.4796
	3	.0442	.17086	1.000	−.3676	.4561
2	1	.1396	.25688	1.000	−.4796	.7588
	3	.1838	.23492	1.000	−.3825	.7501
3	1	−.0442	.17086	1.000	−.4561	.3676
	2	−.1838	.23492	1.000	−.7501	.3825

Based on observed means.
 The error term is Mean Square(Error) = 1,380.