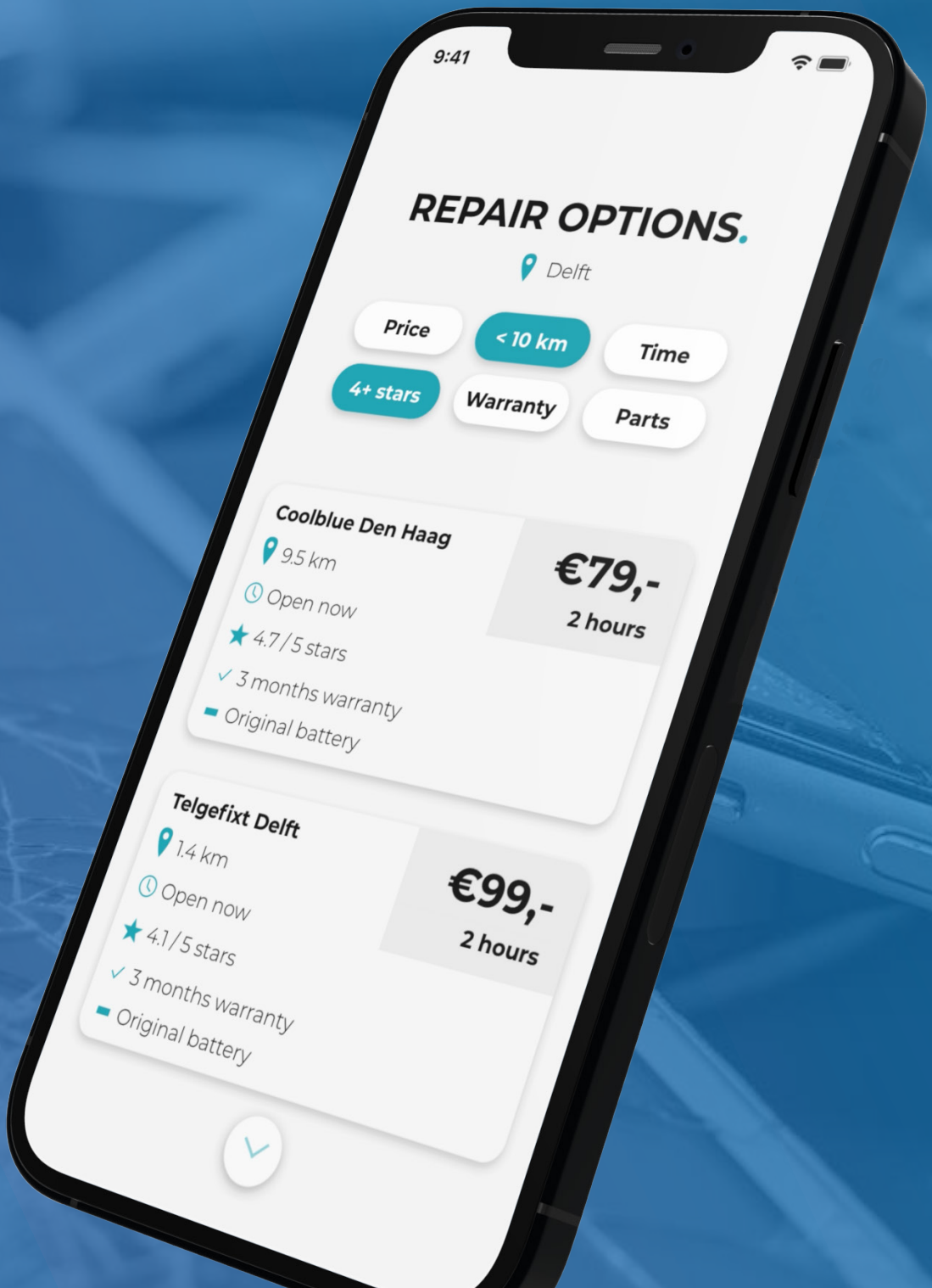
Repairable smartphones

Developing a Product-Service System that stimulates consumers to choose for repair over replacement

Louise Platell



TU Delft

Repairable smartphones

Developing a Product-Service System that stimulates consumers to choose for repair over replacement

Louise Platell

TU Delft

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I. Abstract

The increasing global need for environmental preservation calls for new methods to increase the material efficiency of products. One way to do this, is by extending the use cycle of a product, by making the product more repairable. This thesis has studied existing use cycle extension strategies to propose a new smartphone Product-Service System that stimulates consumers to choose for repair over replacement. The developed Product-Service System is a smartphone application. This application is provided to the user for free, and helps him to perform failure diagnosis, failure solution and failure prevention of the smartphone.

The main objective of this research has been to develop a smartphone Product-Service System that stimulates consumers to choose for repair over replacement. I have developed the app based on a literature review, consumer interviews, expert interviews, design iterations, and user tests. Literature review, consumer interviews, and expert interviews have provided insight into a way to assess the repairability of smartphones, as well as existing strategies that increase repairability. Based on the provided insights, I developed several directions for a possible Product-Service System to take shape. Based on consumer input, the most promising direction was chosen, after which the final concept has been developed in two main iterations, including a user test. Finally, I have shown that the app does not only seem to contribute to use cycle extension, but that it also fulfils consumers' needs and preferences, is economically sustainable, and is feasible for any business to achieve.

This thesis has two main contributions. First of all, the developed repairability scoring system can be applied in both academia and businesses to rate a product's repairability. In this thesis, the framework has only been applied to smartphones, but its theoretical background allows it to be applied to any other electronic product as well. Secondly, I have shown that the developed app poses an interesting business opportunity, and that it can be applied in practice by anyone who is willing to take up the development of the app.

II. Abbreviations and definitions

B2C	Business-to-Consumer: The business of selling products directly to consumers, without intermediaries.
Obsolescence	The state of a product in which it is no longer used.
OEM	Original Equipment Manufacturer: The manufacturer of product parts that are to be assembled by another party.
PSS	Product-Service System: "A mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs" (Tukker & Tischner, 2006, p.1552).
Repair	"The process of returning a faulty product to a condition where it can fulfil its intended use" (Cordella et al., 2020a, p.3).
Replacement	The process of obtaining a substitute for an obsolete product.
Smartphone	"A mobile phone that performs many of the functions of a computer, typically having a touchscreen interface, internet access, and an operating system capable of running downloaded apps." (Lexico, n.d.)
TBL	Triple Bottom Line: The equal consideration of economic, environmental and social factors for implementing business decisions (Elkington, 1997).
Use cycle	"The duration of the period that starts at the moment a product is released for use after manufacture or recovery and ends at the moment a product becomes obsolete." (Den Hollander et al., 2017, p.519)
Desirability	The extent to which a design outcome "meets the needs and wishes of people." (Calabretta et al., 2016, p.10)
Feasibility	The extent to which a design outcome "can be given tangible or concrete form in the present, or in the foreseeable future, with the resources – technology, processes, and people – available." (Calabretta et al., 2016, p.11)
Viability	The extent to which a design outcome "can be sustained within the organization effectively enough to generate value in terms of relevant key performance indicators – profit, brand equity, triple bottom line, customer satisfaction – over the medium to long term." (Calabretta et al., 2016, p.11)

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1. Introduction

Over the last five years, an average of 1,5 billion smartphones have been sold on the worldwide market each year (Statista, 2021). The production of smartphones has significant effects on the global environment, such as raw material depletion and greenhouse gas emissions (Cordella et al., 2020a). In order to protect the environment from these effects, the efficiency of raw materials should be maximized by extending their useful lives. One strategy is to recycle the materials at the end of the smartphone's use cycle. However, this is not optimal because at least 10% of these materials are lost per cycle (Bracquené et al., 2021). With an average weight of a smartphone being 160 grams, this means that at least an estimated 24 million kilograms of raw materials would be lost each year, when every smartphone buyer hands his obsolete phone back in for recycling.

1,5 billion

smartphones being sold each year

24 million kg

wasted raw materials each year when all obsolete smartphones are recycled

This scenario is too optimistic, however, as studies indicate that about half of all obsolete smartphones are kept unused at home instead of being recycled (Cordella et al., 2020b). Therefore, extending the use cycle of a smartphone, and thus postponing recycling practices, is a more promising strategy to increase material efficiency (Cordella et al., 2020a). One of the use cycle extension strategies is increasing a smartphone's repairability, which is supported by the "right to repair" movement of the European Parliament (2020). Currently, consumers are not stimulated to choose for repair, because repair has many perceived obstacles that often make replacement of the smartphone a more attractive option. By understanding the reasons consumers have for not repairing their smartphone, this thesis tries to find an answer to the following research question: *How can consumers be stimulated to choose for repair of their smartphone over replacement?*

Problem statement

Studies show varied results when it comes to the average use cycle of a smartphone, but most sources argue that it is around two years (e.g., Consumentenbond, 2016; Cordella et al., 2020b). Although use cycles have been extending over the last few years, Cordella et al. (2020b) argue that current smartphones already have the potential of a five-year lifespan, leaving three years of unused potential. There is little data available that describes what the most significant contributing factors of smartphone replacements are, but it is possible to make a rough estimation based on a statement by Haines-Gadd et al. (2018). They stated that a quarter of electrical products are replaced because of a failure, whilst the majority (three-quarters) is replaced because the consumer

3 years

gap between average and potential lifetime of smartphones

375 million

smartphones to be saved by repair each year

wants to have a better device. This implies that each year, the lifetime of at least 375 million smartphones could be extended by making them more repairable. However, it also implies that over 1,1 billion smartphones are replaced every year for reasons that cannot be solved by repair. Although repairability is relevant for a large number of smartphones, this study needs to focus on more than repair alone, because users need to be satisfied with their functional smartphone for longer.

Research objective

This thesis has one main objective, which is to develop a smartphone Product-Service System (PSS) that stimulates consumers to choose for repair over replacement. The reason that I focus on a PSS rather than a product or service alone, is because PSSs are regarded by many scholars to hold more potential in achieving the triple bottom line (TBL) of business. In other words, PSSs can be relatively more sustainable than singular products and services, from an economic, societal and environmental point of view (Khan et al., 2018). However, PSSs do not provide a guaranteed road to success in this regard, because there is an abundance of PSS examples that disregard one or two TBL aspects, where the focus is often too much on the economic aspect (Bansal, 2002). For the design of a PSS in this thesis, it is therefore important to pay attention to all aspects of the triple bottom line and avoid pitfalls that previous PSSs have encountered. In order to reach the main objective, there are three sub objectives to be achieved.

- **RO-1**: To understand why consumers choose for smartphone repair or replacement.
- **RO-2**: To understand what solutions are effective in stimulating repair over replacement.
- **RO-3**: To understand to what extent current smartphone offerings stimulate repair over replacement.

Research position

By reaching the stated research objectives, this thesis demonstrates several aspects. First of all, it shows why consumers are currently not stimulated to choose for repair but are instead stimulated to choose for replacement. Secondly, the findings show a variety of strategies that could stimulate repair among consumers. And thirdly, this thesis demonstrates what strategy is expected to have a significant effect on repair behavior, which could be implemented in the future. These findings can be used by academic researchers to understand repair and replacement behavior of smartphone users. Furthermore, decision makers in businesses can implement the strategies that are mentioned in this thesis, and policy makers can use this as input for future regulations. Lastly, consumers associations can use the findings of this thesis to inform consumers how to use their smartphone for as long as possible.

Content overview

This thesis consists of a research part and a design part. The research part focusses on sub objectives 1, 2 and 3, while the design part focusses on the main objective. In the research part, I conduct a literature review, consumer interviews, expert interviews, and market analysis. The research methodology is discussed in Chapter 2. The focus of Chapter 3 is understanding the problem (RO-1), while the focus of Chapter 4 is understanding possible solutions (RO-2). Chapter 5 consists of a market analysis of the current state of businesses and technologies related to smartphone repair (RO-3). In the design part, I conduct ideation, concept creation, concept development, and final concept design. Chapter 6 discusses the design methodology. In Chapter 7, I show the results of this methodology, that serve to achieve the main research objective. In chapter 8, I discuss what answer the findings provide for the research question, and what implications this has for academia and business. Chapter 9 concludes this thesis with a final answer to the research question and reflections on this, including limitations and recommendations for future research.

2. Research methodology

In the research part of this thesis, I focus on the three sub objectives as stated in the introduction. For each objective, I have developed several research questions. In order to answer these questions, I implement a theoretical framework from which the consumer's decision to choose for repair can be studied. I apply this framework in a literature review, consumer interviews, expert interviews, and market analysis. The research findings serve as input for the design part of this thesis, which is further addressed in Chapter 6.

Theoretical framework

To first understand why consumers replace or repair their smartphone, and to later test to what extent my developed solution stimulates consumers to repair, I implement a framework of factors that determine the attractiveness of smartphone repair for consumers. I take this framework from the central design methodology within the Faculty of Industrial Design Engineering at TU Delft. According to this methodology, a strategic designer should consider the extent to which a design outcome "fits the needs and wishes of people (desirability), the assets and processes of the company (feasibility), and the performance objectives of the company" (Calabretta et al., 2016, p.10). The central questions to be asked are thus whether a design outcome is what the consumer wants, what the company can provide, and what makes its costs worth it for the company (see Figure 2.1). By considering all three aspects, the designer is able to provide a design outcome that is relevant to both the consumer and the company. The aspects partly overlap each other. For instance, the extent to which consumers want to own the latest smartphone (desirability) influences the prospective sales of a new smartphone and thus the profit to be made (viability). It is the spot where all three aspects overlap that the designer should focus on. In the design part of this thesis, I will follow this approach in order to create a relevant outcome.

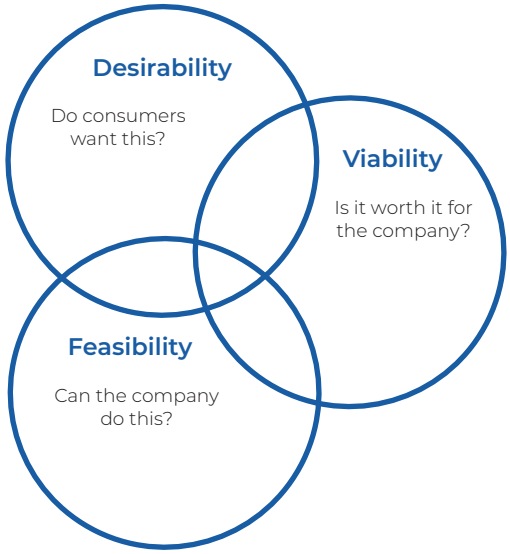


Figure 2.1: Strategic design principles (based on Calabretta et al., 2016).

In the research part of this thesis, I apply the framework not to the overarching question whether a design outcome is relevant, but whether repair is attractive for consumers. To determine the attractiveness of repair, I look at its desirability, feasibility, and viability for the consumer. By adapting the definitions of the three aspects by Calabretta et al. (2016), I have developed working definitions for repair desirability, repair feasibility, and repair viability (see Table 2.2). I define repair desirability as the extent to which smartphone repair meets the consumer's needs and wishes. Repair feasibility is the extent to which repair is

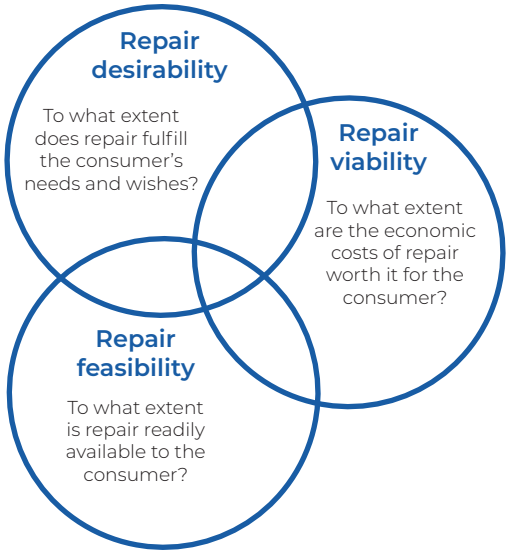


Figure 2.2: Repair principles (adapted from Calabretta et al., 2016).

readily available to the consumer. Repair viability is the extent to which the economic costs of repair are worth it for the consumer. Thus, an attractive repair strategy fulfills the consumer's needs and wishes, is readily available to the consumer and is worth the economic costs from the consumer's point of view.

Sub questions

The problem exploration of this thesis focusses on RO-1: to understand why consumers choose for smartphone repair or replacement. In order to reach this objective, I first study for what reasons smartphones become obsolete (see Table 2.3). The framework of repair desirability, feasibility and viability is then used to understand what role repair plays in obsolescence. The answers to these two questions serve as input for the solution exploration. The solution exploration focusses on RO-2: to understand what solutions are effective in stimulating repair over replacement. I first use the discussed framework to study what solutions have been proposed for stimulating consumers to choose for repair over replacement. Then, I study what role a PSS can possibly play in stimulating repair. Finally, the market analysis focusses on RO-3: to understand to what extent current smartphone offerings stimulate repair over replacement. I first conduct a repairability analysis of the offerings by smartphone manufacturers, as well as an analysis of their additional product/service offerings. Then, I study the repairability of product/service offerings by smartphone retailers and other repair parties.

Theme	*Sub questions*
Problem exploration	- What makes smartphones obsolete for consumers? - What role does repair play in obsolescence?
Solution exploration	- What solutions exist to stimulate consumers to choose for repair? - What role can PSSs play in stimulating repair?
Market analysis	- How do manufacturers stimulate repair? - How do retailers stimulate repair? - How do other repair parties stimulate repair?

Table 2.3: Sub research questions per theme.

Literature review

I have conducted a literature review for both problem exploration and solution exploration. The goal of this literature review is to compare existing academic literature and subsequently draw conclusions to answer the sub research questions. I have used keywords of the sub questions to search for relevant literature in scholarly databases, such as 'smartphone obsolescence' in Google Scholar. Because literature on the obsolescence and repair of smartphones specifically is scarce, I have also included literature that studies obsolescence and repair of other products. The consumer and expert interviews then serve to test whether the knowledge gained from these studies is applicable to smartphones.

Consumer interviews

In order to contextualize my findings from the literature review, I performed interviews with five consumers (see Table 2.4). The participants have been found through convenience sampling whilst ensuring to include a variety of age groups. Admittedly, the sampling method does not allow for a sample that is representative of the entire population of smartphone users, but the sample remains adequate because representativeness is not the aim of the interviews. Rather, the aim is to contextualize findings from the literature review, which are based on studies that were already proven to be representative of larger populations. It must be noted that academically educated consumers, as well as females are over represented in this sample, which makes that the findings might be biased towards these groups of consumers.

In order to study the factors that play a role in the participants' decision to replace or repair their smartphone, and their opinions about possible repair solutions, I developed

	*Sophia**	*Anna*	*Ron*	*Isabella*	*Emma*
Gender	Female	Female	Male	Female	Female
Age	17	25	26	45	59
Occupation	Student	Student	Employed	Employed	Unemployed
Smartphone					
Model	iPhone 11	Samsung J5	OnePlus 5t	iPhone 8	iPhone X
Age	1 year	4 years	3 years	2 years	2-3 years
Purchase price	€600	€200	€400	24 * €20	€1000

*Table 2.4: Overview of interview participants. *The provided names are fictional, in order to ensure full anonymity.*

a semi-structured interview guide (see Appendix A). In the first three parts of the interview, participants were stimulated to talk about the positive and negative experiences they have had with their current and previous smartphones. In the fourth part, I introduced several hypothetical scenarios of physical obsolescence (for more information on physical obsolescence, see Chapter 3.1), and allowed the participants to imagine how they would react to such a scenario. The final part zooms in on the participants' opinions about smartphone PSSs, with the focus on leasing, insurances, and repairable designs.

After the interviews had been conducted, I transcribed the audio files and used the grounded theory method to apply open codes to the participants' statements. Later, I apply axial coding and selective coding to find the variety of themes that the participants raised. The grounded theory method allowed the findings to emerge from the data (Saldaña, 2013), which I could then apply to the theoretical framework of repair feasibility, viability, and desirability. All interviews were held in Dutch, which means that the quotes as discussed in Chapter 3 and 4 are translated from Dutch to English by me.

Expert interviews

In addition to the consumer interviews, I also performed two expert interviews to further contextualize the findings from the literature review and consumer interviews (see Table 2.5). Both experts have been contacted through the PROMPT project of which the Faculty of Industrial Design Engineering at TU Delft is part. The Premature Obsolescence Multi-Stakeholder Product Testing Programme is an independent testing programme that is funded by the European Union and assesses the lifetime of consumer products, including smartphones (PROMPT, n.d.). One of the experts is Peter, who works at iFixit, where he studies how to measure the repairability of electrical products. On behalf of iFixit, Peter also lobbies at the European Union to promote regulations for increasing repairability. iFixit is an American-based company with offices in Europe. It hosts a website that helps consumers to repair products on their own, by offering equipment, spare parts, and manuals, the latest of which are provided by both iFixit employees and community members (iFixit, n.d.-a). The second expert is Edward, who works at the Dutch consumers association, Consumentenbond, where he is an expert on smartphones and refurbishment. The Consumentenbond is an independent association without profit motives that tries to make products safer and fairer (Consumentenbond, n.d.).

	*Peter**	*Edward*
Company	iFixit	Consumentenbond
Country	Belgium	the Netherlands
Job position	Researcher of repair and lobbyer at the EU	Researcher of smartphones and refurbishment

*Table 2.5: Overview of interviewed experts. *The provided names are fictional, in order to ensure full anonymity.*

Market analysis

In order to study the current landscape of smartphone repair, a number of case studies have been chosen for market analysis (see Table 2.6). I have included the three most popular smartphone manufacturers, as well as two exemplary ones in terms of repair. The most popular smartphone brands in the Netherlands include Apple (38,7%), Samsung (38,5%), and Huawei (7,0%), as they account for 84% of all smartphones that have been sold on the Dutch market over the last five years (GlobalStats, 2021). None of these brands produce phones that can be considered 'easy' to repair by the standards of iFixit (n.d.-c), i.e., the most recent models of all three brands

Manufacturer	*Model*
Apple	iPhone 12 Pro Max
Samsung	Galaxy S20 Ultra
Huawei	Mate 40 Pro
Fairphone	Fairphone 3+
Shift	Shift 6m

Table 2.6: Overview of smartphone model case studies.

received a repairability score lower than 8 out of 10. There are other brands that do offer repairable smartphones. Google, Lenovo, LG, Puzzlephone, and Phonebloks abandoned their modular smartphone projects (One Army, n.d.), but Fairphone and Shift are still offering modular smartphones today. These two brands are therefore included in the analysis as well. To study the repairability of the smartphones, I chose each brand's 2020 top model. Note that this excludes the Samsung S21 from 2021, as the amount of available information about it is scarce. Also, Shift's most recent phone was released in 2018, which only allowed me to include this one.

In addition to smartphone manufacturers, consumers can also purchase smartphones at electronics retailers and mobile service providers (see Table 2.7). I consulted Tweakers, an independent platform that compares electrical products, to find out what the most popular retailers are that sell the top models of Apple, Samsung, and Huawei. I only included those retailers that operate in the B2C market and received more than 100 reviews on the platform (Tweakers, n.d.). This allowed me to include Bol, Coolblue, MediaMarkt, Mobiel, Belsimpel, and Azerty in the analysis. For exemplary case studies, I looked at Swapphone and Commown, because these retailers are unique in providing smartphone leasing plans. I also analyzed the nine most popular mobile service providers, as defined by the Consumentenbond (Vrijdag, 2021), including Simyo, Simpel, Hollandsnieuwe, Youfone, Ben, KPN, T-mobile, Vodafone, and Tele2.

For the other repair options, I included iFixit, which helps consumers to repair their smartphone on their own by offering manuals, equipment and spare parts. I also included other repair options that are available in the municipality of Delft, being GSM Paradise Delft, Telgefixt Delft, and Repair Café Delft. Admittedly, Delft cannot be regarded as an average representation of a Dutch municipality, as the number of residents it hosts (i.e., 100.000+) is within the highest 10% of all municipalities in the Netherlands (CBS, 2020). This means that Delft likely has more repair facilities than most Dutch municipalities. However, I found that the repair options in Delft do not differ significantly in terms of price and service time from those that are available in larger and smaller municipalities.

The market analysis consists of two main parts: repairability analysis of the product/service offerings, and analysis of other relevant product/service offerings. For the offerings that are specifically related to repair, I apply the repairability framework of Chapter 3.2, apart from the desirability aspect. The desirability aspect is excluded, because only little objective data is available about it, which makes it irrelevant to compare these aspects in a relatively small market analysis. However, for future research, I recommend to study smartphone repair by using the entire framework, because desirability remains one of the most important factors of smartphone repair (Haines-Gadd et al., 2018). For each manufacturer or retailer, I first underwent the entire check-out process of the latest smartphone model, up until the point of purchase, to find out what service options are offered. Then, I consulted the websites' support pages to see what (repair) support services are being offered. I use the French Repairability Index and the iFixit repairability score as a reference to analyze the feasibility and viability of repair.

Manufacturers	*Retailers*	*Mobile service providers*	*Other*
Apple	Bol	Simyo	iFixit
Samsung	Coolblue	Simpel	GSM Paradise Delft
Huawei	MediaMarkt	Hollandsnieuwe	Telgefixt Delft
Fairphone	Mobiel	Youfone	Repair Café Delft
Shift	Belsimpel	Ben	
	Azerty	KPN	
	Swapphone	T-mobile	
	Commown	Vodafone	
		Tele2	

Table 2.7: Overview of business case studies.

3. Problem exploration

As discussed in the introduction, I estimate that the lifetime of approximately a quarter of all obsolete smartphones can be extended by repair. Although this makes up for a significant number of smartphones that can be saved each year, three quarters of all obsolete smartphones cannot be saved by repair alone. Therefore, it is relevant to focus on these other obsolescence reasons in addition to repairable failures, because these seem to play a relatively larger role and may also play a significant role when the consumer is confronted with a repairable failure. In the following sub chapter, I discuss academic literature on the reasons that consumers have for finding their smartphone obsolete. Thereafter, I discuss what role repair plays to reverse obsolescence.

3.1. What makes smartphones obsolete for consumers?

In order to design for the extension of a smartphone's use cycle, it must be understood what causes this use cycle to end. A use cycle begins when the user acquires a product and it ends when the product has become obsolete, which most often leads to the replacement of the product (Den Hollander et al., 2017). Obsolescence has been defined and categorized in many different ways. According to Cooper (2004), Packard was in 1960 the first one who differentiated between different types of obsolescence: function, quality, and desirability. Later studies narrowed this categorization down to two types (e.g., Guiltinan, 2010), expanded it to six types (e.g., Munten et al., 2021), and anything in between (e.g., Kostecki, 1998). Cooper (2010) argued that all of the categorizations that had been made before his time of writing correspond with Packard's but add a fourth type: economic obsolescence. I have identified several studies that have proposed other ways of categorization than these four types (e.g., Burns, 2010; Munten et al., 2021), but in general, Cooper's conclusion still seems to hold. For instance, Proske & Jaeger-Erben (2019) also use these four types in their study of smartphone obsolescence.

In the following paragraphs, I discuss physical, technological, psychological, and economic obsolescence (see Table 3.1) by addressing their definitions, subtypes, examples, and contributing factors. The obsolescence types can be categorized as objective or subjective, and absolute or relative. Objective factors refer to the

Obsolescence type	*Definitions*
Physical obsolescence	A product's loss of its original performance.
Technological obsolescence	A product's loss of its performance relative to other models.
Psychological obsolescence	A decreased fit of a product with a consumer's needs and preferences.
Economic obsolescence	A product's decrease in mental book value relative to the price of keeping it.

Table 3.1: Categorization of obsolescence (by author).

characteristics of a product, while subjective factors refer to the perception a consumer has of these characteristics (Munten et al., 2021). Although objective criteria do play a role, Den Hollander et al. (2017) argued that all types of obsolescence are eventually subjective, because reasons for obsolescence only exist in the consumer's mind. Granberg (1997) used absolute factors to refer to intrinsic characteristics of a product, while relative factors refer to differences between product models. The push and pull factors, as mentioned by Van Nes & Cramer (2005), correspond with absolute and relative factors, respectively.

Physical obsolescence

A product becomes physically obsolete when it has lost a significant share of its original performance, which can either be in terms of functionality, aesthetics or compatibility (see Figure 3.2; Packard, 1960; Guiltinan, 2010; Cooper, 2004; Burns, 2010). Physical obsolescence is mostly caused by physical failures (e.g., a crack in the display), but it can also be caused by software changes (Proske et al., 2016). For instance, the security of a smartphone's software can only be maintained by means of regular updates. When these updates are unavailable to a certain smartphone model, this model can become obsolete. The loss of performance itself is absolute and objective, but it eventually depends on the user's subjective perception whether it leads to obsolescence (Munten et al., 2021).

Both manufacturers and consumers play a role here (see Figure 3.3). A manufacturer may fail to ensure a high quality for its products, such as materials that can withstand extreme usage as well as wear and tear (Granberg, 1997; Guiltinan, 2010; Munten et al., 2021). A consumer may fail to properly care for and maintain the product because he lacks the required knowledge or motivation (Van Nes & Cramer, 2005), which the manufacturer, media or peers may fail to provide (Proske & Jaeger-Erben, 2019; Van Nes & Cramer, 2005).

Technological obsolescence

Technological obsolescence refers to the loss of a product's performance, relative to other models (see Figure 3.4; Packard, 1960; Guiltinan, 2010; Proske et al., 2016). Similar to physical obsolescence, technological obsolescence thus also refers to a loss of performance. However, technological loss of performance is relative to other models rather than absolute for a single model. Physical obsolescence can thus be reversed by repair, whilst technological obsolescence cannot. Guiltinan (2010) discussed two sub types of technological obsolescence: functional additions or enhancements, and aesthetic changes of new models. Proske et al. (2016) added that new models on the market can also cause the infrastructure around products to change, which could make the user's model incompatible with new hardware or software products. Sometimes, the manufacturer stops its compatibility support for economic reasons, but technological trends also force manufacturers to focus on new systems of compatibility, making the old one obsolete (ibid.).

When a manufacturer produces a product with objective differences from previous generations, Heiskanen (1996) argued that it depends on the consumer how he perceives the difference between his own model and the new one (see Figure 3.5). Specifically, Lee et al. (2013) found that non-essential attributes of a product (e.g., a

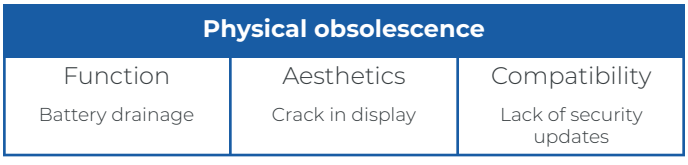


Figure 3.2: Physical obsolescence.

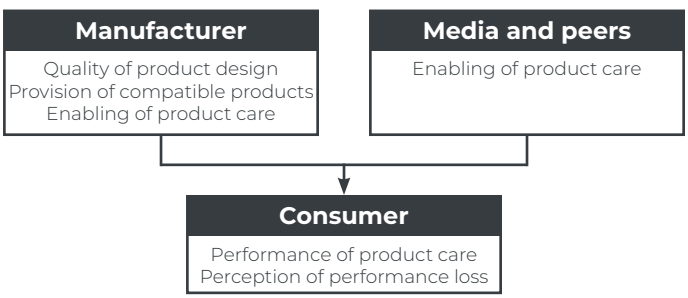


Figure 3.3: Contributing factors of physical obsolescence.

Figure 3.4: Technological obsolescence.

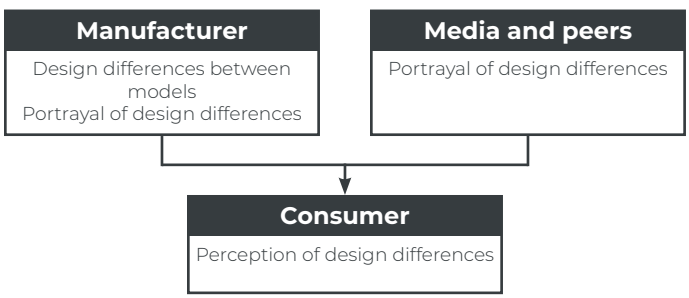


Figure 3.5: Contributing factors of technological obsolescence.

smartphone's camera) play a larger role in this perception than essential attributes do (e.g., memory). Furthermore, Kuppelwieser et al. (2019) found that the higher the frequency of product updates is, the more likely it is that the consumer perceives a smartphone to be technologically obsolete. The perception is also influenced by the way in which marketing strategies, as well as media and peers portray the differences between models (Van Nes & Cramer, 2005). While Packard's (1960) main argument was that obsolescence is intentionally planned by the manufacturer, Munten et al. (2021) demonstrated that the compatibility of a product model also depends on the compatibility support that is offered by manufacturers of other products.

Psychological obsolescence

A product becomes psychologically obsolete when its perceived value fails to correspond to the consumer's needs and preferences (see Figure 3.6). Both Van den Berge et al. (2021) and Hou et al. (2020) used emotional, epistemic, social, and conditional values of a product, as defined by Sheth et al. (1991), to study psychological obsolescence. Emotional value refers to the arousal of feelings and affection, epistemic value refers to the arousal of curiosity and the provision of novelty, social value refers to group belonging, and conditional value refers to the influence of specific circumstances on a consumer's perception (ibid.). Social value was also addressed by Kostecki (1998), as he referred to it as symbolic value, which allows a consumer to construct and express his social identity through consumption.

Psychological obsolescence			
Emotional	Epistemic	Social	Conditional
Poor camera quality fails to correspond with one's passion for photography	Older generation smartphone fails to provide novelty	Brand goes out of fashion and fails to allow one to belong to his peer group	Poor camera quality fails to serve one's need to make high quality photos

Figure 3.6: Psychological obsolescence.

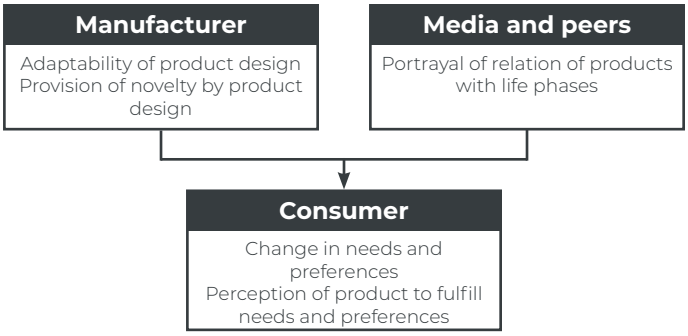


Figure 3.7: Contributing factors of psychological obsolescence.

When a consumer has obtained new experiences or achieved a new status in life (Granberg, 1997), or when his personal circumstances such as his family situation, have changed (Heiskanen, 1996; Van Nes & Cramer, 2005; Proske et al., 2016; Van Munten et al., 2021), his needs and preferences for a product may have altered (see Figure 3.7). Burns (2010) argued that peers, media, and marketing may influence a consumer's perception of a product, while Van Nes & Cramer (2005) argued that social norms may also relate a product to a certain phase or status in life. When studying the influence of these values on replacement behavior, Hou et al. (2020) found that decreased enjoyment of a product, 'satiation', mediates the role of decreased emotional and social value in obsolescence. This satiation is oftentimes designed on purpose to make consumers purchase a new product after a certain use period (ibid.).

Economic obsolescence

A product becomes economically obsolete when its mental book value has decreased to a point at which it cannot compensate for the difference between the price of keeping the product and the price of replacing it (see Figure 3.8; Burns, 2010; Proske et al., 2016). Defined by Okada (2001), and much cited by other authors (e.g., Cooper, 2010), mental book value is "the positive difference between the initial purchase price and cumulative enjoyment" (p. 435). According to Okada (2001), this value decreases over time, based on several factors. Okada found that when the use experience of a product is positive and frequent (negative and infrequent), the mental book value is likely to be higher (lower). Hamilton et al.

Economic obsolescence		
Price of lifetime extension	Mental book value	Price of replacement
Initial expected lifetime has passed	High perceived price of display repair	Low perceived price of new smartphone

Figure 3.8: Economic obsolescence.

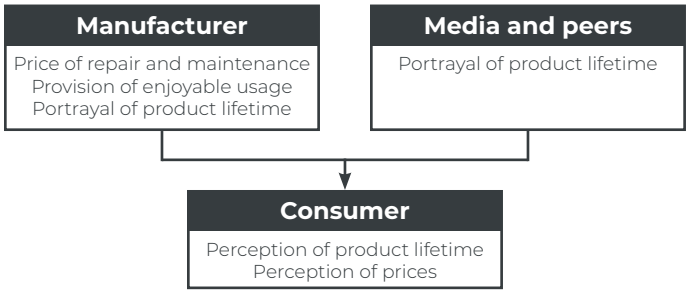


Figure 3.9: Contributing factors of economic obsolescence.

(2011), on the other hand, found that a high perceived use frequency makes a consumer more likely to purchase a new model soon. Thus, this would suggest that the mental book value depreciates quicker when the use frequency is high. However, this is only my interpretation, as Hamilton et al. (2011) did not refer to mental book value in any way. Therefore, I adopt the findings by Okada (2001) in this thesis, but I do take them with some precaution.

Because past experiences determine a product's mental book value, Guiltinan (2010) concluded that this value is at least partially determined by the other types of obsolescence (see Figure 3.9). Although other authors did not make this explicit conclusion, I argue that their studies are in line with this. For instance, when a product breaks down often (physical obsolescence; Okada, 2001), or when better models have arrived on the market (technological obsolescence; Tröger et al., 2017), or when a product does not fit anymore with the user's new lifestyle (psychological obsolescence; Proske et al., 2016), the enjoyment of use will be relatively low, which leads to low mental book value, and thus to potential obsolescence. In addition to the performance of the product itself, Proske et al. (2016) and Tröger et al. (2017) added that mental book value also decreases more quickly when the initial expected lifetime of a product is lower. As discussed by Burns (2010), economic obsolescence is not only determined by a product's mental book value, but also by the price of extending the product's lifetime. This price is mostly determined by the manufacturer, as he may ask a high price for repair and maintenance services, spare parts, compatible products, consumables, and upgrades. Although these prices are objectively comparable, it depends on the consumer's perception of these prices whether a product becomes economically obsolete.

Conclusion

Based on academic literature that has been written between 1960 and 2021, I propose a framework of the possible reasons that a consumer might have for choosing product replacement (see Figure 3.10). Because this framework is based on literature that discusses obsolescence of a wide variety of products, and for a wide variety of conditions, this framework can only be regarded as a theoretical one, rather than a practical one. Moreover, the obsolescence types in the framework should not be regarded as single determinants of obsolescence. Rather, at the moment that physical, technological or psychological obsolescence arises, a product potentially becomes obsolete. When this happens, economic obsolescence starts to play a role, where the user compares the product's mental book value with the price of lifetime extension and the price of replacement. When the mental book value is too low to compensate for a relatively high price of lifetime extension and a relatively low price of replacement, a product becomes obsolete. With regards to the decrease in mental book value, Guiltinan (2010) showed that technological and psychological factors play a more significant role than physical factors. This is in line with the statement by Haines-Gadd et al. (2018), as mentioned in the introduction, that three quarters of products becomes obsolete without being physically broken. Thus, in order to extend the lifetime

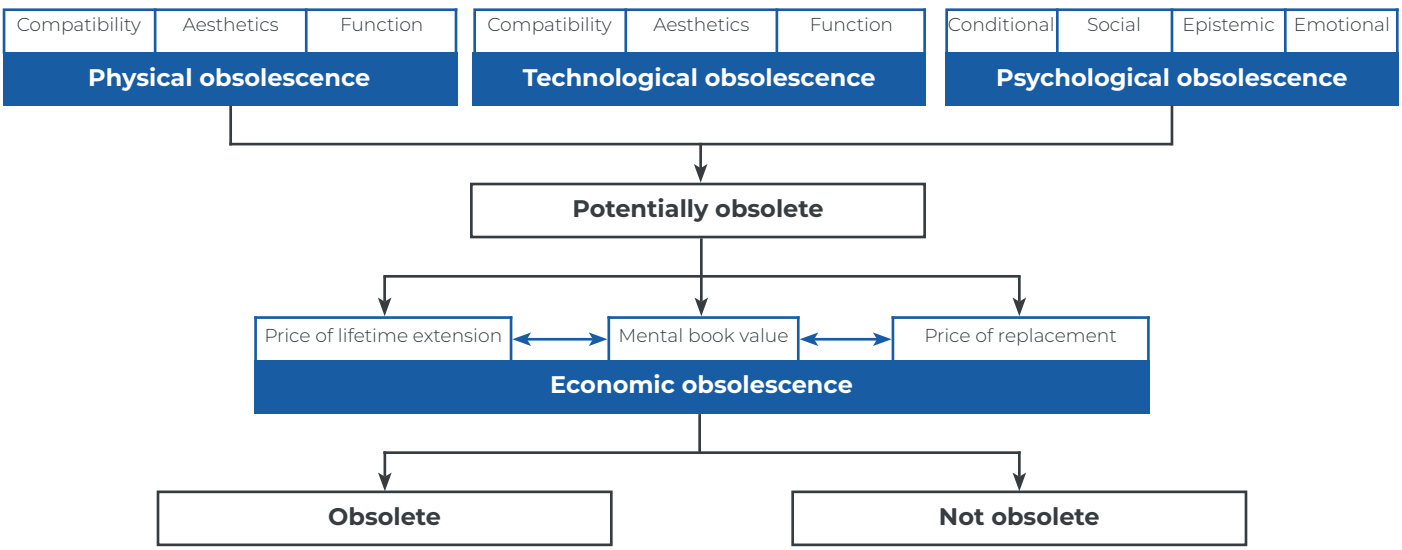


Table 3.10: Framework of possible obsolescence reasons

of smartphones by means of repair, it remains relevant to regard all four obsolescence types. The conditions which determine that some factors make a smartphone potentially obsolete while others do not, are not clearly addressed in the discussed literature. For instance, what determines whether a crack in the display makes the smartphone obsolete? These conditions are further addressed in the consumer interviews of Chapter 3.3.

Several studies raised that consumer's personal characteristics influence whether a product becomes obsolete. For instance, Tröger et al. (2017) argued that a consumer's willingness to stay up to date with technological and fashion trends determines the probability that he will find a product technologically obsolete. And Van Nes & Cramer (2008) argued that the mental book value's rate of decline is determined by the user's 'discount rate', which is his ability to be patient. The discussed literature fails to make these personal characteristics measurable. For instance, how patient must a consumer be to extend the lifetime of a smartphone that has become out of fashion? Although personal characteristics are not the main focus of this study, findings in this thesis provide insight as to what characteristics of consumers can be addressed to change the perception of obsolescence. In the next sub chapter, I apply this obsolescence framework on smartphone repair, to study what role repair can play to reverse obsolescence.

3.2. What role does repair play in obsolescence?

In their study of the durability of smartphones, Cordella et al. (2020a) defined repair as the "process of returning a faulty product to a condition where it can fulfil its intended use" (p. 3), where a 'faulty' product is one with an absolute failure. In other words, repair can reverse physical obsolescence. When a physical failure occurs, the consumer assesses the feasibility, viability and desirability of repair. For repair feasibility, the availability of repair options is most relevant. For repair viability, the consumer assesses the smartphone's economic obsolescence by comparing the price of repair with the smartphone's current mental book value (which is partially determined by physical, technological and psychological obsolescence) and the price of replacement. For repair desirability, the consumer takes the physical, technological and psychological obsolescence of the smartphone into account. Thus, although repair can only reverse physical obsolescence, the other types of obsolescence play a significant role whether the consumer chooses for repair. Before I address the feasibility, viability and desirability of repair, I discuss the (most frequently) occurring physical failures of smartphones.

There is only little data available about the occurrence frequency of specific failures. Survey results in Spain, performed by OCU (2018), showed that most smartphone failures occur within the first three years of use (86%): 47% in the first two years, and 39% in the third year. Based on repair requests, Cordella et al. (2020b) concluded that the display and battery are the parts that fail most often, followed by the back cover, operating system, and electronic components (see Table 3.11). Because occurrences of failures and subsequent repair requests are highly dependent on the age and model of the specific smartphone, and current literature lacks a central overview of this data, it is irrelevant to apply exact percentages to each failure. Cordella et al. do estimate that screen and battery repair take up about two-thirds of all smartphone repairs. However, this is only based on repair requests, there is no data available about the physical failures of obsolete smartphones that have not been repaired. Because it is these obsolete smartphones that should be saved, I further study physical obsolescence reasons in the consumer interviews.

With regards to the display, it is either the glass screen, the LCD/LED screen, or the touchscreen that loses aesthetic or functional performance. These failures are usually caused by a combination of accidental drops by the consumer and the screen's failure to resist mechanical stress. The most common battery failure is loss of capacity because of battery ageing, which can be measured in two ways. The calendar life is equal to the time that a battery can be stored with minimal use,

Part	*Failure*	*Type of failure*	*Consumer*	*Consumer*
Display	Glass screen (cracks, scratches, splinters)	Aesthetics	Drops	Failure to resist mechanical stress
	LCD/LED screen (black screen, dead pixels, no background light)	Function		
	Touchscreen (response failure)	Function		
Battery	Capacity loss	Function		Ageing
	Charging	Function	Charging port damage	Failure of charging port or battery connection
	Overheating	Function	Use of wrong charger	Increased internal resistance
Back cover	Breakage (cracks, scratches)	Aesthetics	Drops	Failure to resist mechanical stress
Operating system	Loss of security or performance	Compatibility		Software updates unavailable
Electronics	Short circuits or disconnected parts	Function	Exposure to water or dust	Failure to resist mechanical stress

Table 3.11: Physical obsolescence of smartphones, based on Cordella et al. (2020a).

and the cycle life is the number of times a battery can be fully charged and discharged. Both last until the battery capacity drops below a certain threshold (usually 80%) of the battery's original capacity. Additionally, the battery may fail to charge or overheat, which can be caused by the battery itself (increased internal resistance), but the cause can also lie outside of the battery (a damaged charging port, or failure of the battery connection). The back cover may break for the same reason that the glass display breaks, i.e., a combination of accidental drops and the failure to resist mechanical stress. The operating system might experience a loss of security or performance, when software updates are unavailable. This can happen when the manufacturer does not provide updates, but also when a lack of internal memory or performance does not allow the smartphone to be updated. Furthermore, the internal electronics might fail in terms of short circuits or disconnected parts. This can happen when the consumer exposes the smartphone to dust or water, drops it, or when the smartphone fails to resist mechanical stress.

Repair feasibility

The availability of smartphone repair options determines the effort that a consumer needs to make in order to repair his smartphone. This depends on both the design of the smartphone itself as well as the services around it (see Table 3.12; Munten et al., 2021). The availability of repair services is arguably more relevant than a repairable product design, because most consumers are not likely to perform the repair by themselves (Cordella et al., 2020b). However, product design aspects remain relevant for these consumers because the availability of repair services depends on them (Proske & Jaeger-Erben, 2019). For instance, when a product design allows for easy repair, it requires less effort and time for repair professionals to perform the repair, which makes that they can offer repair within a shorter timeframe.

Before a product can be repaired, the failure should be diagnosed. The ease of failure diagnosis determines to what extent consumers are able to make an informed decision on the feasibility of repair (Pozo Arcos et al., 2020). Cordella et al. (2020a) argued that one of the most important aspects of a repairable smartphone design is the ease of disassembly. Furthermore, the ease of data transfer and deletion from the obsolete smartphone (to other devices) also influences the effort that is required for repair (ibid.). Neither Cordella et al. (2020a) nor Pozo Arcos et al. (2020) studied to what extent these aspects stimulate consumers to eventually choose for repair. This is where the consumer interviews and design findings of this thesis make a contribution. It is relevant to understand this influence on the repair decision, because easier disassembly can also lead to less reliability, which should be avoided (Cordella et al., 2020a). Cordella et al. proposed to measure the number of steps it takes to disassemble the product so that the faulty part can be replaced and the average time this takes. Pozo Arcos et al. (2020, p.1) did not explicitly mention these measurements but stated that a "product's design influences how time-consuming and complicated the repair will be [...]". Here, I relate 'complicated' to the number of steps and 'time-consuming' to the average required time. Therefore, in this thesis, I measure not only the ease of disassembly, but also the failure diagnosis and data management by the number of required steps and the average required time to complete the task. For instance, when deleting data requires a minimal number of steps and a minimum amount of time, repair is relatively more feasible. For both failure diagnosis and disassembly, the battery and screen should be prioritized, because these are functionally important and are most likely to fail (Cordella et al., 2020b).

The availability of spare parts, repair information, and repair services also determine repair feasibility. Availability of repair services by the manufacturer or other parties (e.g., a local smartphone repair

Feasibility factors	*Measurements*
Product design	
Ease of disassembly	Number of required steps Required time in hours
Ease of failure diagnosis	Number of required steps Required time in hours
Ease of data management	Number of required steps Required time in hours
Service design	
Availability of repair services	Geographical proximity in kilometers Service time in hours Duration of availability in years
Availability of spare parts	Number of required steps Delivery time in days Duration of availability in years
Availability of repair information	Amount of available information Type of available information Duration of availability in years

Table 3.12: Factors that influence repair feasibility (by author).

shop) can be measured in terms of their geographical proximity to the consumer, and the time that these services take up (Cordella et al., 2019). The availability of spare parts can be measured by the number of steps it takes to purchase the parts, as well as their delivery time. The availability of repair information can be measured in terms of the amount of information that is provided. The duration in years for which all of these services are available is also relevant for the feasibility of repair.

Repair viability

Whether the costs of repair are worth it, depends on the price of repair, the mental book value, and the price of replacement (see Table 3.13). According to Burns (2010), the price of repair is one of the most significant factors that determine whether the consumer chooses for repair or not. This price is determined by the prices of spare parts, which influence the price of repair services by both the manufacturer and third parties. Cordella et al. (2020a) found that the repair of a smartphone display can cost up to 15-40% of the original purchase price. It is questionable whether the mental book value of the smartphone is high enough to justify these costs. The price of repair is weighed against the smartphone's mental book value, and as discussed in Chapter 3.1, this is determined by its physical, technological, and psychological obsolescence. These obsolescence types also play a role in the desirability of repair, for which the measurements are discussed below.

Repair desirability

When a consumer considers repairing a smartphone's physical failure, not only the feasibility and viability of repair play a role, but the consumer also considers whether repair will fulfill his needs (see Table 3.14). These needs can be regarded in terms of how the user perceives the current state of the smartphone (physical obsolescence), how he perceives differences with newer models (technological obsolescence), and how he perceives that changes in his own life leads to new product needs (psychological obsolescence). In addition to the obsolescence reason that the consumer considers repair for, the consumer thus considers all possible other obsolescence reasons to determine whether he is willing to choose for repair. And as addressed before, these other obsolescence reasons seem to play a more significant role in the replacement decision than repairable failures alone (Guiltinan, 2010; Haines-Gadd et al., 2018).

The obsolescence factors as discussed in Chapter 3.1, can be used to measure the desirability of repair. For physical obsolescence, the main measurements include the reliability of the smartphone itself, the information and tools that are provided to the consumer for maintenance and product care, as well as the average duration for which compatible products are provided. For technological obsolescence, the differences between different generations of models, their portrayal, and the frequency of updates play a role. Because compatibility is part of both physical and technological obsolescence, the duration for which compatible products are offered is included here as well. For psychological obsolescence, the adaptability of the model to the consumer's changing needs is relevant, as well as the novelty that the phone provides during its functional lifetime.

Viability factors	*Measurements*
Economic obsolescence	
Price of repair	Price of spare parts in euros Price of repair services in euros
Price of replacement	Price of replacement in euros
Mental book value	Physical obsolescence Technological obsolescence Psychological obsolescence

Table 3.13: Factors that influence repair viability (by author).

Desirability factors	*Measurements*
Physical obsolescence	
Reliability	Functional lifetime in years
Product care	Amount of available information Type of available information Number of available tools Type of available tools
Compatible products	Duration of availability in years
Technological obsolescence	
Design differences	Number of differences per model Portrayal of differences Number of new models per year
Compatible products	Duration of availability in years
Psychological obsolescence	
Adaptability	Number of adaptable parts per model
Novelty	Number of updates per year

Table 3.14: Factors that influence repair desirability (by author).

Conclusion

When the display, battery, back cover, operating system, or electronics of a smartphone have failed and made the smartphone obsolete in the mind of the consumer, there is a variety of reasons that the consumer may have (not) to choose for repair. Based on the theoretical framework as discussed in Chapter 2, I propose a framework for the attractiveness of repair (see Figure 3.15). In addition to the aspects that I mention in this framework, which manufacturers and third parties are responsible for, it is also relevant to consider the personal characteristics of consumers. Van Nes & Cramer (2005) stressed that these characteristics play a significant role in the decision to repair. For repair feasibility, it depends on a consumer's willingness to put effort into repair, which is partially determined by the desirability and viability of repair. Secondly, a consumer's technical know-how of repair determines whether he is able to perform the repair by himself. Repair viability also depends on the consumer's willingness to pay, which is again partially determined by the feasibility and desirability of repair (ibid.). Also, the willingness of a consumer to keep a product in possession that can return to a functional state can play a role for the desirability of repair. This willingness is determined by the mental ability of a consumer to retire a product when it has not yet fulfilled its monetary purchase (Okada, 2001).

Just as the personal characteristics of consumers that play a role in obsolescence, were not thoroughly addressed in the literature, the characteristics that play a role in repair also lack any measurements. Therefore, I further address these personal characteristics in the consumer interviews and contextualize these to the use case of smartphones.

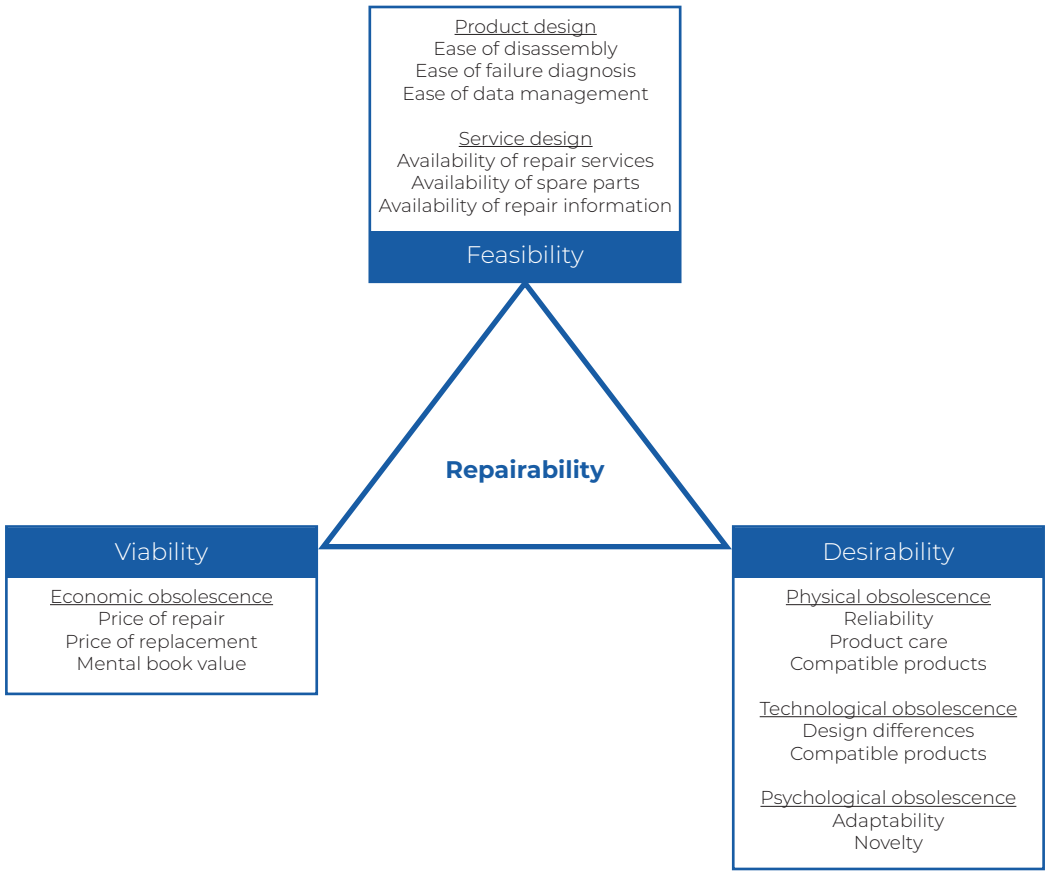


Figure 3.15: Framework of factors that influence the consumer's decision to choose for repair, at the moment that a smartphone has become physically obsolete.

3.3. Consumer interviews

Just as the literature review pointed out, consumer interviews also showed that the process of a smartphone becoming obsolete and choosing for repair involves many different considerations. All four types of obsolescence arose in at least one of the five interviews. When participants were asked about the specific reason(s) why they decided to purchase their current smartphone, they mostly mentioned physical and technological obsolescence of their previous smartphone (see Table 3.16). One aspect of psychological obsolescence that was not addressed in the literature review, is the habit of purchasing a new smartphone every couple of years, without having a specific reason for it. Both Ron and Isabella said to do this because they felt this was the norm. However, Ron indicated that he quitted this habit because he did not see any major improvements on the smartphone market over the last several years. This is in line with findings that technological maturity in smartphones may make consumers less willing to purchase a new one (Proske & Jaeger-Erben, 2019). None of the participants raised economic costs in their discussion of the reasons for obsolescence. However, when I asked Sophia, Anna, and Emma why they had not repaired their previous smartphone (their reason for obsolescence being physical), they all indicated that the price of repair was too high. This is in line with the framework from the literature review, which states that only physical, technological, and psychological factors can make a smartphone potentially obsolete, and the consumer only considers economic factors in a subsequent phase. It would be valuable for future research to further address these specific obsolescence reasons in a quantitative format, so that a better overview can be created of the most relevant issues to be solved.

Obsolescence reasons

Most participants mentioned to have had experience with damage to the battery or screen but indicated that this did not automatically make the smartphone obsolete. The most important factor that determined whether screen damage made the phone obsolete, was whether the damage caused any problems in the use experience. When damage to the screen would only be small (e.g., a small corner of the display), most participants indicated that this would not make the phone obsolete.

Several participants indicated that whenever the battery capacity is unreliable, or drains quickly, they would find it obsolete. Because 'unreliable' and 'quickly' are subjective terms, the threshold at which the battery capacity causes obsolescence may differ per consumer. Furthermore, the interviews showed that there is a difference between a degraded battery causing obsolescence and a degraded battery causing just irritation. This irritation does lower the mental book value of the smartphone, but not to a point where it becomes obsolete. When another issue arises, the lowered mental book value makes the smartphone economically obsolete more quickly. In addition to this, specific conditions may also make consumers think differently. For instance, Anna indicated that she was fine with the quick drainage of her current smartphone, because she is mostly at home all day and is thus able to charge it anytime: *"When Covid lockdowns are over and things are starting to happen again, I would probably have to buy a new phone."*

Damage to the back or side of the smartphone was found by most participants as not being an issue, whereas several participants even mentioned that their smartphone already had some dents and

	Physical obsolescence	*Technological obsolescence*	*Psychological obsolescence*
Sophia	Battery drainage Small crack in display	Need to download specific apps	
Anna	Battery drainage		
Ron			Try something new Usually buy one new every 3 years
Isabella		Desire for better camera Need to download specific apps	Usually buy one new every 2 years
Emma	Battery drainage		

Table 3.16: Overview of participants' reasons to purchase their current smartphone.

scratches on the side or back. Emma said: *"I could not care less about a scratch on the back."* Ron indicated that he would not care to repair his current aluminum back cover, but he would want to repair it if it were made from glass. This implies that the extent to which the materials of the outer case allow damage to arise, may influence the mental book value of the smartphone. Furthermore, Sophia indicated that damage to the back or side would make her fear that there is also internal damage to the phone. This suggests that damage to the outside of the smartphone may have an influence on the consumer's perception of the phone's (future) performance.

Considerations of repair and replacement

At the point that the smartphone has become obsolete, the consumer can either choose to repair the failure or replace the smartphone all together (see Figure 3.17). Based on the interviews, the main factor in this decision seems to be the price of repair, which is in line with findings by Burns (2010). Additionally, the expected effectiveness of repair played an important role as well. When participants found repair to be reasonably priced, they indicated to be relatively likely to choose for repair over replacement. The reasonable price was literally indicated by Anna as *"for the time that I have used the phone, I don't think repair is worth the price"*. This is in line with the mental book value as described by Okada (2001). One aspect that was not mentioned by Okada, is the influence of the consumer's plans for the phone's second life on its mental book value. For instance, Isabella indicated that if she decides to pass down her phone to her son, this will make repair worth the price and make her likely to choose for repair over replacement. Furthermore, both Emma and Ron indicated that they would still be relatively willing to purchase a new smartphone just because they have the monetary resources available.

Another point that come to the fore, is whether the consumer expects that the failure will be solved by repair, and whether other failures might arise after repair has taken place. For instance, Sophia indicated that she would not choose to replace her battery, because she was not sure whether this would solve the quick drainage of her smartphone's battery: *"I would purchase a new one, because replacing the battery is quite expensive and there is no proof [...] sometimes it does not work."* Ron, on the other hand, was convinced that battery replacement would solve the issue of battery drainage and that it would prevent the issue from happening again anytime soon. Following this, he was willing to choose for battery repair. He also indicated that he would not be likely to choose for replacement of the screen, because it was not guaranteed that he would not drop the phone shortly after repair, and thus break the screen again: *"[With] a new battery, you know that this will last for some time, this one is already lasting 3, 4 years. So, you know you can use it for a long time, and I think for such a display, you can still drop it anyhow."* Finally, some issues were not always interpreted as being solvable by repair. For instance, Anna did not expect that repair would have any influence on the performance speed: *"I will just have to deal with it or purchase a new one."* Performance speed cannot always be solved by replacement of the battery alone, but together with a fresh installation of the operating system, it could be improved. Therefore, consumers may require more information about the options that are available to them when they encounter issues.

Finally, although the participants addressed the feasibility of repair in terms of the certainty that they have towards repair being a solution to their issue, none of the interview participants mentioned to consider the convenience or availability of repair options. This does not mean, however, that this does not play a role, as it could be a more latent consideration. For instance, when Sophia was talking about her broken screen protector, she mentioned that she was *"waiting for the MediaMarkt to open up again"*, so that she could let someone else apply a new screen protector to her phone. This implies that the convenience of repair does play a significant role in their decision.

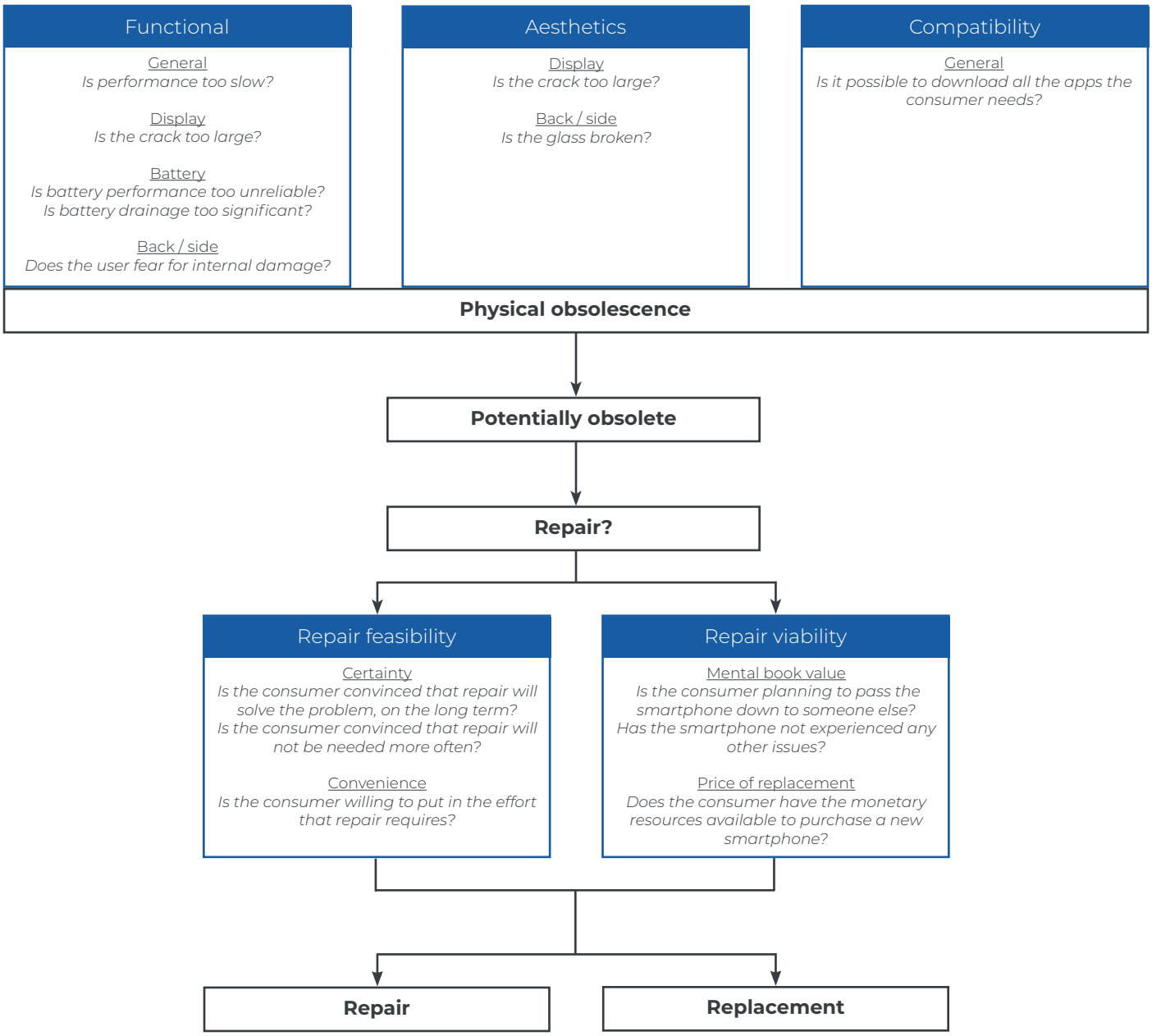


Table 3.17: Process of a smartphone becoming obsolete and needing repair or replacement, based on the performed interviews

3.4. Expert interviews

Both my expert interview participants from iFixit and the Consumentenbond indicated that it is difficult to define what the most common reasons are that consumers choose for either repair or replacement of their smartphone, or how often repair is being performed. Peter argued that the best way to find this out, is to ask consumers, because manufacturers are unwilling to share this information and other repair parties are too scattered to be able to provide a representative sample. Furthermore, Peter argued that it is difficult to compare repair services on price, because this differs per country (average costs of working hours differ per country) and time period (the price of spare parts changes over time). Overall, Edward indicated that he found that smartphones are becoming less repairable because they are getting thinner, which is in line with findings by Cordella et al. (2020a).

Considerations of repair and replacement

Just like Burns (2010) indicated and the consumer interviews pointed out, both Peter and Edward thought that price is one of the most important factors in a consumer's decision to choose for repair or not. According to Peter, this is one of the reasons that the European Union is working towards maximum prices of replacement parts. With regards to the price of repair, Edward also stressed that the initial expected lifetime plays a role. He thought that the average expected lifetime currently lies somewhere between 2-3 years, which is in line with earlier findings by Cordella et al. (2020b) and corresponds with the consumer interviews as well. Also in line with Cordella et al. (2020b), Edward said that the average use cycle of smartphones is increasing, partly because of technological maturity and sustainability reasons. Additionally, Edward argued that refurbished devices are interesting for parents to give to their children. This is in line with the finding from the consumer interviews that smartphone life expectancy and mental book value may increase when a parent passes down his smartphone to one of his children.

Peter admitted that iFixit does not provide cheap spare parts, which he explained by the goal of iFixit being to create a 'good' repair experience, where consumers can be certain that repair will solve the problem. Just as consumers indicated, Peter thus also recognized the need of providing certainty to consumers in order to convince them of repair. Additionally, Peter indicated that iFixit's philosophy states that effort should be minimized for consumers in order to make them choose for repair, both from a product and service point of view. iFixit tries to do this by the provision of repair information, tools, and spare parts. Both the product side and service side of it should be considered. One aspect brought up by Peter, which was not mentioned in any literature or by any consumers, is that high brand value can lead to more willingness among consumers to repair. He argued that repair of Apple's iPhones is more popular for this reason than repair of Oppo smartphones, for instance. This suggests that low budget smartphones might become economically obsolete sooner than premium smartphones, which is in line with the findings by Proske et al. (2016) that high enjoyment leads to a higher mental book value.

3.5. Conclusion

Input for PSS design

- Preventing failures is more important than solving them, because without failures, the user has less incentive to replace the smartphone.
  Therefore, the PSS should enable and motivate users to perform product care.

- Some failures cause irritation without the user knowing that the failure can be solved. When a more significant failure arises later on, the user is more likely to choose for replacement.
  Therefore, the PSS should make failure diagnosis as easy as possible.

- When the use experience before a failure is not positive, the user is more likely to choose for replacement.
  Therefore, the PSS should optimize the use experience.

- When a user is not convinced that repair will solve a failure on the long term, without needing additional repairs, he is more likely to choose for replacement.
  Therefore, the PSS should convince the user of the eventual outcome of repair, as well as the phone's future performance.

- Even though it might not be salient in the user's mind, the convenience of repair makes a significant contribution to his willingness to repair.
  Therefore, the PSS should make repair as effortless as possible.

- When a user perceives his smartphone to be significantly outdated compared to more recent models, the user is more likely to choose for replacement. This perception is mainly based on marketing messages of smartphone brands, rather than on objective design differences. Because smartphones are technologically mature, the objective design differences are relatively small.
  Therefore, the PSS should provide an objective comparison between the user's smartphone and the more recent models.

Input for future research

- Current literature does not clearly address the influence of consumer characteristics on the willingness to repair or replace a product. Therefore, future research should study why a certain failure causes obsolescence for one user, while not for another user.

- Current literature does not provide any clear measurements for the mental book value of a product. Because this plays one of the most significant roles in the decision to replace a product, it is relevant to understand how this mental book value can be measured. Therefore, future research should study this. One way of doing this, is by providing users with hypothetical scenarios of obsolescence and studying at what ratio between repair price and replacement price, the user chooses for repair or replacement.

- Current literature fails to address the actual reasons that consumers have for replacing their smartphone. Most studies have only focused on theoretical obsolescence reasons or repair requests. However, increasing the attractiveness of repair requires the understanding of the actual reasons that consumers have for not repairing a physically broken smartphone. Therefore, future research should study what the reasons of obsolescence are when repair is not chosen.

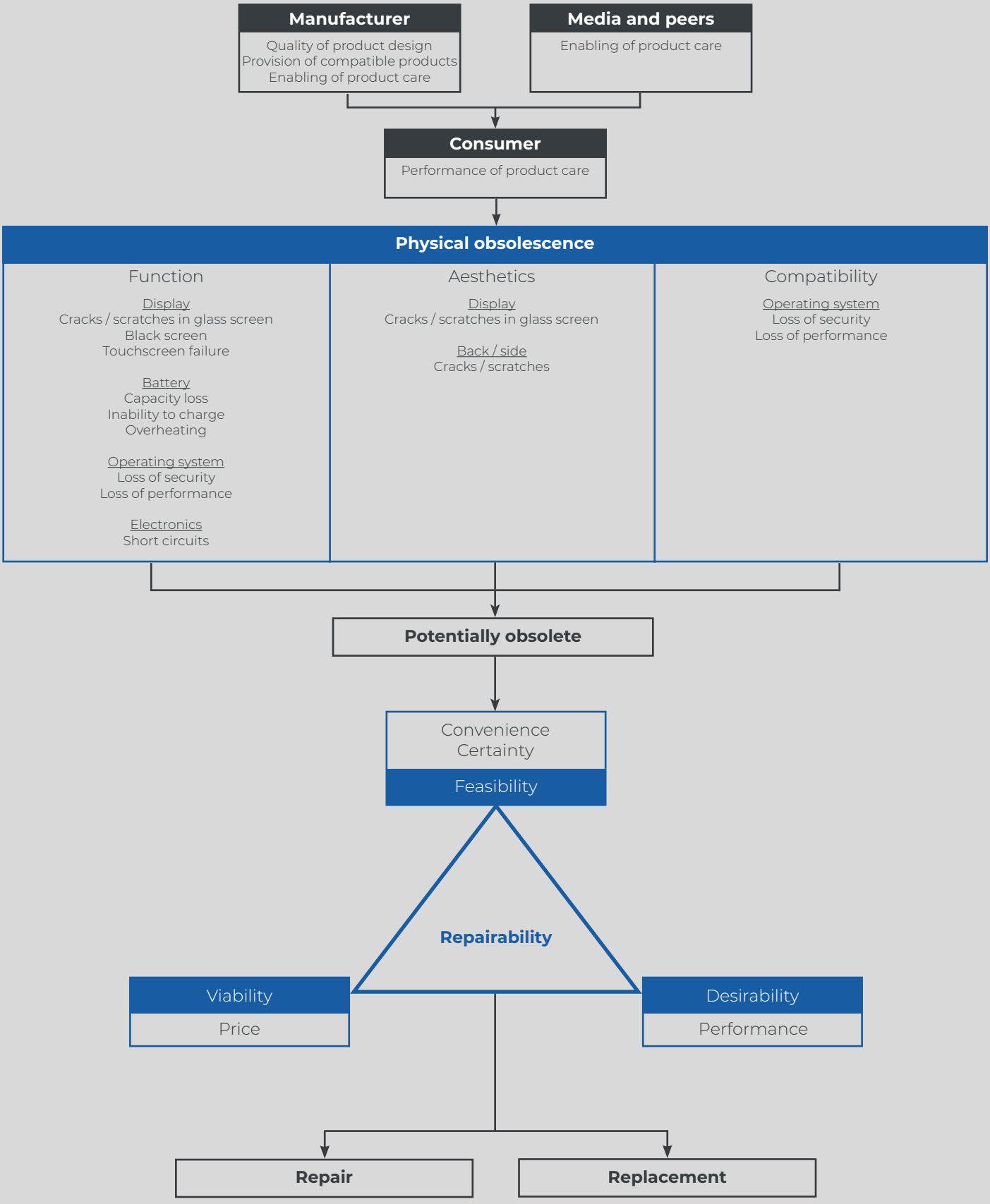


Figure 3.18: Theoretical framework of the physical obsolescence of smartphones, and the considerations leading to repair (by author).

4. Solution exploration

In this chapter, I discuss what solutions have been proposed throughout academic literature to stimulate consumers to choose for repair over replacement, which includes both strategies to make repair more attractive and strategies to make replacement less attractive. In the second part of this sub chapter, I discuss what role a PSS can play in stimulating consumers to choose for repair.

4.1. What solutions exist to stimulate consumers to choose for repair?

During the last two decades, an extensive number of design principles and strategies have been proposed to extend a product's lifetime (Haines-Gadd et al., 2018). None of these are specifically targeted at stimulating consumers to choose for repair over replacement, but all of them have the potential to play a role in this. Van Nes & Cramer (2005) divided all use cycle extension strategies into five categories (see Table 4.1), which have been adopted by many authors (e.g., Den Hollander et al., 2017). Therefore, this thesis adopts the categorization by Van Nes & Cramer (2005) as well. Design for reliability and robustness, and design for product attachment focus on creating products that resist obsolescence. Design for repair and maintenance, design for upgradability, and design for variability allow consumers to reverse obsolescence. In this sub chapter, I discuss how the design strategies can play a role in terms of the feasibility, viability, and desirability of smartphone repair.

Repair feasibility solutions

Design for repair and maintenance can play a role in increasing the feasibility of smartphone repair. As discussed in Chapter 3.2, the feasibility of smartphone repair can be regarded in terms of product design and service design. With regards to product design, the ease of disassembly should be prioritized for those parts that are both functionally important and likely to fail: the display and battery (Cordella et al., 2019). Disassembly can be simplified by minimizing the number of fasteners and joints (Soh et al., 2015), whereas mechanical fastening

Strategy	*Definition*
Design for reliability and robustness	Making it unlikely that the product will fail or break.
Design for product attachment	Making disposal more difficult because of attached feelings to the product.
Design for repair and maintenance	Making it easy for consumers to maintain and repair a product themselves.
Design for upgradability	Making it easy for consumers to change product parts for more advanced ones.
Design for variability	Offering variation of the product without needing additional parts.

Table 4.1: Use cycle extension strategies, as defined by Van Nes & Cramer (2005).

techniques (e.g., screws) are preferred over adhesive bonding techniques (e.g., glue) because they are easier to remove (Cordella et al., 2020b). Although it may seem an easy task to remove fasteners from the product design, a trade-off has to be made between the repairability, reliability, aesthetics, and functionalities of the smartphone. For instance, a battery that is glued to the back cover is relatively difficult to remove, but a battery that is joined by screws instead increases the smartphone's thickness. Furthermore, glue is often used to make smartphones waterproof, which makes it difficult to simply remove it from the design. Cordella et al. (2020b) did find that easily repairable smartphones are currently comparable in weight and size to fully integrated smartphones, which suggests that it is possible to combine repairability and aesthetics. However, repairable smartphones seldom have advanced features and are usually less reliable, which suggests that advanced functionalities and reliability cannot be combined with repairable designs (e.g., Fairphone 2; Cordella et al., 2020a). Furthermore, the joining and fastening points should be as easy as possible to access (Soh et al., 2015; Vanegas et al., 2018), as many points as possible should be dismantlable with a minimal amount of commonly available tools, such as Phillips screw drivers (iFixit, n.d.-c), and the smartphone's core should be protected as much as possible (ibid.). For these aspects, there are again trade-offs to be made. However, because the technical design of the smartphone is not the focus of this thesis, I will not further discuss these aspects, but I recommend Soh et al. (2015) and Vanegas et al. (2018) for further reading.

In addition to design for disassembly, Cordella et al. (2019) proposed several other principles to design for repair and maintenance. First of all, it should be easy for the consumer to diagnose possible failures. For a cracked smartphone display, diagnosis seems rather obvious, but failure of the touchscreen or battery can be more difficult to diagnose for regular consumers (Pozo Arcos et al., 2020). Then, it should be easy to find replacements and information for the repair of (at least) the priority parts. This helps third party repair professionals to deliver improved services to the consumer, and it helps consumers to perform the repair by themselves. Relevant for the last type of consumers is to help them train their repair skills, which will make them more knowledgeable and confident with regards to performing the repair themselves (Cordella et al., 2019). Furthermore, the quality of replacement parts should be guaranteed, which means that the parts are either produced by the OEM or that the parts are produced by third parties which are OEM approved. When the smartphone design includes parts with standardized interfaces, the availability of high quality spare parts will increase, because it becomes easier for third parties to produce compatible spare parts, which is in line with the design for standardization and compatibility principle as proposed by Bakker et al. (2014).

With regards to service design, Cordella et al. (2020a) suggested that repair information should include an exploded diagram of the disassembly steps, illustrations that show how parts can be

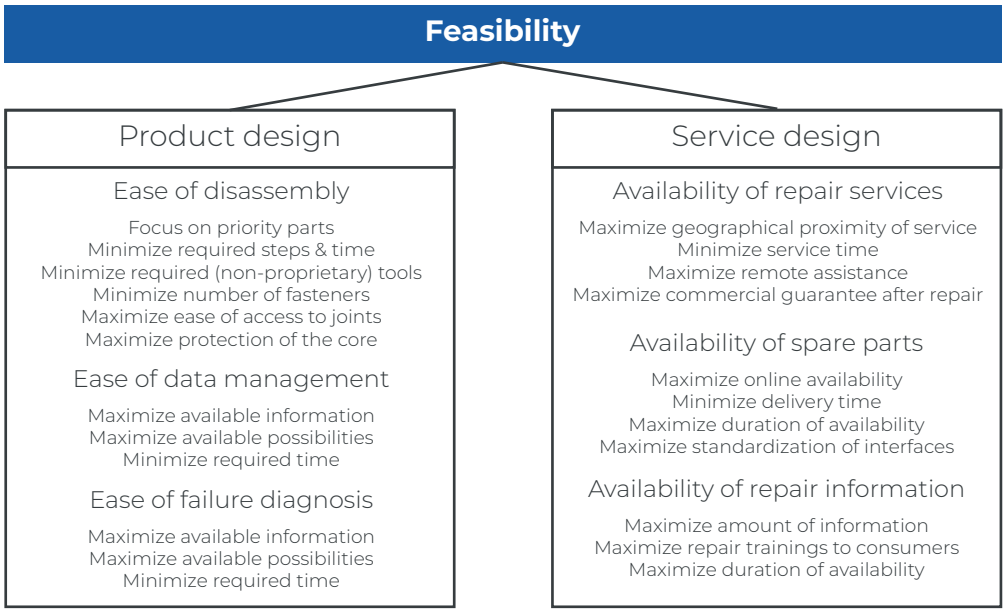


Figure 4.2: Possible solutions to make smartphone repair more feasible.

accessed, replaced, and reassembled, and an indication of the required tools and associated difficulty. Cordella et al. (2019) suggested that both the information and parts should be readily available for a minimum of 3 to 5 years, listed online and the parts should be delivered to the consumer or repair professional within a maximum of 2 days after the order. Furthermore, commercial guarantees that functionality is fully recovered after repair could convince consumers of the effectiveness of repair. This commercial guarantee can either be included in the price of repair or be an add-on. Finally, with regards to data management, Cordella et al. (2020a) argued that this should be as easy possible for the consumer, by providing relevant information and a variety of options to choose from.

Repair viability solutions

Smartphone repair can be become more viable by deploying strategies that lower the perceived price of repair, or increase the smartphone's mental book value, (see Figure 4.3). Based on stakeholder input, Cordella et al. (2019) concluded that repair costs should be below 30% of the smartphone's value. I do not adopt this as a specific threshold, because Cordella et al. did not address what they meant by 'value', who these stakeholders were or how they came up with this number, but it does provide a reference point: the repair costs should not exceed 30% of the purchase price. As described in Chapter 3.1, mental book value depends mostly on the time that has passed since purchase, as well as the frequency and quality of use. These factors influence the perceived future enjoyment of the product and the psychological costs of discarding the product (Guiltinan, 2010). Following this, when another obsolescence reason has arisen in addition to the physical failure for which repair is being considered, a consumer does not have much incentive to extend the use of this product. Therefore, making smartphones resistant against these types of obsolescence is another way to make repair more viable. Strategies to do this are further discussed in the following section on repair desirability solutions.

Repair desirability solutions

By decreasing the physical, technological, and psychological obsolescence of a smartphone, repair can become more desirable because the consumer feels less need to replace his smartphone with a new model. One potential strategy to decrease the psychological obsolescence of a smartphone is design for product attachment, or emotional durability. Design for upgradability and design for variability can play a role in decreasing technological obsolescence (see Figure 4.4), and design for reliability and robustness can play a role in decreasing physical obsolescence. All four strategies potentially lead to an increase in the desirability of repair.

Mugge (2007) found that consumers who feel attached to a product are more likely to take good care of it and repair it if needed. For the enhancement of this attachment, Haines-Gadd et al. (2018) defined nine themes which constitute a total of 38 principles that focus on building a connection between the consumer and the product. A point that Haines-Gadd et al. made in addition to the design principles is that repair can also serve as a way for consumers to gain more attachment to a product: "repair and maintenance need not be a chore and instead be an act of love, care, and appreciation" (p. 16). They argued that repair and maintenance

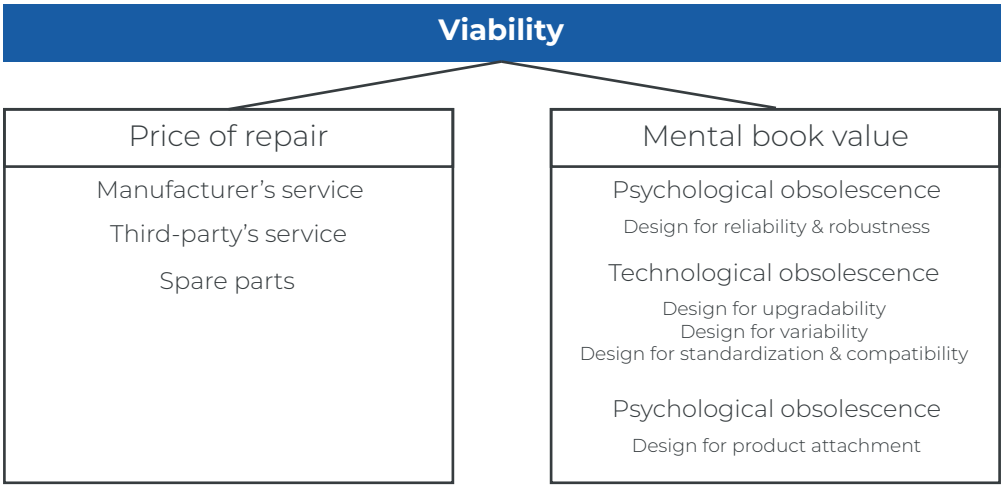


Figure 4.3: Possible solutions to make smartphone repair more viable.

allow users to interact with a product on a deeper, emotional level. Although they argued that their findings were based on a grounded literature review, little evidence was provided for the effectiveness of the proposed strategies. When I relate this to Mugge's (2007) findings that design for product attachment does not work for all products or user groups, I conclude that the design principles do have potential but cannot be regarded as a guaranteed road to success. However, I do adopt the importance that both Mugge and Haines-Gadd et al. attach to making a consumer emotionally invested in a product. Specifically with regards to decreasing psychological obsolescence, Van den Berge et al. (2021) proposed that the implementation of a timeless design, a design principle that was proposed by earlier authors already, can allow for product retention. A study by Wallner et al. (2020) showed that a timeless design has positive effects on consumer acceptance of refurbished phones, making it a possibly interesting avenue for the delay of smartphone replacement as well.

For both design for upgradability and design for variability, the most important condition is that the smartphone is modular, which means that the design of its parts and connectors allows the user to easily replace parts with an upgrade or variation (Proske & Jaeger-Erben, 2019). Put in the words of Van Nes & Cramer (2005), this "can be as simple as changing a battery or a CD" (p. 295). In addition to the ease of changing modules, information should also be provided to the consumer on the functionality of modules, as well as the interdependencies of these modules. For instance, a higher resolution camera might require the user to upgrade his processor (Proske & Jaeger-Erben, 2019). When designing for standardization and compatibility, it is important that the interfaces of the smartphone are compatible with other products and modules. When this principle is applied to the outside interfaces of the smartphone, such as the charging port, the headphone jack and connectivity interfaces, it is less likely that the smartphone becomes incompatible with other products (Munten et al., 2021).

Conclusion

In order to make smartphone repair more attractive to consumers, the feasibility, desirability, and viability of repair should be improved. All five strategies that have been proposed by Van Nes & Cramer (2005) can be assigned to one or more of these three aspects. Smartphone repair can be made more feasible through design for repair and maintenance, by focusing on the disassembly of the product design and provision of repair services. The viability of smartphone repair can benefit from a lower price of repair, as well as decreased obsolescence of the smartphone. The desirability of smartphone repair can increase when designing for product attachment, upgradability, variability, as well as reliability and robustness.

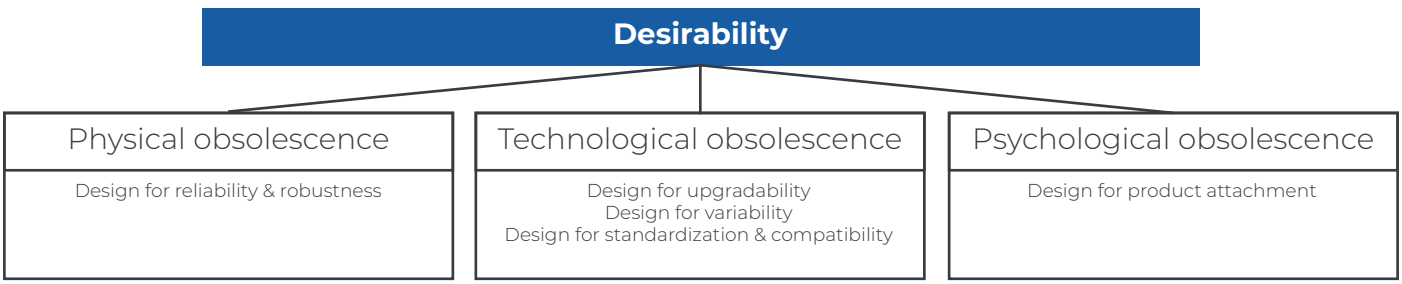


Figure 4.4: Possible solutions to make smartphone repair more viable.

4.2. What role can a PSS play in stimulating repair?

Ackermann et al. (2018) argued that a PSS is suited for integrating several use cycle extension strategies into one offering, because the unique characteristic of a PSS is that it allows the consumer and manufacturer to share the responsibility of product care. A sustainable PSS can therefore deliver benefits to all its stakeholders if it is executed in the right way. Although PSSs have originally been introduced to reach sustainability goals, their implementation do not guarantee sustainable outcomes (Tukker, 2015). Therefore, Vezzoli et al. (2018, p. 41) specifically defined a 'sustainable PSS' as an "offer model providing an integrated mix of products and services that are together able to fulfil a particular customer demand (to deliver a "unit of satisfaction"), based on innovative interactions between the stakeholders of the value production system (satisfaction system), where the ownership of the product/s and/or its life cycle responsibilities remain by the provider/s, so that the economic interest of the providers continuously seek new environmentally and/or socioethically beneficial solutions."

Vezzoli et al. (2018) categorized the potential benefits and downsides of a PSS in those for the environment, society, and the providing company. Beuren et al. (2013) developed a separate category for consumer benefits, which is relevant because these benefits will eventually determine whether the consumer will adopt the PSS or not. This sub chapter serves to explore the current state-of-the-art of PSSs. I discuss what forms PSSs exist in, and what benefits and downsides a PSS can hold for the environment, the consumer, the providing company, and society.

A categorization of PSSs

Tukker & Tischner (2006) defined the core of a PSS as "a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs" (p. 1552). A product can then be defined as "a tangible commodity manufactured to be sold", and a service as "an activity (work) done for others with an economic value and often done on a commercial basis", but the difference between products, services, and PSSs remains ambiguous (Baines et al., 2007, p. 3). Gemser et al. (2012) and Kuijken et al. (2016) argued that whether an offering can be called a product, or a service is based on its level of tangibility and interaction. A PSS then combines two offerings that are located in different places on the matrix of tangibility and interaction. According to Kuijken et al. (2016), a PSS is unique from other types of offerings because the product and service complement each other in a synergetic way, which means that "the whole is valued higher than the sum of its parts" (ibid., p. 3). Gemser et al. (2012) added that both the product and service should serve the same set of user goals.

Tukker (2004) defined three main categories of PSSs, constituting a total of eight different types (see Table 4.5). This categorization is used throughout all literature on PSSs that has followed (e.g. Kuijken et al., 2016; Khan et al., 2018). Product-oriented services are mostly focused on selling a product, whilst adding extra services. Use-oriented services also focus on the product, but not on selling it, as the provider remains the owner of the product. Within result-oriented services, the consumer and the provider agree on a certain outcome, without determining beforehand what the product exactly entails.

Benefits

The most significant environmental benefit of PSSs is that they allow new consumption behaviors to arise, because the focus moves away from acquiring a product to using it (Beuren et al., 2013; Khan et al., 2018). This should decrease the frequency at which consumers purchase a new product for the sake of owning it and should thus eventually lead to the extension of a product's average lifetime (Rousseau, 2020). Upgradability and maintenance PSSs can also take away reasons for obsolescence and thus lead to lifetime extension (Munten et al., 2021). When product lifespans increase, the use of (toxic) (unrenewable) resources is minimized (see Figure 4.6; Vezzoli et al., 2018). Additionally, because the provider is responsible for the takeback of products at the end of a use cycle, waste can be reduced (Beuren et al., 2013).

PSSs allow consumers to provide continuous feedback about their experience, both in terms of verbal communication and sharing performance data. This allows the providing company to continuously improve

PSS type	*Explanation*
Product-oriented services	
Product-related services	Services offered during the use phase of a product.
Advice and consultancy	Advice on how to best use a product.
Use-oriented services	
Product lease	The user has unlimited access to a product that the provider takes care of.
Product renting or sharing	The user has only limited access to a product that the provider takes care of.
Product pooling	A product is used by multiple users at once.
Result-oriented services	
Activity management/ outsourcing	Using performance indicators for outsourcing services.
Pay per service unit	Pay per use of a product.
Functional result	Pay for an abstract result.

Table 4.5: Categorization of PSSs by Tukker (2004).

the offering, whilst it also allows the user to feel empowered (Valencia et al., 2015). The interaction with the PSS provider delivers a more personalized and flexible experience to consumers, which makes them more likely to be satisfied with the offering (Beuren et al., 2013; Riisgaard et al., 2016). For instance, when the product of the PSS breaks down, consumers do not have to invest much time in researching and finding the best repair or replacement option, because the PSS provider does this for them (Vezzoli et al., 2018).

Because PSSs offer a wide variety of benefits to the consumer, integrated into a single solution, a PSS provider has a competitive advantage over the traditional product manufacturers that he competes with (Rousseau, 2020; Tukker, 2015; Vezzoli et al., 2018). Also, a PSS enhances the interaction between company and consumer, allowing the offering to be continuously improved, which increases the customer's trust in the company (Riisgaard et al., 2016), and increases customer satisfaction in general (Vezzoli et al., 2018). A PSS also allows a company to optimize its value chain, because products that have become obsolete for one user can be reused by another user. This makes that production becomes cheaper because less products can be made whilst maintaining revenue. Additional services to the main PSS can also generate extra revenue (Beuren et al., 2013; Riisgaard et al., 2016).

Lastly, PSSs also provide benefits for society at large. Because services generally require more human capital, job opportunities will rise (Beuren et al., 2013). Also, a PSS can offer high quality products and services for a relatively low entry price, which makes that a product or service becomes accessible for more socio-demographic groups (Vezzoli et al., 2018).

Downsides

As stated before, a PSS is not guaranteed to create sustainable environmental effects. The most imminent threat is the rebound effect that a PSS may cause. When consumers do not have to invest much money to use a new product, they are likely to replace a product more often. Also, when users are not the owners of a product, they are likely to be less careful with it (Schneider et al., 2018). Both effects would decrease a product's lifetime. Therefore, a PSS should be designed in such a way that these types of behaviors are prevented.

The main barrier that consumers face when considering adopting a PSS, is its lack of intangible value (Rousseau, 2020). Currently, most consumers prefer to own a product over renting (or leasing, etc.) one, because ownership contributes to self-esteem and the possibility to seek variety and novelty (Tukker, 2015; Bocken & Short, 2016; Baines et al., 2007). Overcoming this barrier requires a cultural shift (Vezzoli et al., 2018). In addition to the lack of intangible value, a PSS can also require consumers to make tangible sacrifices. For instance, a sharing PSS does not guarantee that the user has access to a product anytime he needs it (Tukker, 2015; Poppelaars et al., 2018; Hobson et al., 2019). For smartphone access models, Rousseau (2020) found that consumers want to be compensated for this lack of availability. The

current lack of awareness and understanding among consumers also poses a barrier. Most consumers are not familiar with PSSs and are unknowledgeable about the environmental and societal damage that the traditional purchase of a product may cause (Hobson et al., 2019; Vezzoli et al., 2018). This makes consumers calculate high lifetime costs of PSSs, in relation to little or no benefits (Cherry & Pidgeon, 2018). For instance, smartphone access models often remain unadopted because consumers are unaware or misunderstand them (Poppelaars et al., 2018; Rousseau, 2020).

Despite the promising outcomes of PSSs, they can possibly create more costs for a company whilst not generating extra revenue to compensate for this. This is referred to as the 'servitization paradox' (Kuijken et al., 2016). One of the largest barriers that companies face, is the initial investment to switch from a product focus to a PSS focus. Because asset management becomes more important than resource throughput, a company's business model needs to change. This can only be facilitated by a large investment in time and money (Baines et al., 2007), because more labor will be required, and production costs might increase as well. For instance, producing modular smartphone parts is more expensive than producing regular smartphone parts (Schneider et al., 2018). As it is uncertain whether the large investment will eventually be paid back, the promotion of the organizational change inside the company is difficult (Schneider et al., 2018). Moreover, a PSS requires the manufacturer to take on financial risks that consumers used to take (e.g., having to purchase a new product when the old product is broken beyond repair). This creates uncertainties with regards to cash flow (Vezzoli et al., 2018).

Finally, PSSs can also create societal problems, because PSS providers have greater ability to determine who has access to a product or service and who has not. This decision is often led by financial interests, which leaves lower socio-demographic groups unserved (Hobson et al., 2019). For instance, shared cars are often only available in more affluent, urban areas.

Benefits	*Downsides*
Environment	
Life cycle extension · Minimization of the use of (toxic) (unrenewable) resources Coordinated take back of products · Reduction of waste	Lack of ownership · Likely more often product replacement · Likely less careful
Consumer	
Continuous feedback · Continuous improvements of the offering · Feeling of empowerment Continuous interaction · Satisfaction with the offering · Personalized and flexible experience	Lack of ownership · No self-esteem · No novelty Lack of continuous access · Tangible sacrifices Lack of awareness and understanding · Low perceived price-quality ratio
Company	
Continuous interaction · Increased customer satisfaction · Increased trust in company Coordinated take back of products · Optimized value chain	Change from product to PSS focus · Increased time and economic investment · Increase financial and organizational uncertainties Share of product responsibility · Increased financial risks
Society	
Need for service providers · Increased job opportunities Low entry price · Increased access to products	Ability to decide who has access · Decreased access to PSS for lower socio-demographic groups

Table 4.6: Benefits and downsides of PSS implementation.

4.3. Consumer interviews

During the interviews, I presented three types of repair PSSs: leasing, insurances, and easily repairable devices. Noteworthy is that all participants had similar reactions to the proposed PSSs (see Figure 4.7).

Smartphone leasing

Only one of the participants indicated to have heard of smartphone leasing before. After I had explained the concept, all participants found leasing an interesting option, but not one that they would want for themselves. The main reason for this was that leasing was found to be too expensive, compared to a one-time acquisition. Ron: *"I have this [phone] for, let's say, 3 or 4 years, and it can easily be used for 3 or 4 years more, and well, it was 400 euros. So, let's say, I use it for 6 years. Well, that's 75 euros per year, I think that it won't be possible to lease a smartphone for that price."* Both Isabella and Emma indicated that leasing is just another form of a loan, which is something they would always want to avoid.

Another factor that played a role in their personal rejection of leasing is that the participants thought that they were not the right target group of smartphone leasing. They indicated that leasing would be more interesting for those who cannot pay the full amount at once, and for those who only need to have the phone for a short period of time. These findings are in line with earlier discussed literature (e.g., Vezzoli et al., 2018). However, it is also slightly contradictory that consumers find leasing too expensive on the one hand, but argue that leasing is more suitable for less affluent consumers on the other hand. This makes it relevant to study whether a lease PSS is more interesting for people who can afford it or for people who cannot afford a one-time purchase.

Eventually, participants indicated that if the costs of leasing were to be like those of an one-time acquisition, they would consider it.

Smartphone insurances

All participants were aware of smartphone insurances but indicated that they would never want to have one. Again, the main reason was that insurances are too expensive. The participants indicated that a reasonable price would convince them to buy insurance. Ron found an approximate 10% of the purchase price to be reasonable. Additionally, Ron and Anna indicated that they preferred to be careful with their smartphone, instead of paying a price for not having to be careful. Ron: *"Well, I do consider insurances sometimes, but you can also easily spare money by just not letting the phone drop. Of course, this may happen anyway, but if you are careful with it, [...], and you can also purchase a protective case or a screen protector, that also gets the job done."* Also, Ron indicated to regret that an insurance does not reward him for being careful and not causing any damages. This implies that consumers are more willing to take good care of their smartphone, than paying a price for not having to be careful.

Easily repairable devices

Most participants were unaware of the existence of easily repairable smartphones. When hearing about it, they all indicated that they would be interested in the option. Isabella indicated that this would likely make her use her smartphone for longer, and save costs down the line. She also expected that repairing by herself would be less expensive than letting professionals do it. Both Ron and Anna indicated that they would have some concerns with regards to the functionality

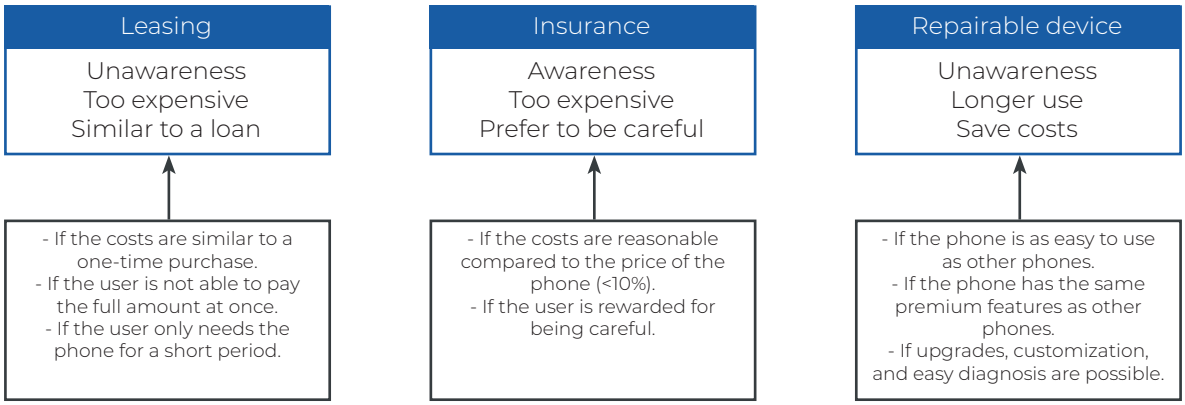


Figure 4.7: First considerations of smartphone PSS options, and conditions for it to be attractive, based on the performed interviews.

of the smartphone. Ron, for instance, knew about the Fairphone and argued that he would not want to have such a smartphone because it does not have premium features. Anna indicated that she would want the repairable smartphone to be as easy to use as other non-repairable phones. On the other hand, Ron also indicated that it would be fine with him to give in on some design elements (e.g., a slightly thicker design) if this would make the smartphone more repairable. Participants also indicated that it would be interesting to be able to upgrade and customize their phones, as well as diagnose any failures by themselves.

Additional services

In addition to the three PSS options, I also proposed three additional services that could come along with the leasing contract of a smartphone (see Figure 4.8). With regards to a temporary replacement device when waiting for repair, the participants expressed two diverging opinions. On the one hand, some thought that it is pleasant to not have to be without a phone when the damaged one is being repaired. On the other hand, some indicated that not having a phone for several days is fine for them. This implies that consumers do not feel the need to have a temporary device, but when it is offered in a convenient way, they might be interested. This is supported by the fact that most participants indicated to keep previous smartphones as backup for when their current phone breaks down. Furthermore, both Anna and Sophia feared that migrating the data from the broken phone to the replacement phone would be too much work. Isabella, on the other hand, found that migrating data is extremely easy.

With regards to device upgrades, the participants indicated that they would not need this per se, but that it would be nice to have. And given that they would already be leasing a smartphone, they would be willing to upgrade their smartphone more easily than they would right now. The main fear that they expressed was that upgrading to a newer model would be expensive.

All participants expressed an interest in personal services. On the one hand, participants liked that the manufacturer would better listen to their customers. On the other hand, participants also liked that they would be able to use their phone even better when they receive personal and honest advice. However, this advice should not be too obtrusive or too frequent. Also, Anna and Isabella indicated that the interests of the manufacturer might not align with theirs, which made them fear that the 'honest' advice of the manufacturer would not be in their interests.

Replacement device	Device upgrade	Personal service
- Difficult **vs.** easy to migrate data - Possible to survive without a phone for a few days **vs.** easy to not have to be without a phone for a few days	- Fun to try out the newest phone **vs.** no need to upgrade often	- Interesting to receive relevant tips **vs.** fear that tips are not in the user's best interest

Figure 4.8: The pros and cons of smartphone PSS options, based on the performed interviews.

4.4. Conclusion

Input for PSS design

- Repair services are currently the most important aspect of repair because most users do not have the knowledge to diagnose or solve a failure on their own. This is not optimal, because receiving the service of a repair professional requires effort.
  Therefore, the PSS should make it easy for the user to diagnose and solve failures on his own, anytime, and anywhere.

- Repair can not only be a method to reverse obsolescence, but also to increase the smartphone's mental book value, because repair and product care possibly allow the user to become emotionally attached to the product.
  Therefore, the PSS should motivate the user to perform (parts of) the repair on his own.

- When a PSS offers easy repair or replacement, the user is more likely to be careless with a product and be willing to replace the product more often. Users are willing to perform responsible behavior but prefer to be rewarded for this.
  Therefore, the PSS should reward users for being careful with their smartphone.

- When a PSS is based on a sharing concept, the lack of ownership and lack of continuous access make the user less satisfied with the offering.
  Therefore, the PSS should provide (a feeling of) ownership, as well as continuous access to the smartphone.

- When a PSS allows the user to make his own decisions and provide feedback to the PSS provider, the user obtains a feeling of personal care and empowerment.
  Therefore, the PSS should allow the user to be independent cocreators of the offering.

Input for future research

- Current literature, as well as consumer interviews, showed that PSSs can both promote access to an offering for certain groups as well as limit the access for the same groups. Therefore, future research should study what target group fits best to each type of PSS.

- Although literature suggested that the maximum repair price should be 30% of the purchase price, it is not clear whether this percentage is accurate as repair is often rejected because of the price, even when it is below 30%. Therefore, future research should study what repair price is both viable for businesses as well as desirable for consumers.

5. Market analysis

5.1. How do manufacturers stimulate repair?

Repairability of product/service offerings

Apart from repair desirability, I apply the repairability framework of Chapter 3.2 to the five case studies of Apple, Samsung, Huawei, Fairphone, and Shift. From Table 5.1, it seems that repair of the iPhone is more feasible than that of the Galaxy and Mate, as the repairability scores of the iPhone 12 Pro Max exceed those of the other two (iFixit, 2020, March 4; iFixit, 2020, November 21; iFixit, 2020, December 7; L'indice de Réparabilité, 2020, October 26; L'indice de Réparabilité, 2020, November 30; L'indice de Réparabilité, 2021, January 19). When we take a further look, however, Apple does not have the upper hand in all feasibility aspects.

First of all, the iPhone and Galaxy turn out to be comparable in terms of disassembly steps and time. Secondly, both Samsung and Huawei provide more help to their users to diagnose failures (Huawei, n.d.-c; Samsung, 2020; Samsung, n.d.-f). Samsung's remote assistance app allows a Samsung employee to take over and inspect the device remotely. The diagnostics apps of both Samsung and Huawei allow users to easily diagnose issues of the phone on their own. Neither remote assistance nor automatic diagnosis is available to iPhone users. Data management, on the other hand, is comparable for all three brands, as transfer and deletion of data take only a small number of steps to succeed (Apple, 2021, April 1; Huawei, n.d.-b).

The repair support that is offered by the three manufacturers is nearly identical. All brands offer the possibility to come by a service center for repair, or send the damaged model in. However, Apple has a major edge over the other manufacturers, because it hosts a significantly higher number of service locations across the Netherlands (Apple, n.d.-b). Samsung and Huawei do compensate for this by offering a quicker send-in service, whereas Samsung even includes a pick-up service of the broken smartphone (Samsung, n.d.-a). Huawei's certified service provider The Fixables offers a pick-up service as well, but only within a ten-kilometer range of its four locations (The Fixables, n.d.-a). All brands offer warranty over the repair, whereas the warranty that Huawei provides is twice as long as the others. The duration for which repair services are offered is relatively similar for Samsung and Apple, but significantly less for Huawei (Apple, 2021, June 14; Samsung, n.d.-d).

When consumers are willing to perform a repair by themselves, none of the three brands offer relevant support. Samsung is the only manufacturer that openly offers spare parts (Mobileparts Shop, n.d.). However, it is currently only possible for businesses rather than consumers to purchase a spare part. With regards to viability, Samsung and Huawei's repair services seem to have a slight edge over Apple's, as they provide both a lower absolute and relative price of repair than Apple does (Apple, n.d.-b; Samsung, n.d.-d; The Fixables, n.d.-b).

The repairability scores of both the Fairphone 3+ and the Shift 6m are relatively high (see Table 5.2; iFixit, 2019, September 11; iFixit, n.d.-b; L'indice de Réparabilité, 2021, January 18). Although iFixit does not provide any screen or battery replacement guides for the Shift phone, the teardown shows

that both phones are comparable in the complexity of disassembly. Furthermore, the disassembly of both phones only requires a Phillips screwdriver, which is even included in the sale of the Fairphone. Failure diagnosis and data management is, however, not supported by Fairphone and Shift as it is by the larger smartphone brands.

Compared to Apple, Samsung, and Huawei, the availability of Fairphone and Shift's repair services is also significantly lower. It is not possible to visit a service center, it is only possible to send smartphones in, for which no indication of service time is given. On the other hand, a major advantage over the large smartphone brands is that spare parts are readily available, with delivery usually being within a few days to a week. Although Shift indicates that there are repair guides available on its website, I have not been able to find these. Fairphone, however, has a clear overview of online manuals and video tutorials that guide people through the process of any repair task (Fairphone, n.d.). Finally, when comparing the prices for repair, these seem comparable for both phones. Although the repair prices of both smartphones are significantly lower than those of Apple, Samsung, and Huawei, the price of repair relative to the price of replacement is similar (~20% for the display and ~5% for the battery).

Additional product/service offerings

In addition to the repairability of the smartphone itself, Apple, Samsung, and Huawei also offer a wide variety of service options that may influence the decision of consumers to choose for repair or replacement. Table 5.3 shows that the service offerings of the three manufacturers do not differ significantly on most aspects. With regards to service options at the point of purchase, all brands offer the possibility to trade in old models (Apple, n.d.-a; Huawei, n.d.-c; Samsung, n.d.-e). Huawei and Samsung offer a better service here, as they offer the option to trade in both smartphones and tablets from other manufacturers as well. The amount of trade-in discount does not differ significantly as they all range from €0 for the oldest models, up to €500-€700 for the most recent models. Both Apple and Samsung offer additional insurances that cover the repair of accidental damages by the consumer, while Huawei does not provide this (Apple, n.d.-c; Samsung, n.d.-b). Within this insurance, Apple provides a temporary replacement device for free, given that the repair falls within the insurance or general warranty. Samsung seems to be the only brand that offers a private lease option for its smartphones (Samsung, n.d.-c). It includes both an initial payment and a monthly payment, of which

		Apple iPhone 12 Pro Max *2020, November 13* *€1.262,10*	**Samsung Galaxy S20 Ultra** *2020, March 15* *€1.349,00*	**Huawei Mate 40 Pro** *2020, November 1* *€1.199,99*
iFixit Repairability Score		6	3	4
Indice de Réparabilité Score		6	5,7	5,6 ***
Repair feasibility				
Ease of disassembly	Steps Time	27 (42) * 1-2h	31 (38) * 30 min. - 1h (45 min. - 2h) *	n/a n/a
Ease of failure diagnosis	Steps Time	n/a n/a	4 (diagnostics app) / 8 (remote assistance) 5 min. / 15 min.	4 (diagnostics app) 5 min.
Ease of data management	Steps Time	7 10 min.	3 10 min.	3 10 min.
Availability of repair services	Proximity Time Duration	50+ locations 1 day (6-8 days) ** 9 years after release	5 locations 1 day (2-3 days) ** 10 years after release	4 locations 1 day (3 days) ** 4 years after release
Availability of spare parts	Steps Time Duration	n/a n/a n/a	8 (only for businesses) 1 day 10 years after release	n/a n/a n/a
Availability of repair information	Amount Type Duration	n/a n/a n/a	n/a n/a n/a	n/a n/a n/a
Repair viability				
Price of repair	Spare parts Repair service	n/a €75 (€361,10)	n/a €69 (€289)	n/a €60 (€260) ****
Price of replacement	Replacement	€1.262,10	€1.349,00	€1.199,99

*Table 5.1: Feasibility and viability of smartphone repair by Apple, Samsung, and Huawei (n/a = no information available). *The first one refers to the battery, and the one in brackets to the display. ** The first one refers to the service locations, and the one in brackets to the send-in service. *** This refers to the Mate 30 Pro, which is similar to the Mate 40 Pro. **** This refers to the Mate 20 Pro, which is similar to the Mate 40 Pro.*

		Fairphone 3+ *2020, September 14* *€439*	**Shift 6m** *2018* *€555*
iFixit Repairability Score		10	9
Indice de Réparabilité Score		8,7	n/a
Repair feasibility			
Ease of disassembly	Steps Time	9 (4) * 5-10 min. (1 min.)	n/a n/a
Ease of failure diagnosis	Steps Time	n/a n/a	n/a n/a
Ease of data management	Steps Time	n/a n/a	n/a n/a
Availability of repair services	Proximity Time Duration	Send-in only n/a n/a	Send-in only n/a n/a
Availability of spare parts	Steps Time Duration	4 2-5 days n/a	4 3-7 days n/a
Availability of repair information	Amount Type Duration	High Videos and manuals n/a	n/a n/a n/a
Repair viability			
Price of repair	Spare parts Repair service	€29,95 (€89,95) n/a	€19 (€99) n/a
Price of replacement	Replacement	€439	€555

Table 5.2: Feasibility and viability of smartphone repair by Fairphone, and Shift (n/a = no information available).

the price is dependent on the model that the user picks. The lease model lasts two years and includes a Protection Plan that covers repair of damages and replacement when the phone is stolen, both being free of charge. After six months, the consumer may decide to upgrade to a newer model, which requires an additional payment and possibly changes the price of the monthly payment.

	Apple	*Samsung*	*Huawei*	*Fairphone*	*Shift*
Trade-in	iPhones only	Smartphones and tablets from most major brands	Smartphones and tablets from most major brands	n/a	n/a
Insurance	€99-229, for 2 years (max. 4 claims, with deductibles of €29-99), with a replacement service.	€79-149, for 2 years (max. 2 claims, with deductibles of €35-59)	n/a	n/a	n/a
Leasing	n/a	€99 + 24 * €30-49, for 2 years, with insurance, and upgrade	n/a	n/a	n/a

Table 5.3: Overview of additional services offered by Apple, Samsung, Huawei, Fairphone, and Shift.

5.2. How do retailers stimulate repair?

Repairability of product/service offerings

Table 5.4 shows that the repair services of retailers are more widely available than those of mobile service providers (Azerty, n.d.-a; Belsimpel, n.d.-a; Ben, n.d.; Bol, n.d.; Coolblue, n.d.-c; Fixtel, n.d.; Hollandsnieuwe, n.d.; KPN, n.d.-a; MediaMarket, n.d.-a; Simyo, 2017; Tele2, n.d.; T-mobile, n.d.-b; Vodafone, 2018; Youfone, n.d.). Coolblue, MediaMarkt and Mobiel have a significant edge over the other retailers and mobile service providers, as they offer the option to repair the product in a service centre within a couple of hours. Also, they present a model specific price list on their websites for all repairs that they perform. These price lists showed that MediaMarkt and Mobiel do not offer repair services for all smartphones that were studied in Chapter 5.1. For Coolblue and MediaMarkt, it is also possible to send in the product for repair and receive it again within a couple of days. Mobile service providers offer less viable repair, as none of them offer a prior indication of repair costs, and charge research costs when the consumer does not agree with the eventual repair costs. Also, most service providers do not show how long the repair will take, only KPN predicts a period of 1-5 days and T-mobile a period of 2 weeks.

Additional product/service offerings

Coolblue and MediaMarkt are the only retailers that provide trade-in discount, whilst Bol and Azerty do offer trade-in options, but without any discount (Coolblue, n.d.-a; MediaMarkt, n.d.-b; Azerty, n.d.-b). About half of the retailers provides additional smartphone insurances (Belsimpel, n.d.-b; Coolblue, n.d.-b; KPN, n.d.-b; Mobiel, n.d.; T-mobile, n.d.-a; Vodafone, n.d.). They all offer

		Bol	Coolblue	MediaMarkt	Mobiel (Fixtel)	Belsimpel	Azerty	Simyo	Simpel	Hollandsnieuwe	Youfone	Ben	KPN	T-mobile	Vodafone	Tele 2
Repair feasibility																
Availability of repair services	*Proximity*	n/a	10*	50*	3*	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	*Time**	n/a	<2h	<2h	±30m	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		±15d	n/a	<5h	<2d	5-10d	n/a	n/a	n/a	n/a	n/a	n/a	1-5d	2w	n/a	n/a
	Duration	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Repair viability																
Price of repair	*Repair service*	n/a + €19,95	A: €75 (€369) S: €79 (€299) H: n/a (n/a)	A: n/a (n/a) S: n/a (€289) H: n/a (n/a)	A: n/a (n/a) S: n/a (n/a) H: n/a (n/a)	n/a	n/a	n/a	n/a	n/a + €36,30	n/a + €29,95	n/a + €42,50	n/a + €42,51	n/a + €36,30	n/a + €36,30	n/a + €36,30

*Table 5.4: Feasibility and viability of smartphone repair by retailers and mobile service providers. (n/a = no information available). * The upper row refers to service time at service timers, the lower row refers to service time of the send-in service.*

	Swapphone	Commown	Bol	Coolblue	MediaMarkt	Mobiel (Fixtel)	Belsimpel	Azerty	Simyo	Simpel	Hollandsnieuwe	Youfone	Ben	KPN	T-mobile	Vodafone	Tele 2
Trade-in	n/a	n/a	n/a	V iPhone	V all phones	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Insurance	n/a	n/a	n/a	V 1-2 years; damage and / or theft	n/a	V monthly; damage and / or theft	V monthly; damage and / or theft							V monthly; damage and / or theft	V monthly; damage and / or theft	V monthly; damage and / or theft	
Leasing	V Apple and Samsung models	V Fairphone	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

*Table 5.5: Overview of additional services offered by retailers and mobile service providers * The upper row refers to service time at service timers, the lower row refers to service time of the send-in service.*

the options of insuring against damage and/or and theft. Furthermore, KPN provides its (business) customers with a temporary replacement device when their smartphone gets stolen or damaged. Finally, none of the traditional retailers provide the option to lease the smartphone. Most mobile service providers, and some retailers, however, do offer the option to pay in monthly installments.

With regards to leasing, the two exemplary case studies of this sub chapter come into play, as both are leasing companies. Swapphone provides several models of Apple and Samsung, while Commown only offers the Fairphone (Commown, n.d.; Swapphone, n.d.). Swapphone does not provide insurance, but charges €50 for replacing a damaged smartphone, and €150 for replacing a stolen smartphone. The replacement device arrives within 24 hours at the customer's home. After 4 months of leasing, the possibility is offered to upgrade to a new device, within the same contract. The information that Commown provides on its website does not address all repairability aspects that are studied in this chapter, but they do offer a unique lease model: when a user leases the phone for more than two years, he is rewarded with a 30% discount in the coming years. Also, if the consumer does not need to, or choose to, repair during these two years, the customer will also receive a 10% discount on the lease price of those past two years.

5.3. How do other repair parties stimulate repair?

Repairability of product/service offerings

In addition to repairing the product at the retailer or manufacturer, there are several other options that consumers can choose from when repairing their smartphone. A common option is to let a local repair professional perform the repair. Additionally, there are also repair cafés. These are get-togethers that are organized several times a month, where consumers can bring in any broken product and let a local member of the community repair it. The largest benefit of this is that repair is completely free of charge, apart from purchasing potential replacement parts. There are several websites that provide replacement parts of smartphones. iFixit is one of those and provides replacement parts for different types of electronic products.

When comparing the repair options, the two repair stores in Delft are similar to each other when it comes to the service they offer in their shops (GSM Paradise, n.d.; Telgefixt, n.d.; see Table 5.6). One of the stores provide the additional possibility to send the smartphone in and return it within 2 days after being repaired. Prices seem to be similar for both shops, but also here, not all smartphones of Chapter 5.1 are supported for repair. The repair café in Delft is only held twich a month (Delft voor Elkaar, n.d.). This means that consumers cannot visit a repair café when they are in immediate need of a repair. iFixit provides spare parts, but again, parts for the Samsung Galaxy S20 Ultra and the Huawei Mate 40 Pro are not provided (iFixit; n.d.-d).

		GSM Paradise Delft	*Telgefixt Delft*	*Repair Café Delft*	*iFixit*
Repair feasibility					
Availability of repair services	*Proximity*	City center	Suburb	Suburb	n/a
	Time	60 minutes	60 minutes	2 / month	n/a
		2 days	n/a	n/a	1-2 weeks
	Duration	n/a	n/a	n/a	n/a
Repair viability					
Price of repair	*Repair service*	A: n/a (n/a) S: €69 (€299) H: n/a (n/a)	A: €79 (€399) S: n/a (n/a) H: n/a (n/a)	n/a	A: €79 (€399) S: n/a (n/a) H: n/a (n/a)

*Table 5.6: Feasibility and viability of smartphone repair by other repair parties. * The upper row refers to service time at service timers, the lower row refers to service time of the send-in service.*

5.4. Conclusion

Input for PSS design

- Transfer, deletion, and back-up of data only requires a small number of steps, which the smartphone manufacturers explain clearly on their websites. This provides the user with no reason to omit repair.
  Therefore, the PSS should make the user aware of the ease of data management.

- Fairphone provides an example of making repair information publicly available by providing help with failure diagnosis, as well as providing explainer videos and manuals with photos of repair.
  Therefore, the PSS should make videos and manuals available for the user to perform the repair by himself.

- Commown provides an example of rewarding a user for responsible behavior, by providing discounts for long ownership and not needing repair. Although Commown does not have profit motives, it does show that it is possible for a company to sustain itself when rewarding users for responsible behavior.
  Therefore, the PSS should reward the user for acting responsibly.

- Several retailers and mobile service providers do not provide a prior indication of repair costs and service time, which makes repair extremely infeasible and unviable.
  Therefore, the PSS should allow the user to compare the repair costs and service times of all repair options.

- Repair cafés offer potential for users to repair their products for a low price (or even for free), while also getting in touch with new people. However, the major downside is that they are only being held a couple of times a month.
  Therefore, the PSS should allow community interaction anytime, anywhere.

Input for future research

- For the purpose of this study, I left out repair desirability. However, because technological and psychological obsolescence reasons are more significant determinants of obsolescence than physical obsolescence reasons, repair desirability might be the most important aspect of repairability. Therefore, future research should hold a comparative study on the repairability of smartphone models by using the entire framework as proposed in Chapter 3.2.

- In addition to studying the theoretical repairability of different models, it might also be valuable to compare the likeliness that consumers choose for repair of different models. This might show what aspects of repairability contribute the most to the consumer's decision to repair or replace.

- On the hand, trade-in services by a smartphone manufacturer help a smartphone to become economically obsolete more quickly. On other hand, because trade-in services offer the highest reward for intact devices, it also motivates the user to be careful with his smartphone, whilst possibly providing a second life to the device. The same contradiction applies to selling a smartphone second-hand. Therefore, future research should study whether trade-in or second-hand sale eventually has a positive or negative effect on the environment.

6. Design methodology

In order to reach the main research objective of this thesis (developing a smartphone PSS that stimulates consumers to choose for repair over replacement), I perform four design iterations and two tests. I start by using the findings from the problem exploration, solution exploration, and market analysis as input for idea generation. Based on the feasibility, viability, and desirability parameters from Chapter 3.2, I choose the most promising ideas and combine these into four concepts. I then tested the concepts with consumers, based on which I draw a conclusion for choosing the final concept. After further development of the final concept, I tested it again. This test allowed me to make a final iteration of the concept and define its limitations as well as recommendations for future research. Before I discuss the methodology of the design iterations and user tests, I first address the theoretical framework that I used to design the PSS.

Theoretical framework

Gemser et al. (2012) defined three primary approaches to develop a PSS (see Table 6.1). The most common approach is servitization, which is the addition of services to existing products. The second approach is productization, which is the addition of products to existing services. The third approach is building a PSS from scratch, by offering a combination of new products and new services. Gemser et al. argued that this last approach is best suited for optimizing consumer benefits, profit, and sustainability. Therefore, in this thesis, I choose to develop a PSS from scratch. However, I need to pay attention to the financial and organizational risks that this approach may hold, because this is the reason that many companies currently choose for servitization or productization when implementing a PSS.

An extensive number of methods have been proposed throughout academic literature to design PSSs. Most of these methods hardly differ from product design or service design methods because all of them eventually come down to methods of creating value for both customer and company (Vasantha et al., 2011). According to Morelli (2002), what differentiates PSS design from traditional product (or service) design, is the interaction between the design of the product/service and their management. Within a PSS, user feedback provides the company continuous input for optimizing its offering. This means that the value proposition of a PSS can be continuously enhanced, rather than just before the launch of a traditional product. As described by Haber & Fargnoli (2017), the initial steps of the PSS design process are relatively similar to those of a product or service design process, consisting of ideation, concept development, detailed development, testing, and market launch. In this thesis, I follow these steps up until market launch, the only difference being that I included an extra consumer testing phase in between concept development and detailed development. The reason for this is

Approach	*Definition*
Servitization	Adding services to existing product offerings.
Productization	Adding products to existing service offerings.
PSS from scratch	Developing a combination of new products and new services

Table 6.1: Three approaches to develop a PSS (Gemser et al., 2012).

that the main research objective of this thesis is focused on the consumer, which means that they are the most significant stakeholder. Because the incorporation of user feedback after market launch is vital to the success of a PSS, I provide a roadmap in the final concept that explains how this should be done.

Ideation

The main purpose of ideation is to develop as many ideas as possible that potentially stimulate repair. For this, I used the main repair considerations from the problem exploration (i.e., convenience, certainty, price, and performance) as input. To develop a variety of solutions, I created separate ideas for each consideration, where I differentiated between product design, service design, and marketing strategies. The ideation process was primarily carried out by myself, but in order to optimize the variety of ideas, I also organized a creative session with four graduation students at the Faculty of Industrial Design Engineering. During a two-hour online session, I explained the four repair considerations to the participants, after which I allowed them to work in groups of two to create ideas for each consideration, and later present their ideas to the rest of the group.

Concept development

During the concept development phase, the primary goal is to create a value proposition for all relevant stakeholders, where I focus on both customers and a fictional company that would carry out the production and management of the PSS. Based on the repair feasibility, viability, and desirability parameters, I chose a variety of ideas to combine into four different concepts. The four concepts are developed in terms of a storyboard, persona, and stakeholder map.

Concept testing

The interview participants from the research part of this thesis were interviewed again to test the four concepts. The goal of these tests was to understand which concept direction would hold the most potential to stimulate consumers to choose for repair over replacement. The tests were held as unstructured interviews with the guidance of a questionnaire. In the questionnaire, I asked the participating consumers to rate all four concepts on the feasibility, viability, desirability, and probability of repair (see Appendix B). Based on the answers they provided to this questionnaire, I asked why they had chosen specific answers. In addition to the consumer tests, I also discussed with the experts from iFixit and the Consumentenbond to what extent they thought that the concepts matched repair feasibility, viability, and desirability. Furthermore, I asked them how feasible they thought that the concepts would be for a company to carry out. Based on input by both the consumers and experts, I choose to combine two concepts into one and used this as the starting point for detailed development.

Detailed concept development

In the detailed development phase, I used several methods to develop the final concept that I could test with users. Based on the feedback that consumers and experts provided during concept testing, I enhanced the usage scenarios and developed a flowchart and mock-ups of the app design.

Detailed concept testing

In order to evaluate to what extent the developed concept stimulates consumers to choose for repair of their smartphone over replacement, a final user test was conducted. The final concept is a smartphone app that incorporates failure diagnosis, failure solution and failure prevention. The tests consist of interviews during which participants try out the main functionalities of the app. The interview participants are listed in Table 6.2. During the interviews, I provided users with three scenarios (see Appendix C). In the first scenario, the user has been experiencing issues with his smartphone for a longer time: the smartphone has been shutting down on random occasions, and the user finally decides to see whether he can do something about it. This scenario tests the failure diagnosis functionality of the app. For failure diagnosis, I have drawn up four hypotheses to test during the interviews (see Table 6.3). In the second scenario, the user breaks the smartphone's screen and is looking for an immediate solution. This scenario tests the hypotheses about the failure solution functionality of the app. In the third and final scenario, the user has just purchased a new smartphone and wants to enjoy it for as long as possible, so he downloads the app to find out how to do this. This scenario tests the hypotheses I have formulated for the failure prevention functionality of the app.

In order to engage the participants in the scenarios as much as possible, I

	*Veronica**	*Martin*	*Laura*	*Emma*
Gender	Female	Male	Female	Female
Age	22	22	25	59
Occupation	Student	Student	Student	Unemployed
Smartphone				
Model	Samsung S10	OnePlus 5t	Samsung S10e	iPhone X
Age	2 years	3-4 years	2 years	2-3 years
Purchase price	€600	€400	€400	€1000

*Table 6.2: Overview of interview participants. *The provided names are fictional, in order to ensure full anonymity.*

incorporated their city of residence and current smartphone model in the app screens (e.g., by providing the actual repair prices of their smartphone model in their neighbourhood). During the interviews, I first read out the scenario text, and then showed the initial screen of the repair app and let the user decide what buttons to press. When the users interacted with the app, I asked them why they decided to press certain buttons, as well as what influence the app had on their perception and willingness of repair.

Final concept development

After final testing, I performed a final iteration of concept development, where I focused on the feasibility, viability, and desirability of the concept (see Table 6.4). Note that these three aspects do not relate to repair feasibility, viability, and desirability as defined by me in Chapter 2, but rather to the design principles as defined by Calabretta et al. (2016). For the desirability of the concept, I used the insights that the users provided in the final tests to further define what value the PSS concept can offer to consumers. This includes a final development of the usage scenarios, flowcharts, app mock-ups, personas, and customer journey maps. For the feasibility of the concept, I developed a roadmap, stakeholder map and marketing strategy. The business model then provides insight in the viability of the concept. It must be noted that feasibility, viability, and desirability partly overlap (ibid.), which means that the included design aspects are not only part of the design principles that I ascribed them to. Rather, Table 6.4 should be interpreted as the overall categorization of the design aspects, where the design aspects can partially belong to the other design principles as well.

Design principle	*Included design aspect*
Feasibility	Roadmap; stakeholder map; marketing strategy
Viability	Business model
Desirability	Usage scenarios; flowcharts; app mock-ups; personas; customer journey maps

Table 6.4: Included design aspects for the final concept.

	Hypotheses
Hypotheses about failure diagnosis (FD)	
H-FD1	FD makes it easier for a user to understand a smartphone's failure. *
H-FD2	FD makes it more likely that a user tries to understand a smartphone's failure.
H-FD3	FD convinces a user of the underlying problem behind the smartphone's failure.
H-FD4	FD makes it more likely that a user chooses for repair.
Hypotheses about failure solution (FS)	
H-FS1	FS's provided repair options make a user doubt whether repair is worth the price.
H-FS2	FS's comparison between repair and replacement makes a user aware of the lack of significant differences between models.
H-FS3	FS's comparison between repair and replacement convinces a user to choose for repair over replacement.
Hypotheses about failure prevention (FP)	
H-FP1	FP's prevention tips provide a user with new insights about prevention.
H-FP2	FP's prevention tips make a user more likely to perform product care.
H-FP3	FP's prevention products marketplace makes a user more likely to purchase a product.

*Table 6.3: Hypotheses per functionality of the final app concept. * When comparative words are used without explicit statement of the comparison that is being made, I refer to a comparison between the use of the app and not using the app.*

7. Results

7.1. Ideation

During ideation, I developed a total of 47 ideas that have the potential to stimulate consumers to choose for repair over replacement. In terms of convenience, I developed ideas that provide consumers with a temporary replacement device during repair, help consumers with data management, or take away the need to visit a repair shop (see Figure 7.1). In order to take away any uncertainty, I developed ideas that bring the duration of repair down or provide information about the likely outcome and possible options of repair. In terms of price, I created ideas that allow consumers to pay for repair over a longer period of time, as well as ideas that make the price of repair (seem) lower. With regards to performance, I created ideas that make a smartphone upgradable, provide an easy way to sell smartphones second-hand, or make repair more popular in general.

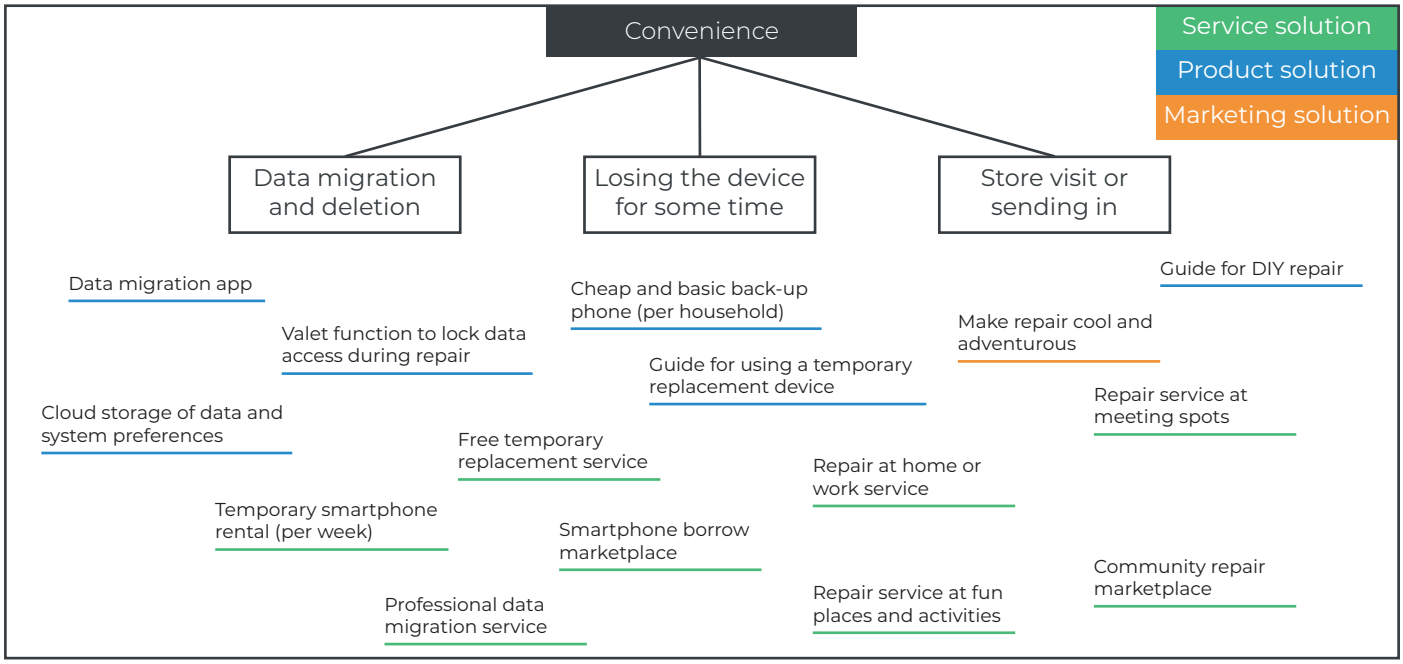


Figure 7.1a: Overview of generated ideas to make smartphone repair more attractive.

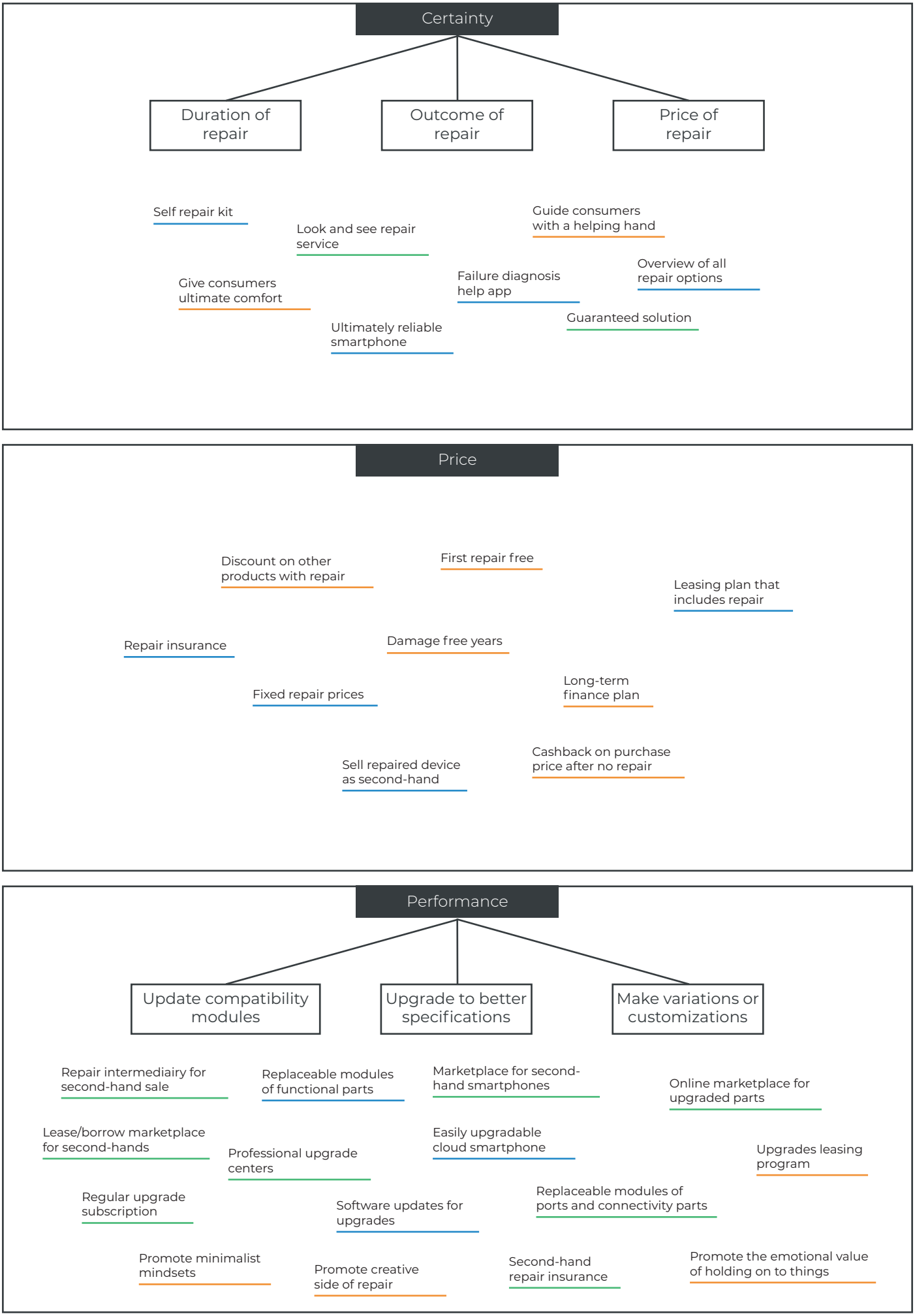


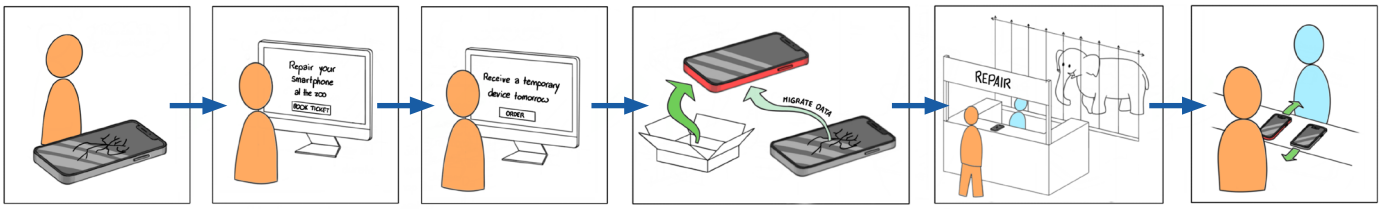
Figure 7.1b: Overview of generated ideas to make smartphone repair more attractive.

7.2. Concept development

By paying attention to the similarities and dissimilarities among the created ideas from Chapter 7.1, I developed four different concept directions. One theme that I identified among the ideas, is making repair an engaging experience. I developed this theme into the Repair Adventures concept. The second theme that I identified is the creation of a long-term financial commitment in combination with upgrades: the Repair and Upgrade Service. The third theme is focused on community interaction, where consumers can sell their second-hand smartphone on a marketplace and offer repair services to each other: the Repair Marketplace. The final theme includes an app that provides all required information that a consumer may need to choose for repair: the Ultimate Repair app.

7.2.1. Repair Adventures

Repair Adventures is a platform that brings together local repair professionals and smartphone users, at entertaining locations. At the point that the user's smartphone breaks down, he visits the Repair Adventures website and sets an appointment with a local repair professional. For this appointment, the consumer does not visit a local repair shop in town, but instead, he visits one of the locations that is being offered by the platform, such as the zoo, a museum, or an amusement park. On those days that the repair professional has Repair Adventures appointments, he sets up a pop-up repair shop at the arranged location.



The display of the user's smartphone has cracked

He discovers that Repair Adventures provides a free ticket to the zoo if he choose to repair his phone there.

The user books a ticket for next Sunday. In the meantime, he orders a temporary device for €10.

The temporary device arrives the next day. He migrates the data from his broken phone to the temporary device.

At the zoo, the repair professional looks at the phone and determines that he can repair the display for €180 in 1 hour. The user agrees.

After an hour has passed, the user picks up his repaired phone and returns the temporary device.

Persona

Age 25-40 years old
Priorities 1. Family; 2. Friends; 3. Work
Lifestyle Busy with kids

Wishes
- Their phone should always work, so others can reach them.
- When their phone breaks down, a replacement should be there as soon as possible.

Dealbreakers
- Finding the solution to the breakdown should not take too long.
- Performing the repair should not take too much effort.

Stakeholders

Company (Repair Adventures)

Benefits Charging a percentual fee for each repair that is being performed.
Requirements Building a platform and creating partnerships with repair professionals and location hosts.

Smartphone users

Benefits Having a reason to go out on an adventure and spend time with family and friends, and not having to visit a repair shop in town.
Requirements Visiting the website and making an appointment with a repair professional. In the case of ordering a temporary device, migrating data from the broken phone to the temporary phone.

Local repair professionals

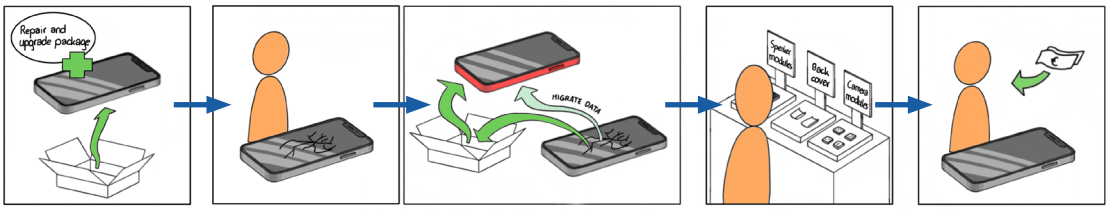
Benefits Attracting extra customers who would not have chosen for repair otherwise.
Requirements Being present at the assigned locations when needed and managing appointments on the website.

Location hosts

Benefits Attracting extra customers who would not have chosen to visit the location otherwise. These customers might purchase food, drinks, or souvenirs, and might be inclined to come back more often.
Requirements Allowing and providing a place for local repair professionals to host a pop-up repair shop on their site.

7.2.2. Repair and Upgrade Service

The Repair and Upgrade Service is an insurance package for smartphones that not only includes repairs but also upgrades. When the customer purchases a new smartphone for a one-time price, he can choose to pay an additional monthly fee, which allows him to get his smartphone repaired whenever he needs, free from any costs. Every year, the customer may also choose an upgraded module (e.g., camera) that a professional from the store will install for him.



The user purchases a new phone. For €15 a month, he pays for the Repair and Upgrade service.

The display of the user's smartphone has cracked.

A temporary device arrives the following day, and the user sends the broken smartphone in. After a week, he receives the repaired phone back.

Every year, the user may choose to upgrade one of the smartphone's parts for free.

If the user does not make any upgrades or repairs for a year, he receives a share of his monthly payments back.

Persona

Age 20-30 years old
Priorities 1. Job; 2. Friends; 3. Family
Lifestyle Busy with work

Wishes
- Their phone should always work, so others can reach them.
- Their phone should always be up to date with the latest trends.

Dealbreakers
- The phone should not perform worse or go out of fashion.
- Finding the solution to the breakdown should not take too long.
- Performing the repair should not take too much effort.

Stakeholders

Company (smartphone manufacturers)

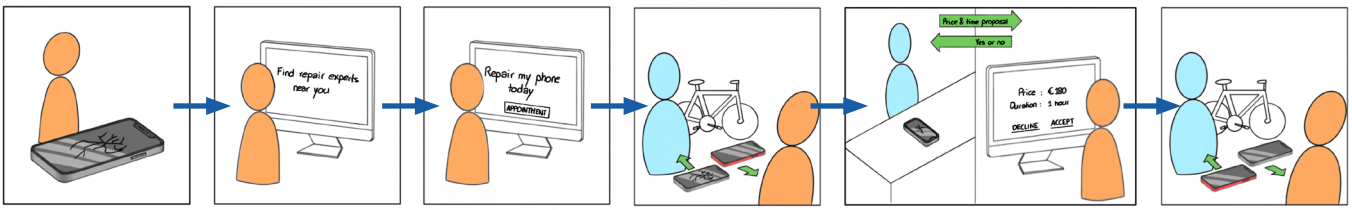
Benefits Building long-lasting relationships with customers and receiving regular payments from them.
Requirements Designing and manufacturing easily repairable and upgradable smartphones and changing its business model to keep customers in the regular payment plan for as long as possible.

Smartphone users

Benefits Having a reason to go out on an adventure and spend time with family and friends, and not having to visit a repair shop in town.
Requirements Visiting the website and making an appointment with a repair professional. In the case of ordering a temporary device, migrating data from the broken phone to the temporary phone.

7.2.3. Repair Marketplace

The Repair Marketplace is a platform that connects smartphone users with nearby repair experts. Whenever a smartphone has a physical failure, consumers can make an appointment with a repair expert nearby, including both local repair professionals and community members who have repair expertise. The broken smartphone is picked up by a bike messenger at a time and place that the consumer decides, and it is delivered again after repair. In addition to repair, the marketplace also allows consumers to sell their smartphone second-hand.



The display of the user's smartphone has cracked

He discovers the Repair Marketplace and finds a local repair shop.

He makes a repair appointment for later that day.

A bike messenger picks up the phone and delivers it at the repair shop.

After receiving the phone, the repair expert diagnoses the failure and determines that he can perform the repair within 1 hour for €180.

After repair, the bike messenger delivers the repaired phone back to the consumer.

Persona

Age 30-50 years old
Priorities 1. Job; 2. Family; 3. Friends
Lifestyle Busy with work

Wishes
- Their phone should last for as long as possible.
- Repair should be as easy, quick, and effortless as possible.

Dealbreakers
- Repair of the phone should not cost too much.
- Repair should not take too long.

Stakeholders

Company (Repair Marketplace)

Benefits Charging a fee for each repair or sale that is arranged through the platform.
Requirements Building a platform that allows users, buyers, and repair professionals to interact, and partnering up with local bike messengers.

Smartphone users

Benefits Putting in as little effort as possible for repair and being able to sell the smartphone second-hand when repair is not attractive.
Requirements Interacting through the platform.

Second-hand smartphone buyers

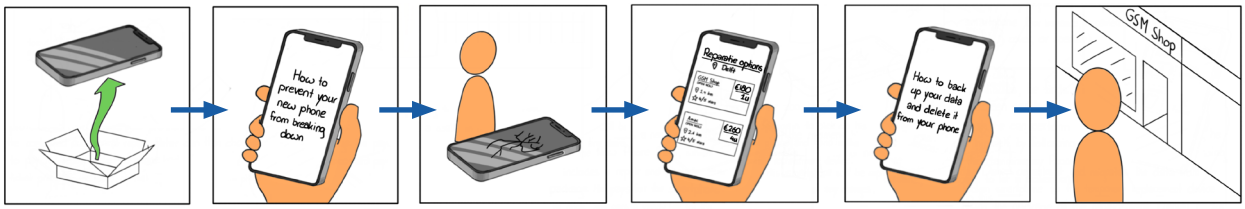
Benefits Purchasing a cheap smartphone that has been checked and approved by a professional.
Requirements Interacting through the platform.

Community repair experts

Benefits Helping other consumers and being part of a community.
Requirements Interacting through the platform.

7.2.4. Ultimate Repair app

The Ultimate Repair app is a free smartphone application that is included in the automatic installation of every newly manufactured smartphone. The app shows how the user can prevent the smartphone from breaking down. At the point that a failure has occurred, the app conducts failure diagnosis and shows what options are available to the user to repair his smartphone.



The user purchases a new smartphone.

When using the phone for the first time, the app shows how the user can prevent failures.

The display of the user's smartphone has cracked.

The app shows what options are available for repair.

The app also shows how the user can make sure that his data will not be lost or stolen during repair.

After choosing a repair option, the user visits the repair shop of his choice.

Persona

Age 40-60 years old
Priorities 1. Friends; 2. Job; 3. Family
Lifestyle Relaxed

Wishes
- They would like to know more about the functionalities of their smartphone.
- Their phone should be easy to use, and failures should be easily diagnosable.
- Their phone should last for as long as possible.

Dealbreakers
- Repair of the smartphone should not take too much effort.
- The outcome of repair should not be uncertain.

Stakeholders

Company (Ultimate Phone app)

Benefits Charging a fee for each repair that is arranged through the app.
Requirements Gathering the required knowledge to create the platform and lobbying at legislative authorities to force smartphone manufacturers to install the app on all smartphones.

Smartphone users

Benefits Receiving clear information on the prevention and repair of failures, which saves them time and effort to search for this information themselves.
Requirements Using the app.

Local repair professionals

Benefits Attracting extra customers to their repair shops.
Requirements Setting up a profile, promoting their store and interacting with customers.

Legislative authorities

Benefits Promoting sustainable consumption behaviour.
Requirements Being convinced by the app's lobbyers to put it on their agenda.

7.3. Concept testing

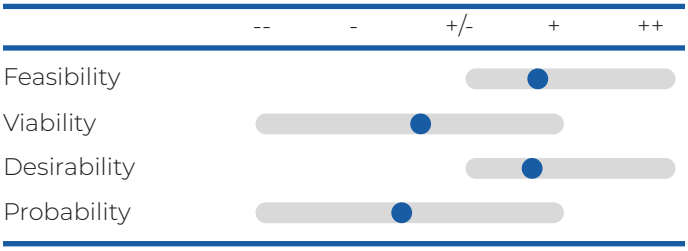


Table 7.2: Consumer scores of Repair Adventures. The blue dot represents the average score of all participants, the grey rectangle represents the entire range of scores.

Repair Adventures

When testing all four concepts with consumers, participants indicated that Repair Adventures makes repair somewhat feasible and desirable, but not viable (see Table 7.2). Mainly the lack of viability made consumers argue that they would not be likely to use the service. Combining repair with going on a trip was found to be efficient, but only when they would already have planned such a trip anyway. Most respondents argued that they would not order a temporary replacement device because they would not need one, transferring data would be too much trouble, and they would still be able to use an old phone if they really wanted to have a temporary device. Only Isabella expressed interest in ordering a temporary device, because she thought that it would be *"perfect so that her colleagues could reach her"*. From her point of view, transferring data would not be needed for such a short time span.

With regards to viability, consumers recognized that Repair Adventures would provide them with a free ticket to the zoo, but they were afraid that the ticket price would still be secretly included in the repair price. Participants indicated, however, that they would not worry about this when other repair options are just as expensive. Still, most respondents found the example of €180 too high, as only Isabella found this to be a reasonable price.

All consumers indicated that having something fun to do while waiting for repair makes repair more interesting. For instance, Isabella suggested that participating in a walking tour through the city centre while waiting for repair would also make her more willing to visit a repair shop in town. Participants also recognized the fun aspect of the service and liked that they would receive something extra when choosing for repair.

From a business point of view, both Peter and Edward indicated that it is possible to create a small pop-up store at several locations, as the repairer only needs a small, dust-free surface to perform the repair on. Peter suggested that Samsung's repair van is the proof that this is possible. Both Peter and Edward did suggest, however, that it is important to require customers to make an appointment with a specific indication of the problem, so that the repairer can take the right equipment and parts with him.

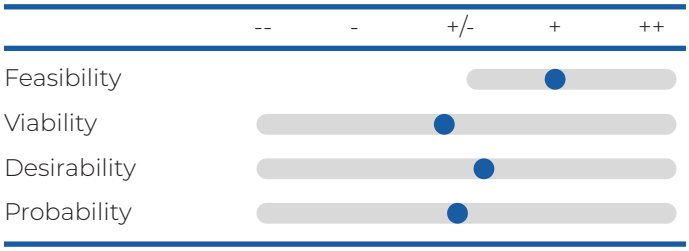


Table 7.3: Consumer scores of the Repair and Upgrade Service.

Repair and Upgrade Service

The Repair and Upgrade Service seems to make repair feasible, but not so viable or desirable (see Table 7.3). Most consumers indicated that they would not be likely to use the service, but when they would use it, they would certainly choose for repair. With regards to feasibility, all respondents indicated that not having to think about repair issues provides ultimate comfort. Some of the respondents did find, however, that sending in a smartphone is a bit too complicated. Visiting a repair shop was thought to be easier.

All consumers mentioned that they find this service similar to an insurance and all of them, except for Isabella, repeated from the earlier interviews that they think of insurances as a waste of money. However, receiving cashback after careful use did make the service more interesting than a regular insurance. Both Ron and Sophia indicated that they expected to get about half of the money back when they would not use the service.

Most consumers liked the ability to upgrade, but not everyone was as enthusiastic about it. For instance, Emma said: *"A Lada with a Porsche engine is still a Lada."* She thought that upgraded parts are not as good as an entirely new phone. Because upgrades would be free, consumers indicated that they would be more likely to upgrade than when they have to buy an entirely new phone. As discussed earlier in Chapter 4.2, this may go

against the sustainability motives behind this project.

From a practical point of view, Peter indicated that upgradable smartphone designs are still far-fetched. It is technically possible to make smartphones upgradable, even more so when the upgrades are performed by a professional. But connectors should be designed differently, and the entire layout of the smartphone design should remain the same over a longer period of time. He admitted that Fairphone is moving towards this direction, but also recognized that Fairphone is not able to produce premium smartphones (yet). Furthermore, he argued that larger manufacturers would not do this without regulations.

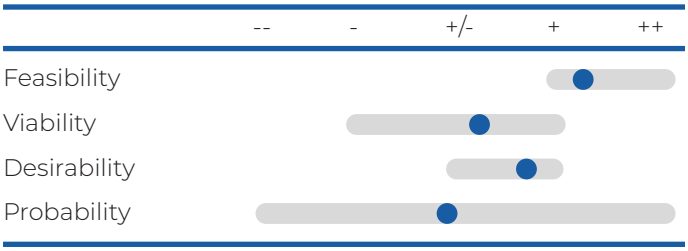


Table 7.4: Consumer scores of the Repair Marketplace.

Repair Marketplace

Consumers found the Repair Marketplace to be very feasible and desirable, but only slightly viable (see Table 7.4). Despite the slightly positive evaluation, consumers differed as to whether they would actually use the marketplace. With regards to feasibility, consumers liked that the platform provides an overview of all available repair options. Also, they valued that it is possible to make an appointment for the same day, and that their phone would be picked up at home. When it comes to community repair experts, consumers showed doubts whether they would trust a stranger to repair their smartphone. When I suggested that a review system would be included in the platform, all consumers indicated that this would make a significant contribution to their trust in the repair expert. Also, Isabella suggested that meeting the repair expert face to face or having a call together would help as well.

With regards to viability, consumers all indicated that they would feel scammed when the repairer himself proposes to buy their phone in order to sell it second-hand. For instance, Sophia said: *"Well, then he is just going to ask a high price for repair so that I would not want to repair. And then he can make a lot of profit."* When I suggested that the marketplace would allow to compare repair and second-hand prices beforehand, consumers indicated that this would make them more willing to sell their phone to a repair expert.

Consumers liked that the platform allows them to meet new people in their neighborhood and be independent from companies. Ron, for instance, indicated to have some knowledge of repair and would be interested to help others on the platform to repair their phones, for a small fee. For this to work, he stressed that the platform needs to arrange all details, such as ordering the right replacement parts.

From a practical point of view, Peter stressed the importance of arranging the accountability of a repair. Whenever something goes wrong with repair by community repairers, the platform should make sure that the consumer is not left with a broken phone. Peter also mentioned that a check whether a smartphone's failure is included in warranty can be valuable for users before they choose a repair option. Furthermore, he suggested that the platform can also be valuable for other products. Edward indicated that second-hand sale would be an interesting strategy for repair shops to increase sales.

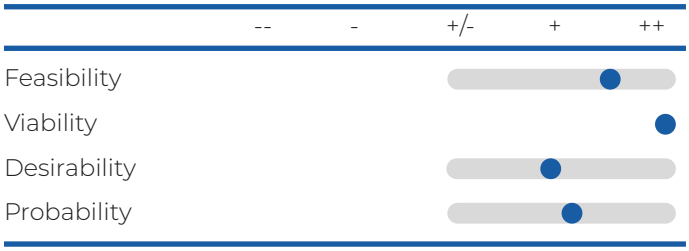


Table 7.5: Consumer scores of the Ultimate Repair app.

Ultimate Repair App

The Ultimate Repair App seemed to be the most popular concept among the participating consumers (see Table 7.5). Most consumers indicated to find repair extremely feasible, all of them found it extremely viable (because it is free), and very desirable as well. Participants also found it probable that they would use the app when their smartphone is broken. With regards to feasibility, consumers indicated to like that the app would provide help in finding the best solution, and they found it convenient that they would not have to find this information themselves. A suggestion made by several participants was to include regular (but not too many) updates with tips on how to optimize the smartphone's performance.

Because the app is free of charge, all

consumers indicated that it is an extremely viable option for them, which makes the barrier to download it very low. Sophia also suggested that providing discounts for repair shops through the app would motivate her to use the app. The eventual viability of repair is determined by the specific repair options that the app shows.

Consumers indicated that by providing all the required information for making an informed decision would make them confident that they make the right choice. Additionally, Emma indicated that she would not need to call her kids to help her find out what issue her phone is having, which would give her a sense of independence. Anne also liked that the app has an educational aspect, because it would teach her something new about smartphones.

From a practical point of view, Peter indicated that it would be difficult to diagnose failures through an app that is not produced by the manufacturer. He thinks more transparency is needed for this, which is something that legislators are already working on, but manufacturers try to slow this process down. Edward agreed with this statement. Both Peter and Edward also indicated that automatic installation would be very difficult to force manufacturers to do, which means that another strategy should be chosen in order to motivate consumers to download and use the app.

Conclusion

In conclusion, both consumers and experts found the Ultimate Repair App to be the most interesting option for repair. If the app is free of charge and consumers know about its existence, barriers for downloading the app are expected to be relatively low. When it provides the right information, consumers can make an informed decision on repair. It is difficult to provide all required information because manufacturers have a monopoly on information about the internal performance of the smartphone. However, by finding other ways to measure performance, it is still possible to provide failure diagnosis to users. Furthermore, the Repair Marketplace was found to be a runner-up, whereas the possibility to let community repair experts perform failure diagnosis and repair was expected to be cheaper and more engaging than conventional repair shops. Consumers also liked the aspect of a second-hand marketplace, because it would provide them with a better way to dispose their old phone than just letting it hibernate in a drawer. However, it must be noted that the second-hand platform should not motivate consumers to discard their phones relatively quicker. Based on these findings, I use both the Ultimate Repair App and the Repair Marketplace as input for the detailed development phase.

7.4. Detailed concept development

In this part of the results chapter, I discuss the detailed development of the final concept. Detailed development includes the second to final iteration of the concept. This means that only one iteration will follow, just after this version of the concept has been tested with users. First, I discuss the concept in general terms by discussing the app's core goals and core functionalities. Then, the discussion dives deeper into the flowchart, usage scenarios, and visual design of the app.

Core goal

The primary goal of the app is to convince the user to keep on using his smartphone for as long as possible. Consumers currently have the willingness to do this but perceive too many barriers. The app will take these barriers away by helping the user understand failures and showing options to prevent and solve these failures. Making consumers aware of prevention in a relatively early stage of the smartphone's use cycle, will help consumers create the right mindset for choosing for repair over replacement at the moment that the smartphone has a physical failure. The combination of failure prevention and solution stimulates users to keep their smartphone for longer (and repairing it if needed), because it is feasible (readily available), viable (worth the costs), and desirable (fulfilling the user's needs and wishes).

Core functionalities

The app has three main functionalities: failure prevention, failure diagnosis, and failure solution. Failure prevention includes the provision of information about common failures of the user's specific smartphone model, and how to prevent these from happening. This information makes it easy for the user to keep the smartphone for a long time. The app also provides an overview of high-quality products that prevent failures, which makes it affordable to keep the smartphone for as long as possible.

By letting the app perform failure diagnosis automatically, it becomes easy for users to understand what the underlying issue of the failure is. If auto diagnosis is not possible, the user is provided with simple steps to diagnose the failure by himself. Because users can perform the failure diagnosis on their own, there is no need for them to visit a repair professional for this. This makes failure diagnosis not only accessible and affordable, but it also fulfils the user's needs as it provides a sense of independence (from repair experts).

The app makes finding the right solution to the failure accessible by providing an overview of all available options. When warranty applies, the app shows official repair options. When warranty does not apply, both official and non-official repair options are shown. Official repair options include the manufacturer, authorized resellers, and authorized repair shops. Non-official repair options include non-authorized repair shops, community repair experts, and repair by the user himself. By offering a wide variety of options, repair becomes more accessible, while the user also has a wider variety of choice to fit repair to his budget. When users are not convinced by the repair options, the app gives a final push to make repair fulfil the user's needs by allowing the user to compare his current smartphone (after repair) with newer models. Because the technology of smartphones is relatively mature, this comparison is expected to show that repair is just as fulfilling as purchasing a new phone. Finally, to take any additional worries away, the app also makes data management easy. The app guides the user through the process of regular or one-time data back-ups, data transfer, and data deletion.

App flow

The user of the app is expected to use it for either tips on failure prevention or help with diagnosing and solving a failure. Therefore, when the user opens the app, the app starts by asking whether the user is currently experiencing any specific issues (see Figure 7.6). If he is, the user is directly taken to failure diagnosis. If he is not, the user is taken to failure prevention. When first opening the app, the user registers his phone. In this process, the app retrieves data about the smartphone (model type), after which the user uploads the invoice of its purchase. From the invoice, the app reads and saves the date and store of purchase.

Failure prevention

Based on the smartphone model, the app shows what the most common failures are, and presents tips on how to prevent these

failures. The app then shows a marketplace of high-quality products that will help the user to prevent any possible failures. These products may include screen protectors, approved charging cables, phone cases, etc. In order to ensure that these products are of sufficient quality, all products are approved by the app developers before they enter the app's marketplace. The app also makes the user aware of the importance to make regular back-ups and explains how this can be done on the user's specific model.

Failure diagnosis

Whenever the user experiences any issues with his phone, he visits the app (or the accompanying website, when the phone is unusable). In the app, the user indicates what the problem is that he is experiencing (e.g., battery drainage, slow internet connection). At first, the app performs automatic diagnosis of the failure. If automatic diagnosis does not allow the app to find a likely solution, the app asks several questions to the user about the phone's performance (e.g., what is your daily screen time, how often do you need to charge). Based on this, the app shows the likely underlying issue of the failure, and the most suitable solution. If it is not possible to propose a solution based on the consumer's input, or if the user fails to answer the questions, the app shows the community page on which the user can chat, call or make face-to-face appointments with community experts to let them diagnose the failure. After consult with the community experts, the user can indicate on the app what he found to be the likely underlying issue.

Failure solution

Now that the user knows what the solution for the failure is, the app helps the user to reach this solution. First, the app checks whether any warranty applies to the failure, based on the type of failure and the date of purchase (which was saved when the user registered his phone). If warranty does apply, the app shows the warranty repair options. If warranty does not apply, the app lets the user choose between the options of DIY repair, community repair experts, and repair professionals. For DIY repair, the app provides a repair guide. For the option of community repair experts, the app shows all available experts nearby. Both options also lead to a marketplace for spare parts. On this marketplace, there are only spare parts that have been approved by the app, in order to ensure sufficient quality. For the option of repair professionals, the app shows an overview of all authorized and non-authorized repair shops. After the user has chosen for one of the repair options, the app provides tips on how to use an old phone as a temporary device. If the user indicates that he is not convinced by the repair options, the app asks why. The user can then indicate that he would prefer to let the failure exist without repair or to buy a new model. If he indicates to prefer a new model, the app shows a comparison between the current phone (after repair) and newer models. This way, the user can decide for himself whether the price/quality ratio of repair is worth it. If the user changes his mind, he can then go back in the app to choose a repair option. Otherwise, the app has not succeeded in convincing the user of the solution. After the user has chosen whether to repair his phone, and whether to use a temporary device, the app helps the user to manage his data. First of all, the app explains step by step how to make a one-time back-up of all data on the phone. This step-by-step guide is based on the model that the user owns. For those users that want to use a temporary device, the app shows how to migrate the data from one phone to another. Lastly, the app shows how to delete all (personal) data from the phone.

Usage scenarios

Prevention

The user has just bought a new smartphone and heard about the app. He wants to make sure that he can enjoy the smartphone for as long as possible, and decides to download the app. Before he accesses any information about prevention, he needs to upload his invoice, or type in the date and store at which he had purchased the smartphone. When the app explains that this allows him to always check whether his phone is within warranty, the user decides to upload his invoice. When the app shows him what failures his smartphone might experience on the long term, he is a bit shocked and pays attention as to what he should do in order to prevent these issues from happening. For instance, he has always used a non-official charging cable for his previous phones, but now that he has found out that this can be detrimental to the phone's long-term performance, he decides to order an official charging cable instead of a cheaper, non-official one.

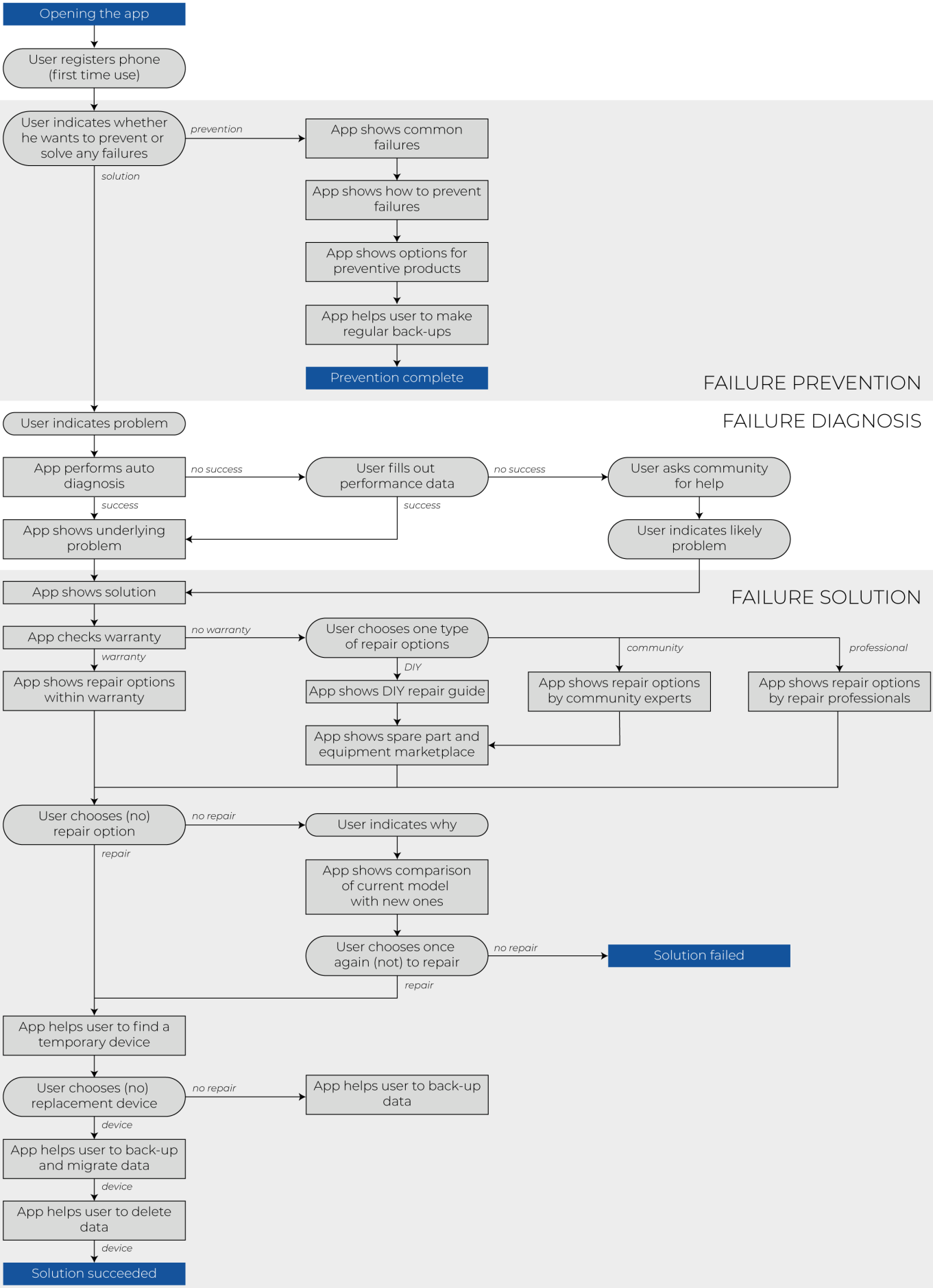


Figure 7.6: App flowchart.

Visible failure

The user has experienced a significant failure of the smartphone: the screen has a large crack in it. This makes him convinced that he needs to do something about it, which is either repairing or replacing it. He remembers the app from TV commercials and decides to give it a shot. When he opens the app for the first time, he is slightly upset that he needs to register his phone: he needs to upload an invoice, but he already knows that he has no warranty left. However, he finds out that he can skip this process and go straight to solving the issue. The app asks then what the problem is. Because he knows exactly what is going (his screen is broken), he indicates this to the app. The app then shows how this problem can be solved: by replacing the smartphone's display. Of course, the user was already aware that the screen should be replaced, so he quickly moves on to the next section.

The app then shows the options of DIY repair, community repair, and repair professionals. The user chooses the professional options, because he wants to have the repair performed on the same day, and he wants to be sure that it will be done correctly. When he looks at the overview of repair options, he compares the price and reviews of all the options. He thinks that they are too expensive, so he indicates that he considers buying a new phone instead. When the app asks what type of phone he would like to have, he indicates that he would want to buy the latest model of the same brand that he already had. The app then shows a comparison between the price of repair and the price of the new model, as well differences in performance of both models. He then finds out that the new model is not so much better than his current phone, but it is four times more expensive than repair. Therefore, he goes back to the overview of repair options and decides to go for the cheapest one. It is still rather expensive, but he now thinks it is worth the price. Inside the app, he makes an appointment to visit the repair shop later that day.

Invisible failure

Over a longer period of time, the user has experienced that his smartphone performs less and less optimally: on random moments throughout the day, the phone just shuts down. He can easily start it back up after that, but it's just annoying for him to experience this several times a week. The user wants to do something about this and opens the app. The app takes him straight to failure diagnosis. First, the app tries to auto diagnose, but this does not work. This makes him slightly frustrated. However, when he fills out some information about the issue he is having, the app shows that battery replacement could solve the issue. When the app shows several options for repair, he chooses for community repair, because this is a bit cheaper than professional repair, and he thinks it is fun to also meet new people. He finds a community expert that lives in the same neighbourhood as he does, who has received several good reviews from people that she had already helped. The user then chats a bit with her about the issue and trusts that she can do the job just right, and she is even willing to do it for free. Inside the app, he orders a new battery for his phone, which will be delivered within several days. Through the chat function, the user makes an appointment with the community expert for next week. There is no need to hurry to solve the issue anyway, because it has been there for some time already.

Visual design

For the design of the app, I focussed on three elements: guidance, simplicity and authority (see Figure 7.7). First of all, the app takes the user by hand. Because most users are expected not to be familiar with the technical aspects of a smartphone and are often unaware of the possibilities of diagnosis and repair, they are also not expected to have a specific question or goal when using the app, rather than getting help to prevent, diagnose or solve a failure. Therefore, the app should provide information in a piece-by-piece manner, and only provide information that is relevant to the user, which can be filtered out by asking questions to the user (e.g., what issue are you currently experiencing?). For those users that do have a specific goal when using the app, the app should also provide the option to navigate to a specific part of the app through a search bar.

Secondly, I focussed on simplicity. As mentioned before, most users lack any technical knowledge of smartphones, which is why the presented information should be piecewise and easy to understand. This will let users not feel overwhelmed by all the information of smartphone repair. Using a simple, sans-serif font and providing only a few lines of text for each screen helps users to focus and fully understand the app's message.

Finally, it is important that the app shows some kind of authority. When users find information on the app, they should be confident that the information is accurate and complete. This is partly achieved through the simplicity of the app, but also by including small statements that confirm the intermediary results of failure diagnosis, for instance (i.e., this is this solution to battery drainage).

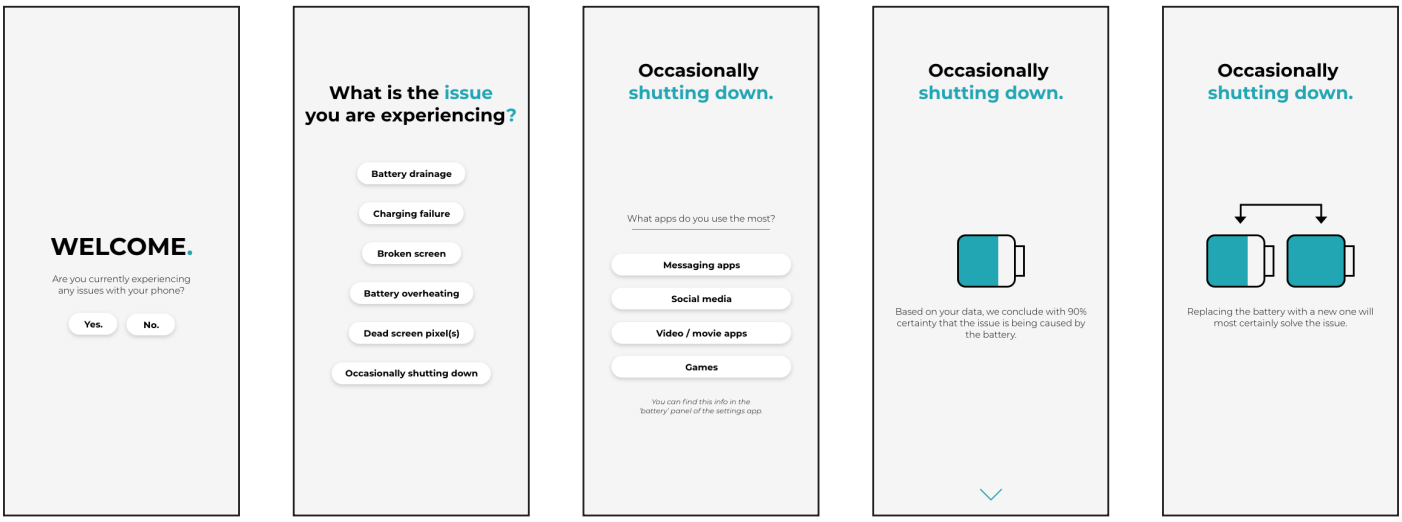


Figure 7.7a: Failure diagnosis screens.

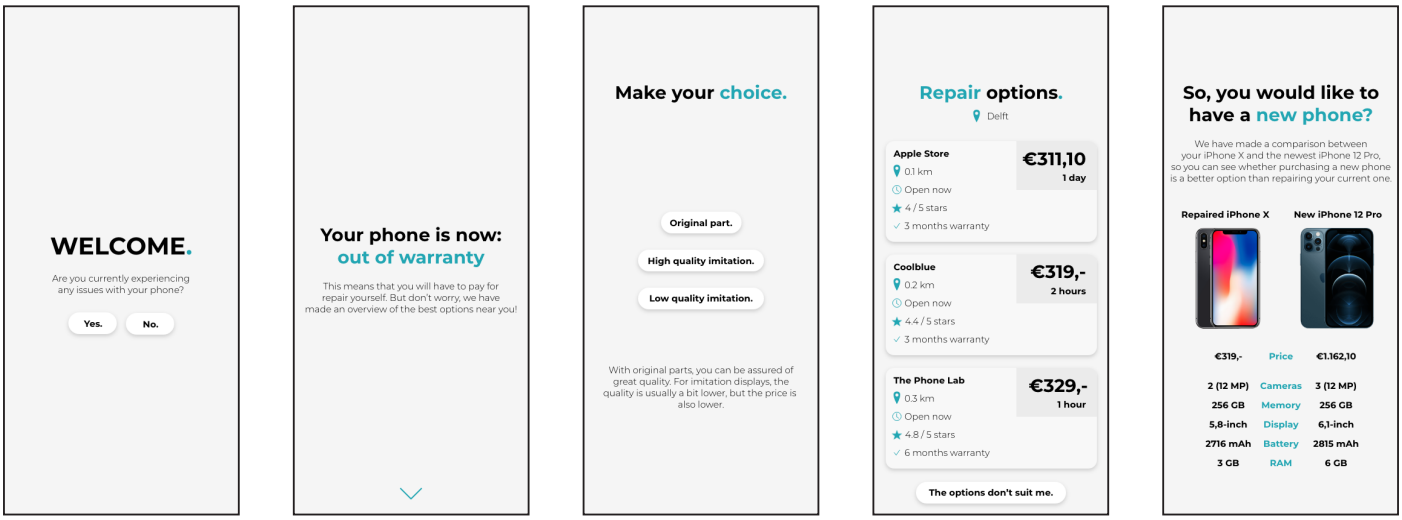


Figure 7.7b: Failure solution screens.

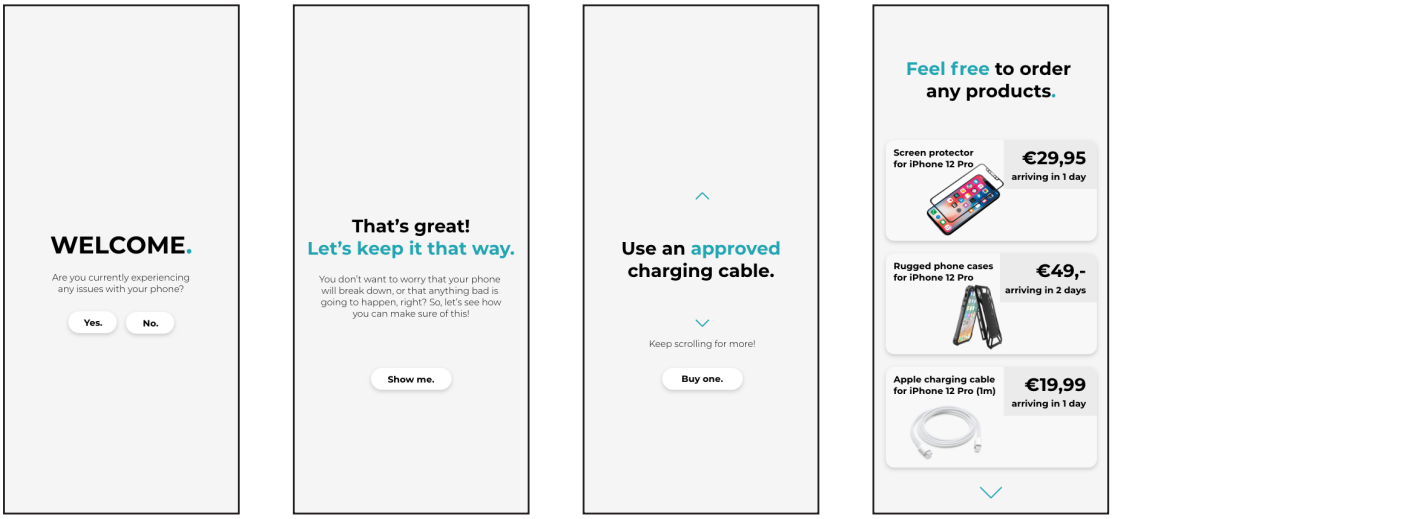


Figure 7.7c: Failure solution screens.

7.5. Detailed concept testing

User tests provided insights into the perception consumers have of the app. With regards to one of the main barriers of the success app (downloading it), only Martin indicated to be likely to download the app right after he learns about its existence. The other participants were more hesitant with regards to downloading the app. Veronica and Laura said that, in general, downloading an app poses a barrier for them. They indicated to prefer to visit a website instead, which lowers the barrier and allows for more anonymity. With regards to setting up the app, both Emma and Laura indicated that they prefer not to make accounts on smartphone apps, and that this would pose a major barrier for their decision to use it. However, when setting up an account would not require too much time or too much personal information, both participants indicated that they would be willing to try it out.

Failure diagnosis

Based on the final user tests, the first hypothesis about the failure diagnosis functionality of the app seems to be true: offering help with failure diagnosis makes it easier for consumers to find out what the issue is that their smartphone is having (see Table 7.8; H-FD1). Moreover, the functionality also seems to make it more likely that consumers choose for failure diagnosis (H-FD2). At first, participants indicated that, when an invisible failure occurs, they would search on the internet for diagnosis tips, ask friends and relatives, or visit a repair shop. Although this suggests that users would perform failure diagnosis anyway, with or without the app, I found that users are not proactive in performing failure diagnosis without the app, contrary to their statements. This is because all participants indicated to have been experiencing issues with their current phone since a longer time (e.g., battery drainage, occasional black screens) and had not searched for a solution because they did not bother to do this. This suggests that smartphone users are relatively more likely to try out the failure diagnosis functionality when this is as easy as possible. Additionally, participants also indicated that their own efforts of failure diagnosis do not always return valuable results, which is where this app can provide help.

	Hypotheses about failure diagnosis (FD)	
H-FD1	FD makes it easier for a user to understand a smartphone's failure. *	TRUE
H-FD2	FD makes it more likely that a user tries to understand a smartphone's failure.	TRUE
H-FD3	FD convinces a user of the underlying problem behind the smartphone's failure.	TRUE
H-FD4	FD makes it more likely that a user chooses for repair.	n/a
F-FD5	A user is likely to first choose for the 'try it myself' functionality and ask community members afterwards.	
F-FD6	A user may have privacy concerns when self-diagnosing or interacting with community members.	

Table 7.8: (Dis)confirmation of hypotheses and additional findings of failure diagnosis.

Based on the diagnosis that the app provided, all participants were convinced that the diagnosis was valid (H-FD3). This was further reinforced by the alignment of the recommendation by community members with the app's conclusion. However, Veronica did have doubts about the 'try it myself' feature: *"What did the app do exactly? How does it know what the problem is? [...] Now, I would probably go back in the app and fill in different answers to find out what the app would say in those cases."* Emma, on the other hand, had doubts about the community members. She indicated that, based on the provided reviews, she would be slightly convinced of the community members' knowledge and skills, but: *"Maybe it would just be his wife that rated him with a lot of stars."* She wanted to know why these community members could call themselves 'experts'. Laura and Martin also indicated that they would probably search further on the internet after receiving the failure diagnosis conclusion of the app, to triangulate and confirm it. This need for triangulation is in line with the finding that all participants were more convinced of the diagnosis conclusion when both the app itself as well as the community member indicated the same. Being convinced of the diagnosis, consumers indicated that their next step would be to find out what repair would cost (H-FD4). Participants indicated that their choice for ignorance of the failure, repair or replacement would eventually depend on the prices of repair. Martin said: *"I know that a battery is not too expensive, so I would just try it out."*

In addition to the (dis)confirmation of the stated hypotheses, the tests provided several extra insights. All participants indicated that they wanted to use the 'try it myself' function before asking a community member for help. For instance, both Laura

and Martin indicated: *"I prefer not to interact with people."* Laura and Emma indicated to prefer a more anonymous set-up of the app, because they felt their privacy was being infringed upon. For Laura, the main point of concern was that community members would know her name, while for Emma, the main point of concern was who (e.g., app developers) would be reading the answers she provides to the diagnosis questions, as well as the texts she sends to the community members.

Failure solution

The consumer tests showed that users are more willing to choose for repair with original replacement parts than imitation replacement parts. However, they did assume that original parts would be more expensive, which made them opt for high quality imitation replacement parts instead. Both Emma and Veronica checked their assumption by looking at both options, which made them conclude that their assumption was true. When the users were confronted with the display repair options in their vicinity, none of the participants indicated to be willing to repair. First, most indicated that the price of repair was simply too high and not worth it (see Table 7.9; H-FS1). Laura said: *"More than half of the purchase price (>€200) is too high."* Even Martin, for whom the option of display repair by the manufacturer had the lowest price (€100), concluded that the price was too high for him to choose for repair. However, it was not only that the price of repair was thought to be too high, but he also indicated to possess a budget that allows him to purchase a new one, which makes him prefer to do this instead. From this, I conclude that even when repair prices are relatively low, consumers may use the state of their current phone (i.e., needing repair) as an excuse to purchase a new one.

When the app showed a comparison between the participants' smartphone model after repair, and a new model, most noticed that there is only a small difference between the specifications of the models, while the price of purchasing a new one is significantly higher than the price of repair (H-FS2). Despite noticing this, the participants still indicated to prefer to purchase a new phone, instead of repairing their current phone (H-FS3). This could be partly explained by the recognition that new models are still slightly better. For instance, Emma said: *"I don't know what mAh means, but it has two times as much GB [referring to the RAM memory], I don't know what to do with that, and the camera is better. […] Then, I would just say, let's buy a new one."* Most users also explained it by the fact that their phone was already experiencing issues, which makes replacement a more attractive option. Laura expressed a feeling that the other participants seemed to express as well: *"I am the type of person that when I buy something, I use it for as long as possible, until it breaks down. However, with phones I am prone to have the feeling to buy a new one rather soon."* This suggests that smartphone users are willing to extend the use cycle of their smartphone but fail to do so when the phone reaches a state where repair or replacement is inevitable. As discussed in the problem exploration, the mental book value decreases slowly after initial purchase (partly because small performance issues arise) and then drops significantly when the smartphone breaks down.

Finally, even though none of the participants indicated to be willing to repair their display, they all valued the provision of repair options nearby, as well as the comparison between their current model and the new model. They valued the clarity of the overview, so that they would be confident that they would make the right choice.

	Hypotheses about failure solution (FS)	
H-FS1	FS's provided repair options make a user doubt whether repair is worth the price.	TRUE
H-FS2	FS's comparison between repair and replacement makes a user aware of the lack of significant differences between models.	TRUE
H-FS3	FS's comparison between repair and replacement convinces a user to choose for repair over replacement.	FALSE
F-FS4	FS's overview of repair options as well as the repair and replacement comparison make a user convinced to make the choice that fits them most.	

Table 7.9: (Dis)confirmation of hypotheses and additional findings of failure solution.

Failure prevention

Most of the provided prevention tips of the user tests were unfamiliar with the participants (see Table 7.10; H-FP1). With regards to the tips they were familiar with, participants indicated to not always act accordingly. Laura, for instance, was unaware that tempered glass screen protectors better prevent her smartphone display from breaking. Veronica, however, indicated to be aware of this, but chose to use another type of screen protector instead, because she did not want to protect her display from breaking, but rather against small scratches from

Hypotheses about failure prevention (FP)		
H-FP1	FP's prevention tips provide a user with new insights about prevention.	TRUE
H-FP2	FP's prevention tips make a user more likely to perform product care.	-
H-FP3	FP's prevention products marketplace makes a user more likely to purchase a product.	FALSE
F-FP4	A user prefers to find protective products on his own, in order to look for the best price/quality.	

Table 7.10: (Dis)confirmation of hypotheses and additional findings of failure prevention.

keys in her pockets. Both Martin and Emma indicated that they purposively chose not to use a screen protector, because they believed they do not need one. When it comes to charging tips, the participants indicated that they found these tips interesting and would be willing to act according to them (H-FP2). However, they indicated to need a bit more information to actually do this. Information should be available about the benefits of a given tip, the technology behind it, and how to perform the tip.

When the users were introduced to the preventive products marketplace, none of them indicated to be willing to purchase any one of the products (H-FP3). This was because they all found the products to be too expensive, which made them prefer to search for the right products on their own instead. Martin argued that the marketplace did have potential for him to be valuable, however, because he liked that only products would be included that are of good quality and would be specific to his smartphone model.

Conclusion

Overall, the user tests showed that most of my hypotheses about the app's functionalities were true. The most valuable aspects of the app seem to include the automatic failure diagnosis, community help, overview of nearby repair options, as well as comparison between repair and replacement. The app seems to make a consumer more likely to perform failure diagnosis and look for relevant repair options, but it remains uncertain whether this would lead to repair. One of the major determinants in this process remains the price of repair, but at least, finding the most suitable diagnosis and solution has become easier for users. Thus, most value for the consumer seems to lie in failure diagnosis and failure solution. However, because the consumer would eventually benefit from failure prevention as well, this part of the app should not be disregarded in the final concept development.

With regards to points for improvement, the app should help users better find the most suitable solution for repair, based on their specific needs and requirements (e.g., distance, price, etc.). Especially for relatively inexpensive repair solutions, this holds potential. Therefore, smartphone failures that are inexpensive (free) to solve should be prioritized in the app design. This will help to maintain the mental book value of the smartphone. What would further help to maintain the mental book value is a diagnostic test of the entire smartphone, that shows how the smartphone is realistically expected to perform over the short to long term. The app should also be less focused on the commercial orientation of the preventive product marketplace, so that users do not feel as if the app forces them to buy certain products. Instead, the app should allow the user to make his own decisions and determine for himself what products he would (not) want to purchase.

7.6. Final concept development

7.6.1. Desirability

Based on the final concept tests, I have adjusted the visual design of the app. Because the tests showed that the prevention, diagnosis, and solution functionalities of the app are relevant as they are, the flowchart and usage scenarios did not need to be altered. Rather, for the desirability part of the final concept development, I focus on using the flowchart and usage scenarios to design relevant personas and customer journey maps.

Personas

This app is designed for all smartphone users. To make the app valuable for every one of them, I have classified them into three groups, based on two characteristics: the consumer's willingness to repair as well as his knowledge of repair (see Figure 7.11). The first target group consists of users that are willing to repair but lack any knowledge of it (see persona 1). This target group needs some sort of guidance but is willing to find information on their own as well. Based on earlier discussed literature and my (admittedly small) sample of consumers, I expect that this is the largest target group of the three. The second target group consists of users that are not willing to repair and do not have any knowledge of it either (see persona 2). These users need to be convinced of repair and need a guiding hand when learning about it. The final target group consists of users that are willing to repair and have knowledge of it as well, they are also expected to be relatively willing to take part in the expert community (see persona 3). These users are expected to be able to find the repair information on their own but use the app just because it is convenient. The final quadrant of the matrix is not included as a persona, because I argue that the combination of little willingness to repair and a large amount of knowledge of repair is improbable.

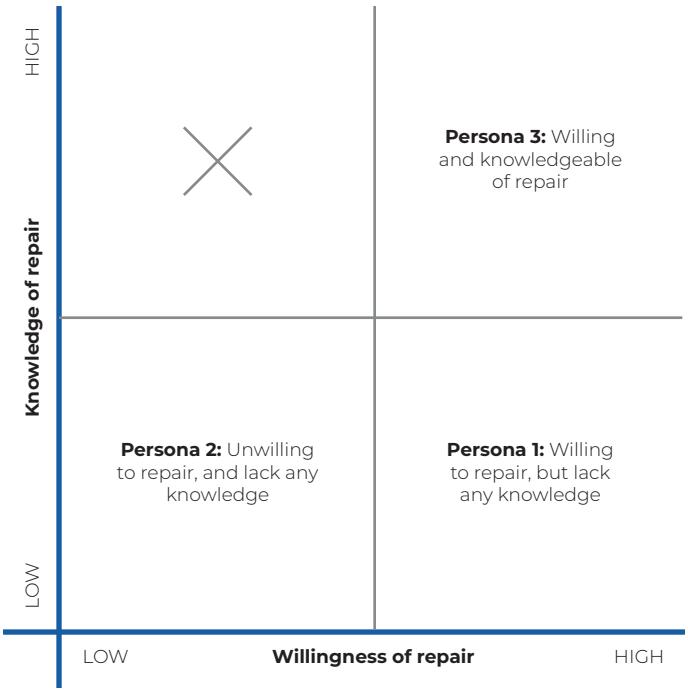


Table 7.11: Matrix of knowledge and willingness of repair.

Customer journey maps

Set-up and prevention

In the first scenario, the user has just purchased a new smartphone. In the following days, the user tries out the phone's new features, which make him completely satisfied with his purchase. After hearing that the Phone Revolution app may help him prevent and solve any potential issues, the user decides to download it. At this point, personas 1 and 3 are intrinsically willing to download the app because they want to preserve their phone for as long as possible. Persona 2, on the other hand, might not be interested enough and need a more convincing argument by both marketing as well as peers who have started using the app already.

When first opening the app (see Figure 7.12), it requests some information from the user. The app indicates that it this would only take a minute, so the user decides to provide the information. Note that when the user would be in a scenario where his smartphone has just experienced a major failure, he might be more inclined to skip this process. The required information from the user consists of the date and time of purchase, which the user can fill in manually or upload the invoice. When the user learns that the app will save the invoice so that he could show it to the repairer when needed, he recognizes the benefits of this option and decides to upload the invoice. Note that when the user is worried about his privacy, or has no immediate access to the invoice, he is more likely to choose for filling in the required data manually.

After checking the required information, the app asks the user whether he is currently experiencing any issues with his smartphone (screen 5). He clicks the 'no' button, and the app then suggests showing prevention tips. Personas 1 and 2 are likely to be unaware of most tips, while persona 3 is likely to know about most tips. The tips make the user aware of his usage behaviour, making him more willing to prevent any issues or damages from happening. For some tips, the user is not sure why he would need to follow them, or how to follow them (e.g., charging up to 80%). The user can then click on the button for more information to read a more elaborate explanation of the tip. Being made aware of several prevention tips, the user considers buying products that help him prevent these failures. When the app shows the preventive product marketplace, the user freely roams around to see what his options are, for instance for buying a screen protector (screen 12-13). Because the app provides a variety of high-quality options to choose from, which are not too expensive, the user decides to purchase one of the provided products. Note that persona 2 is not easily convinced of the app's tips and is likely to be unwilling to purchase any of the products.

Invisible failure (failure diagnosis)

Over a longer period, the user has been experiencing performance issues: on random moments throughout the day, his smartphone simply shuts down. He can easily start it back up after the shutdown, but the user thinks it is annoying that this occurs several times a week. Because the user remembers to have installed an app that can help him with these kinds of issues, he decides to give it a try to find out what is happening. After opening the app (see Figure 7.13), it takes him straight to failure diagnosis. First, the app tries to auto diagnose, but this does not work. The failure of the automatic diagnosis would make all three personas slightly frustrated at first, especially persona 2. However, when the app indicates that it would be relatively easy to diagnose the failure based on some input by the user, he is likely to give it a try. When he fills out some information about the issue that he has been experiencing, the app succeeds in diagnosing the failure. According to the app, battery replacement could solve the issue. Although the user is convinced that the app provides accurate information, he still doubts whether the diagnosis is right. He might, for instance, be worried that he had not provided accurate information for the app to make the diagnosis. Therefore, he decides to find a community member and ask her what she would think that the underlying issue of his problem is. When the community member proposes the same solution as the app, the user is extremely convinced that battery repair will solve his problem. Note that persona 3 is likely to already have some idea about the possible failure when opening the app. At the moment that the app diagnosis is in line with his idea, he would be likely to accept it. However, when the app diagnosis provides a different solution, he would be likely to be sceptical about it and ask community members or search on the internet for more information. Persona 2 is also likely to search on the internet to find out more about the problem, but he lacks the knowledge to judge what information on the internet is accurate and what not. The authority of the app should make him convinced that the app provides the most accurate solution. When the app shows that battery replacement is an easy and cheap option, persona 1 is likely to be easily convinced of the solution that the app proposes.

The user feels lucky when the app shows that battery replacement is included in the smartphone's warranty. Based on this, the app provides an overview of all options that are available to the user within the warranty conditions of the smartphone's purchase. The user then fills out some filters in order to find the solution that fits him most. Even though repair would be free, persona 2 is still likely to discard the option of repair when the available options in the app require too much effort, such as being too far away from the user's location. Personas 1 and 3 are relatively more likely to eventually choose for repair, because they would not perceive any downsides when it is free of charge. Having compared the different repair options, the user picks one and schedules an appointment through the app. This way, the user is certain that repair will be performed at the moment that he visits the store.

Visible failure (failure solution)

In this scenario, a significant failure has occurred: the smartphone's display has cracked. Although the phone is still somewhat usable, both the looks and user experience are very poor. Therefore, the user is certain that he wants to either fix this or purchase a new smartphone. Thus, he wants to find out what

his options are. He remembers that he had installed the Phone Revolution app sometime earlier and decides to find out what options this app provides to him. Note that persona 2 is unlikely to already have the app installed. However, when he would learn that the app provides a clear overview of the options available to him, he might be convinced to download the app for this occasion. Both personas 1 and 3 are more likely to have the app installed, but when this is not the case, they should also be convinced to download the app for this occasion. When opening the app (see Figure 7.13), it asks whether the phone is experiencing any issues. The user indicates that the display has a large crack in it, and that he does not want to keep his phone like this. Based on this information, the app proposes to show the options for replacing the broken display with a new one. The user recognizes that this is exactly what he wanted to know, so he is curious to see what the app will show.

Before showing the available options, the app indicates that the user has no right of warranty for this failure, because display failures are not included in any warranty. Then, the app shows all options that are available to the user for replacing his broken display with a new one: from official repair options to DIY and community repair, from service centres to send-in services, and from original replacement parts to low quality imitation parts. In this case, persona 1 would likely be interested in the official repair options and original replacement parts, while persona 2 would likely be interested in the cheapest option. Persona 3, on the other hand, would likely be interested to perform the repair by himself. The user fills in the filters that fit his requirements (screen 8) and studies the available options. Although persona 1 and 3 would be relatively more likely to pursue the repair than persona 2, all three personas are likely to be put off by the prices of repair. Being put off by the high prices of repair, the user is not sure whether he wants to pursue repair. When he clicks the 'the options don't suit me'-button, he indicates that he would be willing to purchase a new smartphone. This is partly because the repair prices are too high, but also because he was willing to purchase a new phone anyway, as his current phone has lately been experiencing small issues, and the newer models are interesting as well. The app then shows a comparison between his smartphone and the latest models on the market. When he compares the specifications, he recognizes that the newer models are not much better than his current phone. Note that persona 2 is likely to recognize the small differences and take this as an opportunity to conclude that replacement is the preferable option. This makes him doubt that replacement would be the right choice. However, he is also worried that his phone will have more small issues in the coming years, which he can prevent from happening when purchasing a new smartphone. When the app shows that it is 90% likely that the smartphone will not have any additional issues over the next two years, the user finally decides that repair is the better option.

After coming back to the repair options overview, the user studies the options again and picks the cheapest one. The app then shows the details of the repair shop he has selected. Although it is possible to make a repair appointment through the app, the user decides to drop by the shop later this week. Note that not making a repair appointment provides the user with another opportunity to rethink his options and decide once more whether he wants to repair or replace his smartphone. Having indicated to drop by the repair shop later this week, the app provides several tips to use a temporary replacement device, to migrate data to this replacement device, as well as to back-up and delete the data on his current device. Both personas 1 and 2 are likely to be unaware of the ease of data management. Despite that they initially regarded data management as a possible barrier for repair, they are now convinced that this will not pose an issue.

Visual design

As can be seen from Figures 7.12, 7.13, and 7.14, the main lay-out of the app has remained the same since detailed concept development. The major change that has been made is the introduction of Adriana, the 'virtual assistant'. By offering a more human interaction with the app, I expect that the user is less likely to be overwhelmed by the amount of information and is more likely to be convinced that the provided information is accurate.

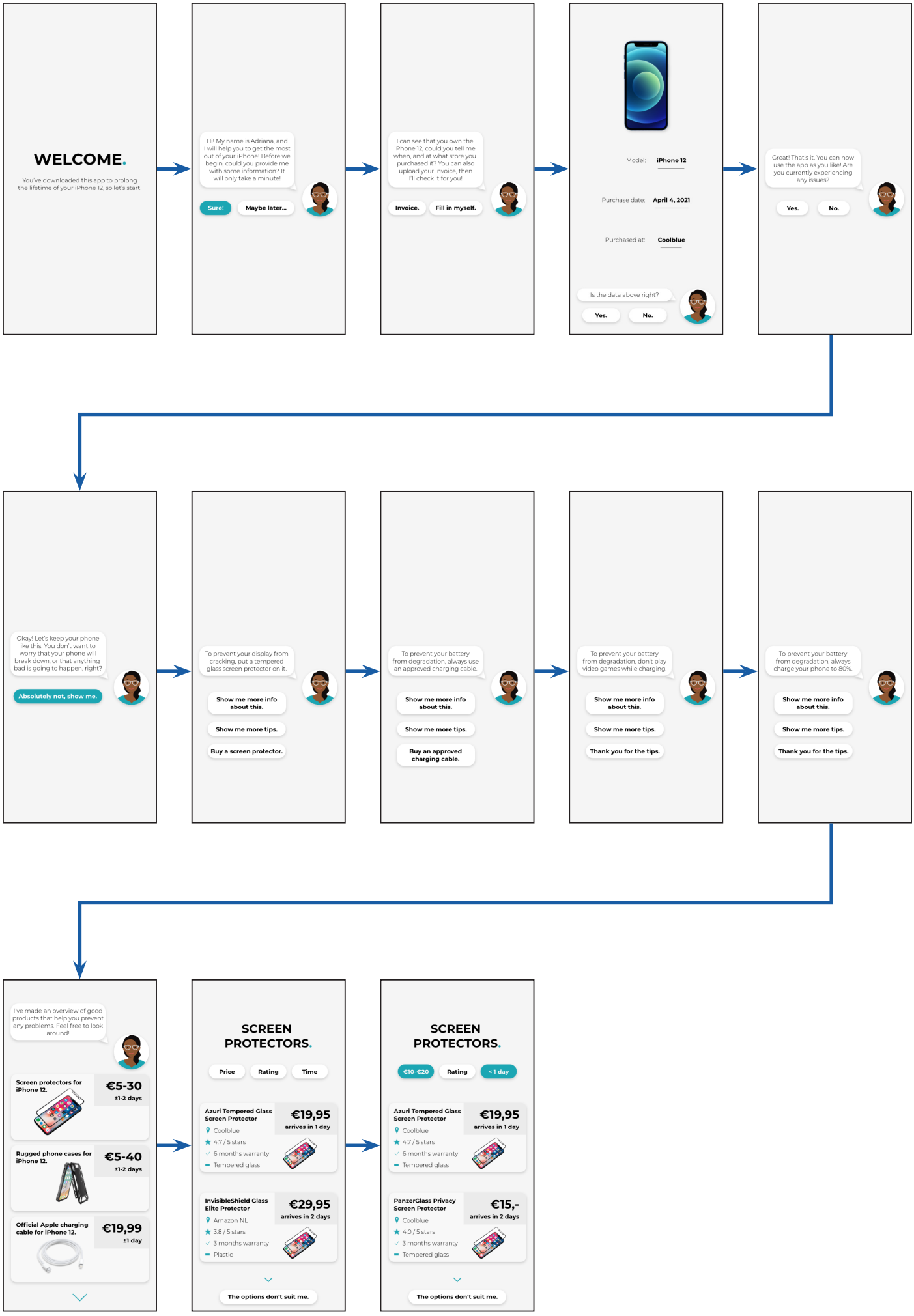


Figure 7.12: Screens for set-up and failure prevention.

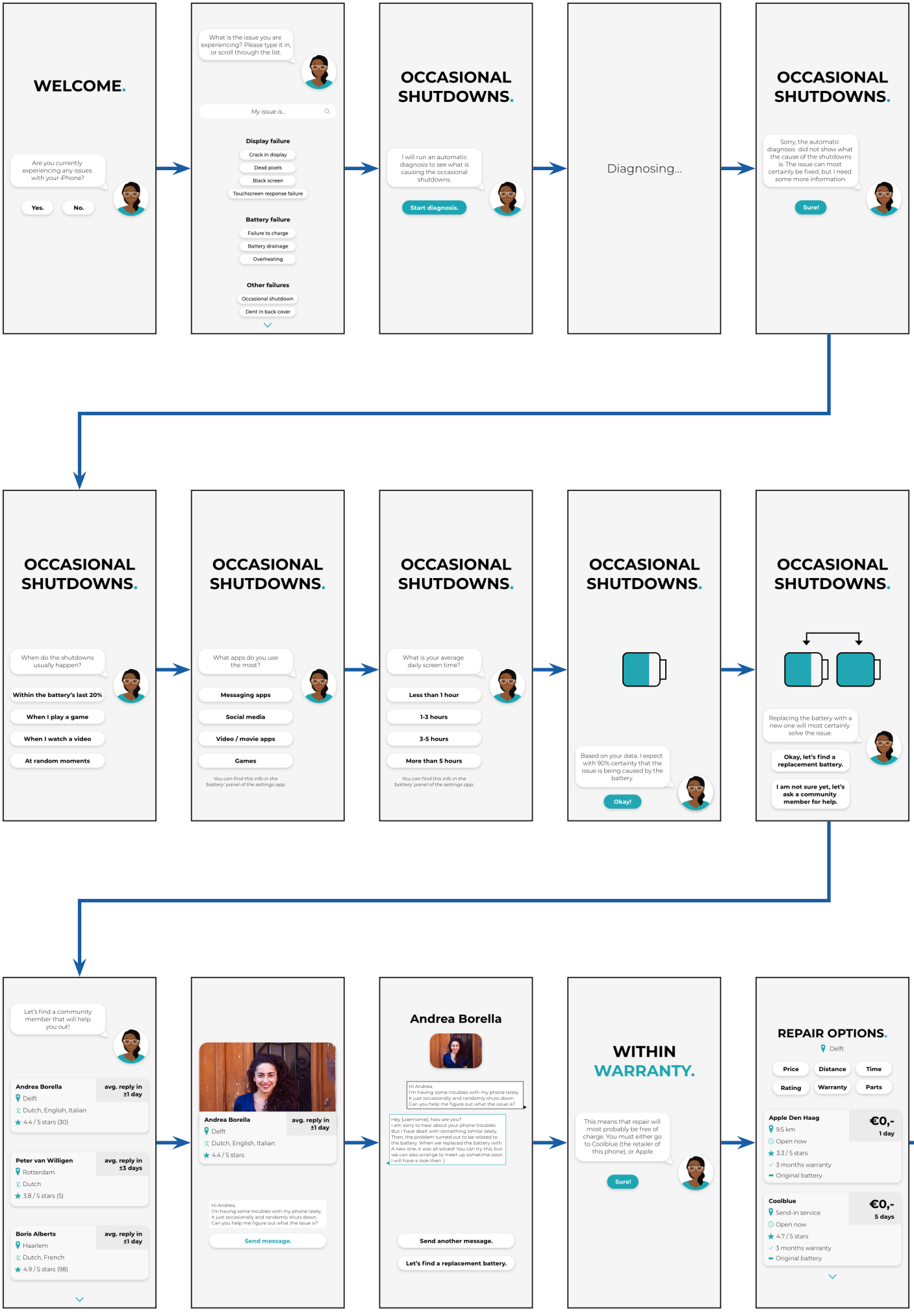


Figure 7.13a: Screens for an invisible failure (failure diagnosis).

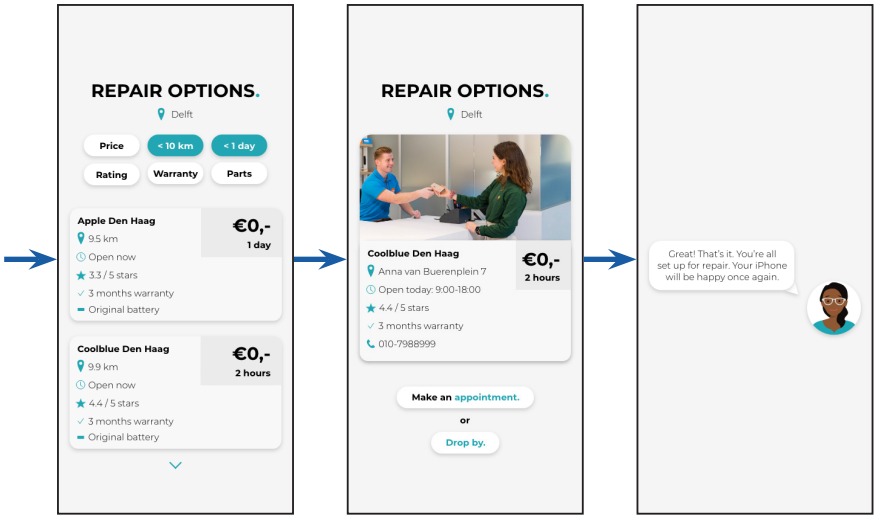


Figure 7.13b: Screens for an invisible failure (failure diagnosis).

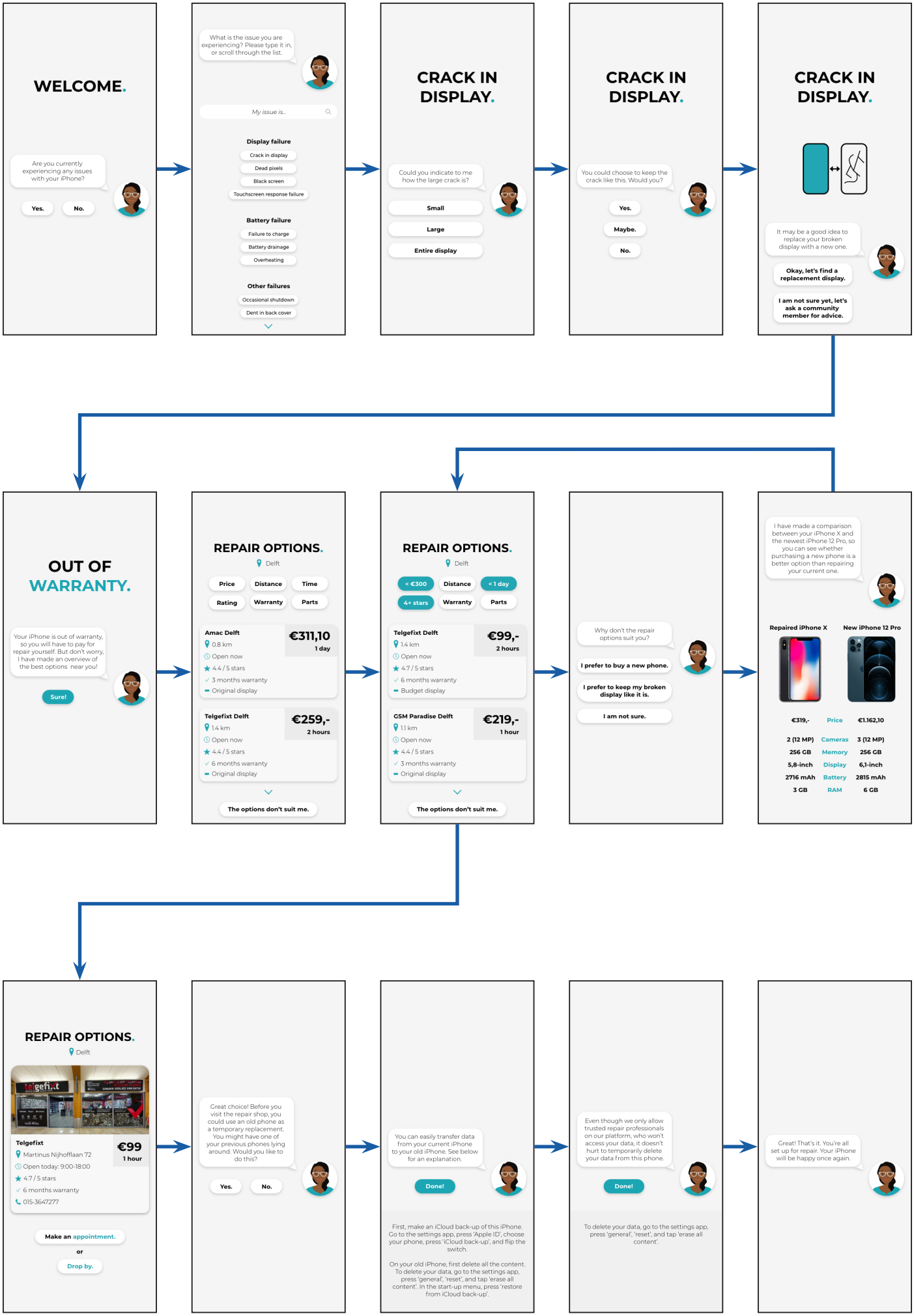


Figure 7.14: Screens for a visible failure (failure solution).

7.6.2. Viability

Market position

Smartphone manufacturers already provide some information to users about the smartphone's performance. For instance, the settings apps of both Android and iOS systems show the smartphone's current battery capacity in terms of a percentage of its original capacity. There is also a wide variety of third-party apps and websites available that provide users with information about failure prevention, diagnosis, or solution. With regards to diagnosis for instance, there are apps available that show the battery temperature and charging current, which is data that is unavailable in the software's settings app. With regards to failure solution, iFixit provides guides, parts, and equipment for repair. Although apps and websites already exist that provide users with failure prevention, diagnosis, or solution information, no app exists today that guides user through the entire process of prevention, diagnosis, and solution. Furthermore, no services exist yet that provide users with a complete overview and comparison of all repair options that are available in the user's vicinity. This means that the Phone Revolution App will be the only all-in-one solution on the market that helps users extend the functional lifetime of their smartphone.

Business model

The app is provided to its users for free. Because literature review and consumer interviews showed that price already poses a barrier for consumers to choose for repair, I expect that this app can only work when it provides all the information for free. Although this will attract as many users as possible to the app, it does not provide a source of revenue. To generate revenue, the app charges a percentual fee for all transactions and bookings that are arranged through the platform (see Figure 7.15). This fee is invisible to the user, as it is being paid by the product and service providers that are connected to the app. The providers include professional repair service providers, preventive product resellers, replacement part resellers, as well as repair equipment resellers. I propose to adopt a fee of 5%, because I expect that this generates sufficient revenue while not driving up the price of the offered products and services too much.

When the user of every newly purchased smartphone (1,5 billion per year; Statista, 2021) purchases a protective product (with an average price of €15; based on the current prices of screen protectors and protective cases on Amazon), a 5% fee would account for a total of €1,1 billion in annual revenue for the failure prevention part of the app. When all 375 million smartphones that have become obsolete per year because of a physical failure (based on Haines-Gadd et al. (2018); assuming that two-thirds are display damage with an average repair price of €150, and one-third is battery damage with an average repair price of €50; Wertgarantie, 2019) are being repaired, a 5% fee would also account for a total of €1,1 billion in annual revenue for the failure solution part of the app. Admittedly, the aforementioned revenues are unrealistic, because it cannot be expected that all smartphone users world-wide would use the app and make at least one transaction, but it does provide an indication of the market size. Furthermore, when the app would on the long term branch out to more products than smartphones alone, revenue could increase significantly. When the actual generated revenue does not cover the costs required to develop the app, the decision could be made to slightly increase

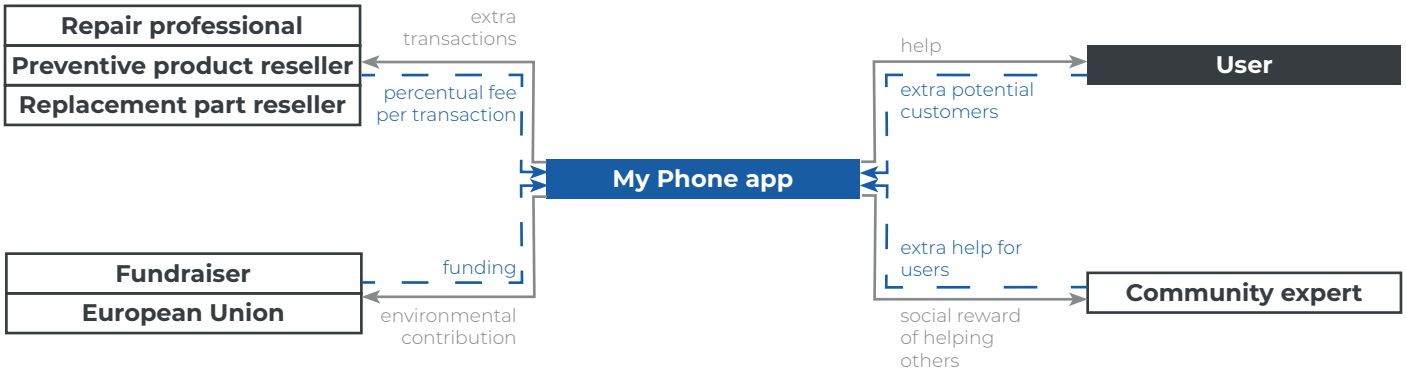


Figure 7.15: Business model logic of the app.

the fee. Other possible sources of revenue could include repair insurances with a monthly fee, a second-hand marketplace with percentual transaction fees, or a subscription model with a monthly fee for users and/or product/service providers to be part of the platform.

Depending on the number of transactions that happen on the platform, the fee should be sufficient to sustain the business model of the app. However, especially during the first phase of development, human capital costs will be high, whilst no revenue will be generated yet. Therefore, development of the app requires start-up capital. The main costs of the app will include human capital costs for developing the app, gathering information about failure prevention, diagnosis, and solution, as well as maintaining support for users and product/service providers that are connected to the platform. Additionally, promotion of the app requires human capital as well as payment of advertisements and marketing campaigns. For instance, when the marketing strategy includes that the app provides discount on existing repair prices, this discount needs to be funded.

There are two available options for acquiring start-up capital. The first one is by obtaining a grant of the European Union (EU). This would for instance be possible within the LIFE programme (L'Instrument Financier pour l'Environnement) of the EU. This is a funding programme for projects in the field of environmental action (European Commission, n.d.-a). The benefit of such a grant is that a large sum of money is available: €5,4 billion for all projects in the period between 2021 and 2027. The downside of such a grant is that it requires the executor of the project to be a non-profit entity, which limits the developer of this app to achieve profit. Additionally, application procedures take a relatively long time: the procedures start in July 2021 and awarding of the grants happens in the first half of 2022 (European Commission, n.d.-b).

The second option for acquiring start-up capital is a public fundraising campaign, such as through Kickstarter. This costs less time than application for an EU grant and does not limit the project executor to be a non-profit entity. However, the capital that can be acquired through this method is significantly lower. Most tech projects (80%) on Kickstarter fail, whereas 73% of the failed tech projects only raise 20% of their initial goal (Crockett, 2019). However, it is not impossible to raise large sums of capital through Kickstarter, as 21% of successful tech projects raise over $100.000 (ibid.). Therefore, to acquire start-up capital, I propose to start fundraising on Kickstarter with an initial goal of raising €100.000, which is sufficient to hire five app developers to work on the project for half a year. When the fundraising exceeds the initial goal, more app developers could be hired to speed up the process of app development. If fundraising leads to enough capital to be able to start generating revenue, the best option is not to obtain an EU grant, so that the project executor is still allowed to pursue profits. However, just in the case that fundraising does not provide enough start-up capital, I advise to apply for at least €500.000 through the LIFE programme. This should be enough to cover all costs that are required to start the project and generate revenue on the long term. When public fundraising exceeds the initial goal, the EU grant could be cancelled.

Another option of acquiring start-up capital would be private fundraising. Using this method, the app developers would pitch the app to large investors and ask for capital in turn for a stake in the company. Because the business model of the app holds many uncertainties, it might not yet be convincing enough to generate large sums of revenue. Therefore, I expect that private fundraising does not provide a solution here, but it could be possible.

7.6.3. Feasibility

Stakeholder map

The relevant stakeholders of the Phone Revolution app can be divided into a group of primary stakeholders and a group of secondary stakeholders (see Figure 7.16). Primary stakeholders include those that are direct users of the platform: smartphone users, repair professionals, protective products resellers, spare parts resellers, and repair community members. Secondary stakeholders include those that are not directly connected to the app but can be affected or have a potential effect on the app: regulatory institutions, smartphone manufacturers, and environmental organizations. In the following paragraphs, I discuss the potential benefits and downsides for each of the stakeholder groups, as well as the likely reaction they will have to the introduction of the app on the market.

Smartphone users

The app provides relevant and easy-to-understand information that allows users to make an informed decision on how to prevent, diagnose or solve failures of their smartphone. This information is accessible at any location and any time of the day. Because the app enables its users to make the decision of repair or replacement on their own, users feel empowered. Despite these benefits, the preventive product marketplace and repair overview may also make users feel forced to purchase a product or order a repair. I expect that when the app is promoted on a large scale, and the peers of potential users start using it, many consumers are likely to try it out. When consumers use the app, it will convince them of the benefits of repair, but they will likely find the repair price too high. At this point, only a convincing message that replacement is not a better option than repair will make users more willing to choose for repair.

Repair professionals, protective product resellers, and spare part resellers

For all repair professionals, protective product resellers, and spare part resellers, the app provides them with additional customers. Customers who would not have chosen for repair or preventive products otherwise, will be attracted through the platform, resulting in a higher number of sales. Paying a percentual fee of the transaction price is worth it for the product/service providers to attract these additional customers. However, it will not be worth the fee when the customers would also have chosen for the specific product/service provider without using the app. Furthermore, especially for repair professionals, it might be inconvenient to manage the app in addition to their own agenda system. When app developers would approach these stakeholders, they are likely to take part, because the potential benefit of

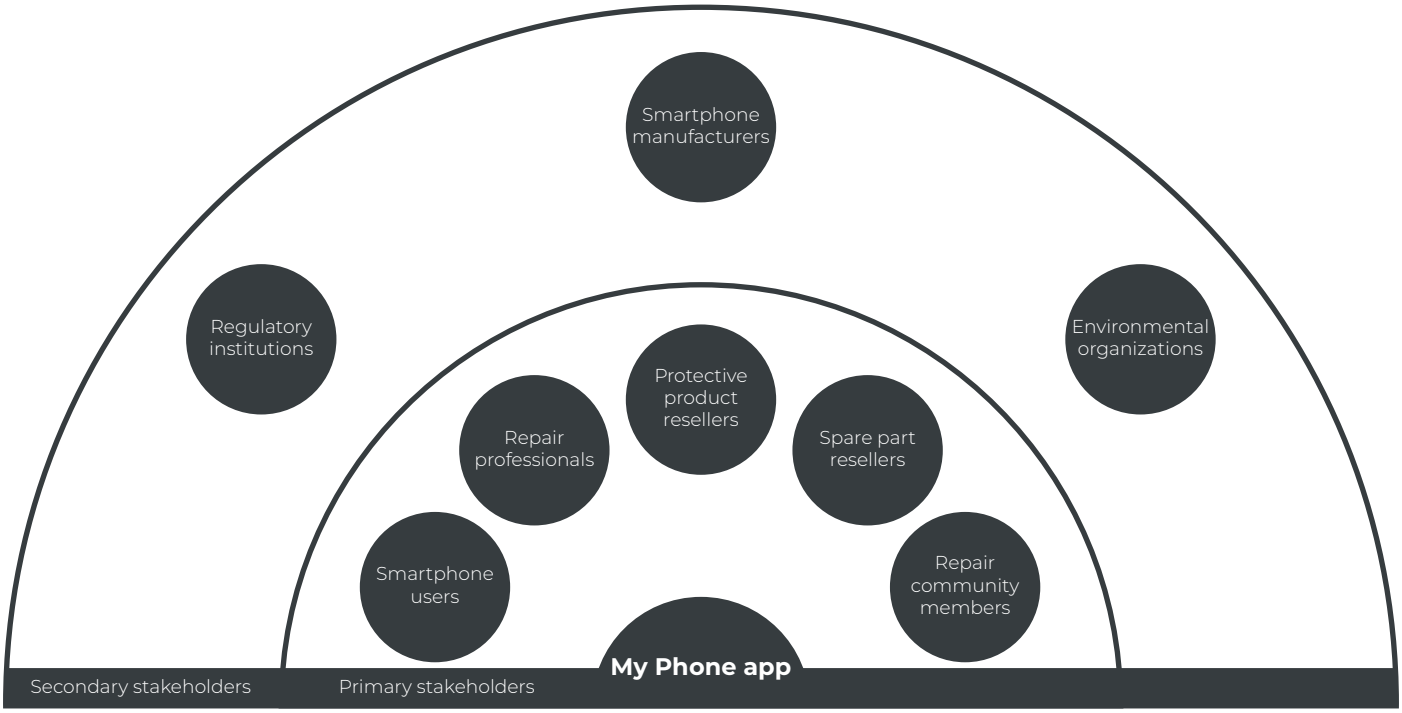


Figure 7.16: Stakeholder map

attracting additional customers is expected to outweigh the downsides. Without a proactive approach by the app developers, I expect that the stakeholders are more hesitant towards taking part in the early phases of the app's existence, because the app has then not had the opportunity yet to prove itself as a potential source of extra customers.

Repair community members

The benefit that community members obtain from the app is a community feeling. The app provides consumers who have knowledge of smartphones and repair with a way to interact with others. This interaction is meaningful to community members because they can help other users. When the app requires too much work for community members to arrange details with other users, or when the app floods them with questions from users, community members might lose interest in the app. However, I expect that when potential community members hear from other repair experts or online influencers about the community (such as repair professionals on Youtube), they are likely to take part and offer their knowledge to the other users. For this to work, being a community member should not take too much time and should be manageable.

Environmental organizations

This app is a method to extend the use cycle of smartphones, and thus increase the smartphone's material efficiency. Also, by making smartphone users more aware of the environmental relevance of lifetime extension, the smartphone might also get a second life after the use cycle has ended for the user himself. The app should not have any negative environmental effects. However, it must be addressed that the app does not accidentally provide users with an extra incentive to choose for replacement (e.g., when they see the comparison between repair and replacement options). It is likely that this app has more positive effects on the environment than negative effects, which makes me expect that pro-environmental organizations would support it.

Smartphone manufacturers

For smartphone manufactures, the app does not seem to have any major positive effects. The only possible benefit of the app seems to be that it may make users happier with their smartphone for a longer time, which results in greater loyalty of the user towards the smartphone brand. However, this potential benefit does not outweigh that the app promotes the extension of the smartphone's use cycle, which will have a major effect on a smartphone's sales. I expect that when smartphone manufacturers find out about the app, they will try everything they can to demote the app and work against its development. Also, I expect them not to be more transparent about internal performance measures when there are no regulations.

Regulatory institutions

As mentioned above, the app is designed to be in line with environmental sustainability. Because many regulatory institutions (such as the United Nations, the European Union, as well as national governments) have a relatively large focus on reaching sustainability goals, the app poses a major benefit to these institutions' ability for reaching those goals, such as increasing the material efficiency of consumer goods. Because Apple and Samsung belong to the largest companies in the world, their influence on regulatory institutions is significant. Therefore, when regulatory institutions want to support the development and promotion of the app, they can expect to be opposed by these smartphone brands. I expect that regulators will be positive towards the app and provide funding because it aligns with sustainability goals. However, forcing manufacturers to be more transparent will be difficult.

Roadmap

I have divided the launch of the app into three main phases (see Table 7.17). During the first two years, a minimum viable product version of the app is launched, which contains the most important aspects of the app, which can be developed in a relatively short time span. These two years allow developers to test the app on a small scale and later branch out to more users. In the following three years, the app is further developed to its full version. In the years that follow, the app is continuously branched out and updated along with changes on the market. For this roadmap, I included possibilities up until 2030, but the app has the potential to be used and changed according to the market beyond this year.

In the minimum viable product phase (2021-2023), the app provides prevention, diagnosis and solution help for those smartphone models that are currently being used the most (at least 75% of market

share), and for those failures that occur the most (at least display and battery failures). In this stage, local repair options are only available in the Netherlands, because it requires extensive promotion to attract all relevant repair professionals to the platform. Community experts are left out in this phase because the app should grow first before a community of repair experts can be built. To decrease the focus of the app, DIY repair options and the preventive product marketplace are excluded as well. This is because these two functionalities require a large amount of developmental work but are not expected to pose the most benefit to the app's users. The first year of the minimum viable product phase is focussed on gathering the required information for developing the platform, including both the mobile application and the website version. For the gathering of information to be successful and efficient, partnerships should be made with knowledgeable players in the field of smartphone repair, such as iFixit. As the platform is starting to take shape, it will be possible to test it with users. Before the official launch of the app in 2022, repair professionals in the Netherlands should be attracted to the platform so that the app can provide a complete overview of all available repair options.

During the three years that follow, the app is further developed to its full version. In this version, DIY repair options, the preventive product marketplace, and the community are introduced to the platform. Also, the number of supported models and types of failures grows to a percentage of at least 90% of models, as well as 90% of failures. In addition to that, the automatic diagnosis functionality should be further improved, which will be possible when manufacturers have become more transparent about internal performance. To reach this transparency, lobbyers at regulatory institutions should put this on the agenda. In 2025, the app will be fully developed as it has been proposed in this thesis. From that moment onwards, the focus of app development is on keeping up with new models that arrive on the market. In addition to that, the app can also include a repair insurance, of which the monthly/yearly fee is based on the user's behaviour. Other options include the incorporation of modular upgrades and include a second-hand marketplace. Finally, the app can also branch out to other products, especially ones that are already connected to the user's phone, such as headphones, smart TV's or refrigerators.

	Activities	Partners	Resources
Minimum viable product [2021-2022]			
2021 2022	· Developing the app and website · Gathering information about prevention, diagnosis and solution · Attracting users to the app · Attracting repair professionals	· Repair professionals	· App and web developers · Smartphone researchers · Marketeers · Partners
Full app [2023-2025]			
2023 2024 2025	· Attracting preventive product resellers · Attracting replacement part resellers · Developing an online platform for local community	· Preventive product resellers · Replacement part resellers	· Lobbyers
App extension [2026-2030]			
2026 2027 2028 2029 2030	· Lobbying at regulators for transparency by manufacturers		

Table 7.17: Roadmap for the development of the app.

Marketing strategy

The marketing strategy should carry a message of guidance, simplicity, and authority, just like the visual design of the app. By setting up a mass media marketing campaign with a simple message, consumers should be convinced to download the app. Key to this message is that the app offers great help and comes from a trusted source. In addition to mass media advertising, it will also be relevant to deploy niche advertising. When influencers in the repair expert community share the app to their followers, it will gain authority and convince consumers to download the app. Additionally, as the followers of repair experts are likely to have more than average knowledge of smartphones and repair, promotion of the app by repair experts will also enlarge the community of repair experts. Online personalized advertising can also serve to target users that have been searching online for new smartphones or repair. These users are relevant to target because they will be likely to need the app.

8. Discussion

The research objective of this thesis is to develop a smartphone PSS that stimulates consumers to choose for repair over replacement. To evaluate to what extent this objective has been met, I apply the newly developed repairability framework of Chapter 3.2 to the final design outcome: the Phone Revolution App (see Table 8.1). With regards to feasibility, the ease of failure diagnosis and the availability of repair information have increased, while the number of required steps to obtain replacement parts has decreased. Although the app has not increased the availability of repair services, nor the ease of data management, the overview that the app provides does make repair more feasible for the user. The app has also not decreased the price of repair, but again, the overview that the app provides does make repair more viable, because it enables the user to make an informed decision. Repair desirability has mostly been improved by the app in terms of physical obsolescence. By providing information about product care, the app makes a contribution to extending a smartphone's lifetime. Furthermore, with regards to technological obsolescence, the objective comparison that the app provides between different smartphone models helps the user to make an informed decision on the technological obsolescence of his current smartphone. Overall, I argue that the app contributes significantly to making repair more feasible. The desirability of repair has also been slightly improved by the app, whilst the viability of repair has not seen any major improvements.

Limitations and future research avenues

A major limitation of this study is that it does not solve one of the most salient barriers of repair: price. In line with earlier discussed literature, this research has shown that the price of repair is one of the most influential factors of a consumer's decision to choose for repair or replacement. By helping the user compare repair prices, this thesis ever so slightly contributes to a solution for this problem. I argue that without changing the product design of a smartphone, lowering the price of repair seems impossible. However, because of the importance of price in the consumer's decision to choose for repair, it is relevant for future research to study what methods possibly lower the costs of smartphone repair.

Additionally, the final app focusses on repair feasibility, whilst regarding technological and psychological obsolescence as only secondary factors. As stated earlier, these types of obsolescence do make up for most of all obsolete products. Moreover, from the physically obsolete smartphones that can be saved by repair, it is yet unknown what role technological and psychological obsolescence play. Therefore, it can be argued that it is more relevant to focus on technological and psychological obsolescence than on physical obsolescence alone. I argue, however, that it is relevant to focus on both sides, because physical obsolescence remains a significant problem. For future research, I recommend supplementing the focus of this study on physical obsolescence by a study that focusses on the technological and psychological aspects of smartphone obsolescence.

Future research on the technological and psychological aspects of repair (i.e., the repair desirability) can be performed by applying the entire repairability framework of Chapter 3.2 to an analysis of recent

smartphone models. In this thesis, I have excluded the desirability aspects of the framework, because it requires a separate study to understand how desirable repair can be. The desirability aspects provide a starting point for future research to focus on. This framework has been developed by me for the purpose of this thesis. It has been based on a literature review, but it has not been theoretically tested. Thus, the framework requires further optimization. For instance, the current framework still includes overlapping aspects (e.g., increased information on product care contributes to the reliability of a smartphone). Therefore, the definitions of the aspects should be further enhanced, and it should be tested whether the framework covers all relevant aspects of repairability.

Although this study is based on a grounded literature review supplemented by consumer interviews and user tests, as well as conversations with smartphone repair experts, the insights gained from this study should be taken with the necessary precaution. The samples of the consumer interviews and user tests include a total of eight unique participants, of which most are female university students or graduates. Therefore, the findings from these interviews and tests cannot be taken as representative of the entire population of smartphone users. As stated in the methodology, representativeness was not the aim of these interviews, as the aim was rather to provide tangible input for concretizing the theoretical findings of the literature review. For future research, I recommend using a representative sample to validate the findings from this research, as well as to study repair and replacement reasons for smartphones in general.

		Phone Revolution App	
Repair feasibility			
Ease of disassembly	*Number of required steps*	–	
	Required time in hours	–	
Ease of failure diagnosis	*Number of required steps*	↓	The app offers failure diagnosis all in one place, with little user input.
	Required time in hours	↓	
Ease of data management	*Number of required steps*	–	The number of steps and required time have not decreased, but the user is made aware that data management is not complex.
	Required time in hours	–	
Availability of repair services	*Geographical proximity in kilometers*	–	The proximity and service time have not decreased, but the user has a better overview of the options to choose from.
	Service time in hours	–	
	Duration of availability in years	–	
Availability of spare parts	*Number of required steps*	↓	The app offers spare parts all in one place.
	Delivery time in days	–	The delivery time has not decreased, but the user has a better overview of the options to choose from.
	Duration of availability in years	–	
Availability of repair information	*Amount of available information*	↑	The app offers a variety of repair information all in one place.
	Type of available information	↑	
	Duration of availability in years	–	
Repair viability			
Price of repair	*Price of spare parts in euros*	–	The prices have not decreased, but the user has a better overview of the options to choose from.
	Price of repair services in euros	–	
Price of replacement	*Price of replacement in euros*	–	
Mental book value	*Physical obsolescence*		See repair desirability.
	Technological obsolescence		
	Psychological obsolescence		
Repair desirability			
Reliability	*Functional lifetime in years*	↑	Information of product care enables the user to extend the lifetime.
Product care	*Amount of available information*	↑	The app offers a variety of product care tips all in one place.
	Type of available information	↑	
	Number of available tools	–	The number of tools has not increased, but the user has a better overview of the options to choose from.
	Type of available tools	–	
Compatible products	*Duration of availability in years*	–	
Design differences	*Number of differences per model*	–	
	Portrayal of differences	↓	The app shows the objective differences between models.
	Number of new models per year	–	
Compatible products	*Duration of availability in years*	–	
Adaptability	*Number of adaptable parts per model*	–	
Novelty	*Number of updates per year*	–	

Table 8.1: Repairability of the designed PSS solution.

Finally, I used consumers' intrinsic willingness and knowledge of repair as factors to segment the app's target groups. Although I have taken these consumer characteristics from the literature review, they were never referred to simultaneously, nor did any study suggest that these two characteristics provide a relevant overview of 'repair personalities.' However, I did use these factors to understand my target group better. Because it has not been tested whether it is relevant to segment consumers in these groups, I recommend for future research to find out more about the repair personalities of consumers.

Theoretical implications

Despite the stated limitations, this thesis poses significant theoretical and managerial implications. First of all, this study has mainly focused on certainty and convenience, two aspects that the literature review, consumer interviews and expert interviews pointed towards as being the most contributing factors of repair, next to price. Convenience has already been mentioned in a large amount of literature, but certainty has not. The more convenient it is to perform failure diagnosis, find a suitable repair solution, and perform the repair, the more willing a consumer is to choose for repair. Certainty plays a role in smartphone repair as consumers want to be certain that a failure can be solved by repair, that the phone's future performance will remain sufficient, and that the costs and service times of repair are clear and adequate. Thus, this thesis confirms the contributing role of convenience in repair but found certainty as a new direction for future research to look into.

This thesis implemented easy failure diagnosis as a strategy to make repair more attractive for consumers. From the final user tests, it was found that failure diagnosis does seem to influence the consumer's willingness to try out repair, especially when the price of repair is relatively low. Furthermore, this thesis also implemented easy data management as a strategy to make repair more interesting. From the consumer interviews, it was found that this also seems to have an effect on the willingness among consumers to choose for repair.

Managerial implications

In addition to theoretical implications, there are several aspects of this thesis that can be used by businesses, policy makers, and consumers associations to improve their work. Companies can take the final design and implement it in their business. For instance, iFixit would be a suitable party for potentially developing the app. Admittedly, my contact person at iFixit indicated that iFixit is currently not working on any ideas like this, because they do not possess the monetary resources. However, I suppose that the business model presented in this thesis may convince iFixit that the app will generate revenue over the long term.

Policy makers as well as consumers associations may use the findings from this thesis to further understand what factors play a role in a consumer's decision to choose for repair. The repairability framework presented in Chapter 3.2 provides a method for both policy makers and consumers associations to assess the repairability of a given smartphone model or brand. Policy makers can use this as input for the development of new laws and regulations, or for the promotion of initiatives like this to become reality. Consumers associations can use the framework to advise consumers which smartphones are more repairable than others.

9. Conclusion

The purpose of this thesis has been to find an answer to the following research question: How can consumers be stimulated to choose for smartphone repair over replacement? I have answered this question by developing a PSS that stimulates repair. The final PSS outcome is a smartphone application that has three main functionalities: failure diagnosis, failure solution, and failure prevention. Using the repairability framework that I have developed earlier in this thesis, I showed that this app contributes to making smartphone repair more feasible, and slightly more desirable. Significant improvement of viability, however, has not been achieved.

With regards to the research question, the PSS shows that a repair app like the one developed in this thesis can be a strategy to stimulate consumers to choose for repair over replacement. In no way do I claim that this is the only, or most promising strategy possible to stimulate repair over replacement, but from the explored options in this thesis, the app seems to hold the most potential. The main academic contribution of this thesis is the repairability framework that has been proposed in Chapter 3.2. Most repairability scoring systems that currently exist (e.g., iFixit, L'indice de Réparabilité) only take into account the aspects of repair feasibility, sometimes in combination with viability aspects. The scoring system that I proposed, however, takes all factors into account that influence the consumers decision to choose for repair, which also includes desirability aspects. Because several studies that have been mentioned in this thesis showed that most products are not discarded for being physically broken, I argue that desirability might be the most important aspect of repairability. Therefore, I argue that previous scoring systems miss a relevant point: when a smartphone is repairable in technical and economic terms (i.e., scoring high on most repairability scores), but the offerings of smartphone manufacturers and retailers make consumers more willing to choose for replacement, the consumer is not likely to eventually choose for repair.

Furthermore, the developed apps shows that it is possible to make repair more attractive in practice. I have not only shown that the app does seem to make repair more attractive, but also that it fulfils consumer needs, provides sustainable business opportunities, and is feasible for a small company to achieve. This thesis has also shown that the app can play a role in achieving environmental sustainability, because it helps consumers to extend the use cycle of a smartphone and thus to increase the material efficiency of smartphones. Therefore, anyone who reads this thesis could use the provided information to start developing the app and creating a sustainable business out of it, whilst contributing to environmental protection. Finally, both the app and the scoring system can be applied beyond the use case of smartphones. For instance, the app could also make the repair of tablets, laptops, or any household appliance more feasible and desirable by providing help with failure diagnosis, failure solution, and failure prevention.

10. References

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

Apple. (2021, April 1). *Gegevens overzetten vanaf uw vorige iOS-apparaat naar uw nieuwe iPhone, iPad of iPod touch*. https://support.apple.com/nl-nl/HT201269

Apple. (2021, June 14). *Getting a service for your Apple product after its warranty has expired*. https://support.apple.com/en-gb/HT201624

Apple. (n.d.-a). *Koop iPhone 12*. https://www.apple.com/nl/shop/buy-iphone/iphone-12

Apple. (n.d.-b). *Reparatie en service voor iPhone*. https://support.apple.com/nl-nl/iphone/repair/service

Apple. (n.d.-c). *Service en ondersteuning door de mensen die je iPhone het beste kennen*. https://www.apple.com/nl/support/products/iphone/

Azerty. (n.d.-a). *Garantie en defecten*. https://azerty.nl/service

Azerty. (n.d.-b). *Oud voor nieuw-regeling*. https://azerty.nl/oud-voor-nieuw-regeling

Baines, T. S., Lightfoot, H., Steve, E., Neely, A., Greenough, R., Peppard, J., Roy, R., ... Wilson, H. (2007). State-of-the-art in product service-systems. *Proc. IMechE, 221*(B), 1-11.

Bakker, C., Den Hollander, M., Van Hinte, E., Zijlstra, Y. (2014). *Products that Last: Product Design for Circular Business Models*. Amsterdam: BIS Publisher.

Bansal, P. (2002). The Corporate Challenges of Sustainable Development. *The Academy of Management Executive (1993-2005), 16*(2), 122-131.

Beuren, F. H., Gitirana Gomes Ferreira, M., & Cauchick Miguel, P. A. (2013). Product-service systems: a literature review on integrated products and services. *Journal of Cleaner Production, 47*, 222-231.

Belsimpel. (n.d.-a). *Garantie & Reparatie*. https://www.belsimpel.nl/klantenservice/aftersales/garantie-reparatie

Belsimpel. (n.d.-b). *Tulip Assist Mobile Telefoonverzekering*. https://www.belsimpel.nl/klantenservice/partners/tulip-assist-informatie

Ben. (n.d.). *Klantenservice*. https://service.ben.nl/service/vraag/844

Bocken, N. M. P., & Short, S. W. (2016). Towards a sufficiency-driven business model: Experiences and opportunities. *Environmental Innovation and Societal Transitions, 18*, 41-61.

Bol. (n.d.). *Garantie & Reparatie*. https://www.bol.com/nl/klantenservice/a/5636762709786624/garantie-reparatie

Bracquené, E., Peeters, J., Alfieri, F., Sanfelix, J., Duflou, J., Dewulf, W., & Cordella, M. (2021). Analysis of evaluation systems for product repairability: A case study for washing machines. *Journal of Cleaner Production, 281*.

Burns, B. (2010). Re-evaluating obsolescence and longer lasting products: Alternatives to the throwaway society. In: Cooper T (ed.) *Longer Lasting Products: Alternatives to the Throwaway Society*. Surrey, BC, Canada: Gower, pp. 39–60.

Calabretta, G., Gemser, G., & Karpen, I. (2016). *Strategic Design - 8 Essential Practices Every Strategic Designer Must Master*. BIS Publishers.

CBS. (2020). *Voorlopige bevolkingsaantallen, 1-1-2020*. https://www.cbs.nl/nl-nl/maatwerk/2020/11/voorlopige-bevolkingsaantallen-1-1-2020

Cherry, C. E., & Pidgeon, N. F. (2018). Why Is Ownership an Issue? Exploring Factors That Determine Public Acceptance of Product-Service Systems. *Sustainability, 10*(2289), 1-15.

Cooper, T. (2004). Inadequate life? Evidence of consumer attitudes to product obsolescence. *Journal of Consumer Policy, 27*(4), 421–449.

Cordella, M., Alfieri, F., Sanfelix, J. (2019). *Analysis and development of a scoring system for repair and upgrade of products*. EUR 29711 EN, Publications Office of the European Union, Luxembourg, 2019.

Cordella, M., Alfieri, F., Clemm, C., & Berwald, A. (2020a). Durability of smartphones: A technical analysis of reliability and repairability aspects. *Journal of Cleaner Production, 286*(125388), 1-11.

Cordella, M., Alfieri, F., & Sanfelix, J. (2020b). *Guide for the Assessment of Material Efficiency: Application to Smartphones*. Luxembourg: Publications Office of the European Union.

Coolblue. (n.d.-a). *Alles over iPhone Upgrade*. https://www.coolblue.nl/advies/alles-over-iphone-upgrade.html

Coolblue. (n.d.-b). *Apple iPhone 11 128 GB Zwart*. https://www.coolblue.nl/product/838341/apple-iphone-11-128-gb-zwart.html#422220710

Coolblue. (n.d.-c). *Telefoon Reparatie*. https://reparatie.coolblue.nl

Commown. (n.d.). *Fairphone 3 avec Services – Essentiel*. https://shop.commown.coop/shop/product/fairphone-3-avec-services-essentiel-326?category=3
Consumentenbond. (2016). *Levensduur digitale producten*. https://www.consumentenbond.nl/test/elektronica/levensduur-digitale-producten
Consumentenbond. (n.d.). *Wie zijn we*. https://www.consumentenbond.nl/over-ons/wie-zijn-we/overzicht
Crockett, Z. (2019). What are your chances of successfully raising money on Kickstarter? *The Hustle*. https://thehustle.co/crowdfunding-success-rate
Delft voor Elkaar. (n.d.). *Repair Café Mijnbouwstraat*. https://www.delftvoorelkaar.nl/activiteit/repair-cafe-mijnbouwstraat/
Den Hollander, M. C., Bakker, C. A., & Hultink, E. J.(2017). Product Design in a Circular Economy - Development of a Typology of Key Concepts and Terms. *Journal of Industrial Ecology, 21*(3), 517-525.
Elkington, J. (1997). *Cannibals with Forks: the Triple Bottom Line of 21st Century*. Capstone.
European Commission. (n.d.-a). *LIFE Programme*. https://cinea.ec.europa.eu/life_en
European Commission. (n.d.-b). *2021 operating grants for non-profit-making entities*. https://cinea.ec.europa.eu/life/life-calls-proposals/2021-operating-grants-non-profit-making-entities_en
European Parliament. (2020, November 25). Parliament wants to grant EU consumers a “right to repair”. *European Parliament News*. https://www.europarl.europa.eu/news/en/press-room/20201120IPR92118/parliament-wants-to-grant-eu-consumers-a-right-to-repair
Fairphone. (n.d.). *Find & fix an issue yourself*. https://support.fairphone.com/hc/en-us/articles/115001041206
Fixtel. (n.d.). *Home*. https://www.fixtel.nl
Gemser, G., Kuijken, B., Wijnberg, N. M., Van Erp, J. (2012). The Experience of Product Service Systems. *Proceedings of 8th International Design and Emotion Conference London 2012 Central Saint Martins College of Arts & Design*, 11-14 September 2012, 1-8.
GlobalStats. (2021). *Mobile Vendor Market Share Netherlands*. https://gs.statcounter.com/vendor-market-share/mobile/netherlands/#yearly-2017-2021-bar
Granberg, B. (1997). *The Quality Re-Evaluation Process: Product Obsolescence in a Consumer-Producer Interaction Framework*. Stockholm: University of Stockholm.
Guiltinan, J. (2010). Creative destruction and destructive creations: Environmental ethics and planned obsolescence. *Journal of Business Ethics, 89*(1): 19–28.
GSM Paradise. (n.d.). *Home*. https://www.gsm-paradise.nl
Haber, N., & Fargnoli, M. (2017). Designing Product-Service Systems: A Review Towards A Unified Approach. *Proceedings of the International Conference on Industrial Engineering and Operations Management Rabat, Morocco*, 817-837.
Haines-Gadd, M., Chapman, J., Lloyd, P., Mason, J., & Aliakseyeu, D. (2018). Emotional Durability Design Nine—A Tool for Product Longevity. *Sustainability, 10,* 1-19.
Hamilton, R. W., Ratner, R. K., Thompson, D. V. (2011). Outpacing Others: When Consumers Value Products Based on Relative Usage Frequency. *Journal of Consumer Research, 37*(6),1079-1094
Heiskanen, E. (1996). Conditions for product life extension. *Working papers 22*, Helsinki: National Consumer Research Centre.
Hobson, K., Lynch, N., Lilley, D., & Smalley, G. (2019). Systems of practice and the Circular Economy: Transforming mobile phone product service systems. *Environmental Innovation and Societal Transitions, 26*, 147-157.
Hollandsnieuwe. (n.d.). Smartphone snel en vakkundig repareren? https://reparatie.hollandsnieuwe.nl/hol_nl
Hou, C., Jo, M.-S., Sarigöllü, E. (2020). Feelings of satiation as a mediator between a product’s perceived value and replacement intentions. *Journal of Cleaner Production, 258*, 1-9.
Huawei. (n.d.-a). *Huawei inruilen*. https://consumer.huawei.com/nl/phones/mate40-pro/buy/
Huawei. (n.d.-b). *Phone Clone*. https://consumer.huawei.com/nl/emui/clone/
Huawei. (n.d.-c). *Problemen oplossen*. https://consumer.huawei.com/nl/support/smart-diagnosis/
iFixit. (2020, March 4). *Samsung Galaxy S20 Ultra Repair*. https://www.ifixit.com/Device/Samsung_Galaxy_S20_Ultra
iFixit. (2020, November 21). *iPhone 12 Pro Max Repair*. https://www.ifixit.com/Device/iPhone_12_Pro_Max
iFixit. (2020, December 7). *Huawei Mate 40 Pro Repair*. https://www.ifixit.com/Device/Huawei_Mate_40_Pro
iFixit. (2019, September 11). *Fairphone 3 and 3+ Repair*. https://www.ifixit.com/Device/Fairphone_3
iFixit. (n.d.-a). *About us*. https://www.ifixit.com/Info/index
iFixit. (n.d.-b). *Shift 6m Repair*. https://www.ifixit.com/Device/Shift_6m
iFixit. (n.d.-c). *Smartphone repairability*. https://nl.ifixit.com/smartphone-repairability
iFixit. (n.d.-d). *Store*. https://eustore.ifixit.com/collections/parts
Khan, M. A., Mittal, S., West, S. & Wuest, T. (2018). Review on upgradability e A product lifetime extension strategy in the context of product service systems. *Journal of Cleaner Production, 204*, 1154-1168.
Kostecki, M. (Ed.). (1998). *The durable use of consumer products*. Dordrecht: Kluwer.
KPN. (n.d.-a). *Schade aan je toestel*. https://www.kpn.com/service/mobiel/schade.htm#/
KPN. (n.d.-b). *Toestelverzekering*. https://www.kpn.com/zakelijk/mobiel/extra-opties/telefoon-verzekeren.htm
Kuijken, B., Gemser, G., & Wijnberg, N. M. (2016). Effective product-service systems: A value-based framework. *Industrial Marketing Management, 60*, 33-41.
Kuppelwieser, V. G., Klaus, P., Manthiou, A., & Boujena, O. (2019). Consumer responses to planned obsolescence. *Journal of Retailing and Consumer Services, 47*, 157–165.
Lee, K., Khan, S., Mirchandani, D. (2013). Hierarchical effects of product attributes on actualized innovativeness in the context of high-tech products. *Journal of Business Research, 66*, 2634–2641.
Lexico. (n.d.). *Smartphone*. https://www.lexico.com/definition/smartphone
L’indice de Réparabilité. (2020, October 26). *Smartphone APPLE iPhone 12 Pro Max 128Go Graphite*. https://www.indicereparabilite.fr/produit/smartphone-apple-iphone-12-pro-max-128go-graphite/
L’indice de Réparabilité. (2020, November 30). *Smartphone SAMSUNG GALAXY S20 Ultra 5G*. https://www.indicereparabilite.fr/produit/smartphone-samsung-galaxy-s20-ultra-5g/

L'indice de Réparabilité. (2021, January 18). *Smartphone Fairphone FP3+*. https://www.indicereparabilite.fr/produit/smartphone-fairphone-fp3/
L'indice de Réparabilité. (2021, January 19). *Smartphone HUAWEI Mate 30 Pro 256 Go Argent*. https://www.indicereparabilite.fr/produit/smartphone-huawei-mate-30-pro-256-go-argent/
MediaMarkt. (n.d.-a). *Schermreparatie*. https://www.mediamarkt.nl/nl/shop/schermreparatie.html
MediaMarkt. (n.d.-b). *Telefoon inruilen bij ons in de winkel*. https://www.mediamarkt.nl/nl/shop/telefoon-inruilen.html
Mobiel. (n.d.). *Vragen & contact*. https://www.mobiel.nl/vragen-en-contact/garantie-reparatie/bieden-jullie-verzekeringen-aan/smartphoneverzekering
Mobileparts Shop. (n.d.). *Samsung Galaxy S20 Ultra*. https://www.mobileparts.shop/samsung-model-group/samsung_galaxy_s20_ultra.htm?lid=1
Morelli, N. (2002). Designing Product/Service Systems: A Methodological Exploration. *Design Issues, 18*(3), 3-17.
Mugge, R. (2007). *Product Attachment* (doctoral thesis).
Munten, P., Vanhamme, J., & Swaen, V. (2021). Reducing obsolescence practices from a product-oriented PSS perspective: A research agenda. *Recherche et Applications en Marketing*, 1–33.
OCU. (2018). *Los móviles acumulan el 51 % de las quejas de obsolescencia prematura*. https://www.ocu.org/consumo-familia/derechos-consumidor/noticias/obsolescencia-prematura
Okada, E. M. (2001). Trade-ins, mental accounting, and product replacement decisions. *Journal of Consumer Research, 27*, 433–446.
One Army. (n.d.). *Other Modular phones*. https://www.onearmy.earth/project/phonebloks
Packard, V. (1960). *The Waste Makers*. Harmondsworth: Penguin Books.
Poppelaars, F., Bakker, C., van Engelen, J. (2018). Does Access Trump Ownership? Exploring Consumer Acceptance of Access-Based Consumption in the Case of Smartphones. *Sustainability, 10*(2133), 1-18.
Pozo Arcos, B., Bakker, C., Flipsen, B., & Balkenende, R. (2020). Practices of fault diagnosis in household appliances: Insights for design. *Journal of Cleaner Production, 265*, 1-11.
PROMPT. (n.d.). *PROMPT Project*. https://prompt-project.eu/
Proske, M., & Jaeger-Erben, M. (2019). Decreasing obsolescence with modular smartphones? - An interdisciplinary perspective on lifecycles. *Journal of Cleaner Production, 223*, 57-66.
Proske, M., Winzer, J., Marwede, M., Nissen, N. F., & Lang, K.-D. (2016). *Obsolescence of Electronics - the Example of Smartphones*.
Riisgaard, M., Mosgaard, M., & Overgaard Zacho, K. (2016). Local Circles in a Circular Economy – the Case of Smartphone Repair in Denmark. *European Journal of Sustainable Development, 5*(1), 109-124.
Rousseau, S. (2020). Millennials' acceptance of product-service systems: Leasing smartphones in Flanders (Belgium). *Journal of Cleaner Production, 246*, 1-9.
Saldaña, J. (2013). An introduction to codes and coding. In: *The coding manual for qualitative researchers, Second Edition*. SAGE Publications Ltd, London, pp. 1-40.
Samsung. (2020, September 23). *Samsung Members: How to perform hardware test?* https://www.samsung.com/levant/support/mobile-devices/samsung-members-how-to-perform-hardware-test/#helpHtg1callOrder0_3
Samsung. (n.d.-a). *Algemene Voorwaarden - Samsung Ophaalservice*. https://www.samsung.com/nl/support/mobile-devices/algemene-voorwaarden-samsung-ophaalservice/
Samsung. (n.d.-b). *Samsung Care+*. https://www.samsung.com/nl/offer/samsung-care-plus/
Samsung. (n.d.-c). *Private Lease*. https://www.samsung.com/nl/privatelease/
Samsung. (n.d.-d). *Reparatieservice: Selecteer je toestel*. https://www.samsung.com/nl/support/repair/booking/#/StepDevice/
Samsung. (n.d.-e). *Samsung inruil*. https://shop.samsung.com/nl/cart/
Samsung. (n.d.-f). *Samsung Remote Service*. https://www.samsung.com/us/support/remoteservice/
Schneider, A. F., Matinfar, S., Grua, E. M., Casado-Mansilla, D., & Cordewener, L. (2018). Towards a sustainable business model for smartphones: Combining product-service systems with modularity. *EPiC Series in Computing, 52*, 82-99.
Sheth, J. N., Newman, B. I., Gross, B. L. (1991). Why we buy what we buy: a theory of consumption values: discovery service for air force institute of technology. *Journal of Business Research, 22*, 159-170.
Simyo. (2017, October 9). *Telefoon en garantie: hoe zit dat precies?* https://www.simyo.nl/blog/telefoon-en-garantie/
Soh, S. L., Ong, S. K., & Nee, A. Y. C. (2015). Design for Disassembly for Remanufacturing: Methodology and Technology. *Procedia CIRP 15*, 407-412.
Statista. (2021). *Number of smartphones sold to end users worldwide from 2007 to 2021*. https://www.statista.com/statistics/263437/global-smartphone-sales-to-end-users-since-2007/
Swapphone. (n.d.). *Shop*. https://shop.swapphone.nl/products
Tele2. (n.d.). *Telefoon laten repareren*. https://www.tele2.nl/klantenservice/mobiel/telefoon/reparatie
Telgefixt. (n.d.). *Home*. https://telgefixt.nl
The Fixables. (n.d.-a). *Afspraak Pick Up Service*. https://fixables.nl/pick-up-voor-reparatie/
The Fixables. (n.d.-b). *Huawei reparatie*. https://fixables.nl/telefoon-reparatie/huawei-reparatie/#prize-table
T-mobile. (n.d.-a). *Onze verzekeringen*. https://www.t-mobile.nl/telefoon/toestelverzekering
T-mobile. (n.d.-b). T*oestelreparatie en verzekeringen*. https://www.t-mobile.nl/klantenservice/mobiel/reparatie
Tröger, N., Wieser, H., Hübner, R. (2017). Smartphone are replaced more frequently than T-shirts. *Portal der Arbeiterkammern*. https://emedien.arbeiterkammer.at/viewer/resolver?urn=um:nbn:at:at-akw:g-490923
Tukker, A. (2004). Eight types of Product-Service System: eight ways to sustainability? Experiences from SusProNet. *Business Strategy and the Environment, 13*, 246–260.
Tukker, A. (2015). Product services for a resource-efficient and circular economy - a review. *Journal of Cleaner Production, 97,* 76-91.
Tukker, A., & Tischner, U. (2006). Product-services as a research field: past, present and future. Reflections from a

decade of research. *Journal of Cleaner Production, 14*(17), 1552-1556.
Tweakers. (n.d.). *Apple iPhone 12 Pro Max*. https://tweakers.net/smartphones/apple/iphone-12-pro-max_p1193686/vergelijken/
Valencia, A., Mugge, R., Schoormans, J. P. L., & Schifferstein, H. N. J. (2015). The Design of Smart Product-Service Systems (PSSs): An Exploration of Design Characteristics. *International Journal of Design, 9*(1), 13-28.
Van den Berge, R., Magnier, L., & Mugge, R. (2021). Too good to go? Consumers' replacement behaviour and potential strategies for stimulating product retention. *Current Opinion in Psychology, 39*, 66–71.
Vanegas, P., Peeters, J. R., Cattrysse, D., Tecchio, P., Ardente, F., Mathieux, F., ... Duflou, J. R. (2018). Ease of disassembly of products to support circular economy strategies. *Resources, Conservation & Recycling, 135*, 323-334.
Van Nes, N., & Cramer, J. (2005). Influencing product lifetime through product design. *Business Strategy and the Environment, 14*(5): 286–299.
Van Nes, N., & Cramer, J. (2008). Conceptual model on replacement behavior. *International Journal of Product Development, 6*(3), 291–309.
Vasantha, G. V. A., Hussain, R., Roy, R., Tiwari, A., & Evans, S. (2011). A framework for designing Product-Service Systems. *International Conference on Engineering Design, ICED11, 15-18 August 2011*, 1-10.
Vezzoli, C., Ceschin, F., Osanjo, L., M'Rithaa, M. K., Moalosi, R., Nakazibwe, V., & Diehl, J. C. (2018). *Designing Sustainable Energy for All*. Cham: Springer.
Vodafone. (2018). *Reparatievoorwaarden*. https://www.vodafone.nl/_assets/downloads/voorwaarden/actueel/reparatievoorwaarden.pdf
Vodafone. (n.d.). *Verzeker je mobiele telefoon*. https://www.vodafone.nl/telefoon/informatie/verzekeren
Vrijdag, S. (2021). *De beste mobiele provider*. https://www.consumentenbond.nl/mobiel-abonnement/beste
Wallner, T. S., Magnier, L., & Mugge, R. (2020). An Exploration of the Value of Timeless Design Styles for the Consumer Acceptance of Refurbished Products. *Sustainability, 12*, 1-17.
Wertgarantie. (2019). *Smartphone Repair Study 2019*. https://reparatur-marktplatz.wertgarantie.de/images/presse/downloads/pdf/clickrepair-smartphone-repair-study-2019-en.pdf
Youfone. (n.d.). *Garantie & Reparatie*. https://support.youfone.nl/support/solutions/folders/14000123587

Appendix A. Consumer interview guide

Hi, thank you for participating in my research project. During the next 30 to 45 minutes, I'll ask you some questions about your smartphone. Before we begin, I'll tell you a little bit more about myself. My name is Louise, I am a student of Strategic Product Design at TU Delft, and for my graduation project I am performing a study on smartphones. Could you tell me something about yourself? Who you are, how old you are, what you do for work or studies, and where you are from?

1. Introduction: current smartphone
Okay, let's get started. I'm curious about your phone. Do you have it with you, and can you show it?

- Can you describe your phone to me?
- What kind of brand and type of smartphone is it?
- Are you happy with it?
- Or would you like to have a new phone?

2. Purchase of the current phone
For my research, I would like to learn more about everything you have experienced with this phone. That may sound like a lot, but let's take it step by step.

- How did you obtain this phone?
- Did you buy it, or did you get it as a gift?
- Where and when was this?
- Do you remember how much it costed?
- Why did you choose this specific model, and not another model or brand?
- What was the reason you purchased a new phone?
- Did you have another smartphone before this one?
- What did you think of your old phone?
- Did it work properly?

3. Life and condition of the current phone
Okay, so if I understand correctly, you've owned this phone [for several years]. I'm curious about your experience during these [years].

- If you think about the last [years] that you have been using this phone, what is your general experience?
- Have you always been satisfied with your phone? Why (not)?
- Have you ever experienced problems when using your phone?
- Did it ever break? How did this happen?
- Have you ever fixed your current phone?
- If so, what did you fix? And what was your experience like?
- If not, why not? Have you considered it?
- Does the phone still meet all your requirements?
- Do you think the phone still works as well as when you first used it? Why?
- Compared to other phones on the market, what do you think of your phone?
- It's also possible that you don't mind this, that's okay.

4. Scenarios of physical obsolescence
Your phone may break. I'm curious about the steps you'd take if this happens. I have prepared some scenarios that you can think about.

- Let's say that tomorrow, the display breaks or gets scratched, what would you do?
- What are other options you might or might not consider? Why?
- What would you do if the back or side breaks or gets scratched?
- What would you do if the phone simply fails to turn on?

Of course, your phone may also perform worse over time. I'm also curious what you'd do in those cases.

- Suppose the battery drains drain quickly, what would you do?
- What would you do if the phone becomes slower?

In all the scenarios we've just discussed, you can choose to fix the phone by returning it to its original state.

- What options would you consider when getting your phone repaired? Who would you allow to do this? Can you name the advantages and disadvantages that you would experience?
- The manufacturer?
- A repair shop in town?
- Or maybe by a friend who has technical knowledge?
- Have you ever thought about doing the repair yourself?

Of course, you can also choose to hand in your phone at the manufacturer, or resell it as soon as you buy a new one.

- How much do you think your phone is worth right now?
- What do you expect to receive if you return

it to the manufacturer?
- And if you would sell it second-hand?
- Would you actually turn the phone in or resell it?
- Or would you do something else with it?
- Do you keep your old phones?

5. Repair PSS

Once you buy a smartphone, there are several options to choose from. Of course, you can choose which brand and model you want, but nowadays, you can also choose from different services that are attached to the smartphone. This is often referred to as a Product Service System. Within such a system, the smartphone is offered in combination with a service. This service can be anything, such as an additional repair insurance. The price of the service can be included in the price of the entire Product-Service System but can also be offered as an additional option. I have laid out several options for you, and I'm curious to hear what you think of them.

The first choice you can make is between buying a smartphone, [as you did for your current phone], and 'leasing' a smartphone. Smartphone leasing works just like leasing a car: you can do whatever you want with the smartphone, but it always remains in the possession of the manufacturer.
- Are you familiar with leasing smartphones?
- Are you familiar with paying a monthly fee for a smartphone?
- What else can you tell me about it?
- What advantages and disadvantages do you see for both options?
- What do you think of it when the smartphone would not be in your possession?
- How do you estimate the costs for both options?
- How do you estimate the price-quality ratio of both options?

When 'leasing' smartphones, there are several additional services that can be offered. Option 1: The manufacturer arranges an equivalent replacement device as soon as your phone needs a repair. Option 2: As soon as you want to have a new smartphone, the manufacturer will provide a new one for you. Option 3: The manufacturer monitors your phone and keeps in touch with you, so that they can optimize their new smartphones and software according to your use.
- What do you think of an equivalent replacement device when your phone needs a repair?
- Would this be interesting for you?
- What do you think about a lease contract allowing you to choose a new phone as soon as you would like to have one?
- Would this be interesting for you?
- What do you think of it when the manufacturer uses your data and maintains personal contact with you to optimize their smartphones and software?
- Would this be interesting for you?
- Which option would ultimately be your preference? Why?

You may also choose between a 2-year manufacturer's warranty, which all products in the Netherlands have, and a full insurance of 2 years. The manufacturer's warranty includes free repairs for all problems that may arise from the phone, this does not include problems that you have caused yourself (e.g., if you drop the phone). For the full insurance, you would need to pay an additional fee in order to freely repair problems that you have caused yourself.
- Are you familiar with this warranty and insurance?
- What else can you tell me about it?
- What advantages and disadvantages do you see for both options?
- How do you estimate the costs for both options?
- How long do you expect a phone to last?
- Is 2 years enough, too little, or too much?
- Which option would you ultimately prefer? Why?

Current smartphones are generally not designed so that you can repair them yourself. However, there are phones on the market that do make this possible. So, you could choose from a smartphone of which repair is always carried out by the manufacturer or repair shop, or a smartphone that you can repair yourself.
- Do you have experience with repair at repair shops?
- Can you tell me more about it?
- Are you familiar with smartphones that you can repair yourself?
- What else can you tell me about it?
- What advantages and disadvantages do you see for both options?
- How do you estimate the costs for both options?
- What would make repair interesting for you?

- Do you know any other options that would make repair more interesting for you?
- Would you be interested in repairing your phone yourself?
- How difficult do you expect that smartphone repair would be?
- Which option would you ultimately prefer? Why?

End

These were all the questions that I wanted to ask. Thank you for your answers. I've learned a lot about your phone usage, and this will help me a lot in my research. I have already found that many people buy a new phone when the old phone is still in a good condition or has only a small defect. In my research, I'm trying to do something about this. I am trying to set up a system in which it becomes more attractive for you as a consumer to have your phone repaired, so that you can extend the lifetime of your smartphone. This ultimately aims to create less new phones, and thus allows less scarce materials to be used to make these phones. With your answers, I have gained more insight in the possible reasons you may have to buy or repair a phone.

Appendix B. Concept testing questionnaire

Please answer the following questions for each service. Tick one of the five options per question. For example, for question 1, ++ means that you would find the service very easy, and -- means that you would not find the service easy at all.

Repair Adventures -- - +/- + ++

1. How easy do you find this service to be?
2. How effortless do you find this service to be?
3. To what extent do you think this service is worth the money?
4. To what extent do you think this service is a good deal?
5. How much satisfaction can you get from this service?
6. How happy would you be with this service?
7. The moment your phone is broken, how likely are you to use Repair Adventures?
8. The moment you use Repair Adventures, how likely are you to have your phone repaired?

Ultimate Repair app -- - +/- + ++

1. How easy do you find this app to be?
2. How effortless do you find this app to be?
3. To what extent do you think this app is worth the money?
4. To what extent do you think this app is a good deal?
5. How much satisfaction can you get from this app?
6. How happy would you be with this app?
7. The moment your phone is broken, how likely are you to use the Ultimate Repair App?
8. The moment you use the Ultimate Repair App, how likely are you to have your phone repaired?

Repair and Upgrade service -- - +/- + ++

1. How easy do you find this service to be?
2. How effortless do you find this service to be?
3. To what extent do you think this service is worth the money?
4. To what extent do you think this service is a good deal?
5. How much satisfaction can you get from this service?
6. How happy would you be with this service?
7. The moment your phone is broken, how likely are you to use the Repair and Upgrade service?
8. The moment you use the Repair and Upgrade service, how likely are you to have your phone repaired?

Repair Adventures -- - +/- + ++

1. How easy do you find this service to be?
2. How effortless do you find this service to be?
3. To what extent do you think this service is worth the money?
4. To what extent do you think this service is a good deal?
5. How much satisfaction can you get from this service?
6. How happy would you be with this service?
7. The moment your phone is broken, how likely are you to use the Repair Marketplace?
8. The moment you use the Repair Marketplace, how likely are you to have your phone repaired?

Appendix C. Final concept testing usage scenarios

1. You've been on train trip for the day. After a long day, you arrive at your home station, and at the moment that you exit the train, your phone falls out of your pocket. When you pick it up, you find out that the screen is completely cracked, over the entire surface of the display. The phone is still somewhat usable, but it is not very good. As soon as you get home, you realize that you want to do something about this and decide to look up the possibilities in terms of repair. You come across this app and try it out right away.
2. You have been experiencing a problem with your phone for a long time now. At random moments, it shuts down. It doesn't seem to depend on the battery percentage at the time, or which app you're using. It does, however, seem to be happening more and more often, and you're starting to get annoyed about it. You decide that you want to know how to solve this problem. You then come across this app and try it out.
3. You just bought a new phone. It's doing great and has new features when compared to your old phone. Because you want to be careful with it, you decide that you want to know how to best manage your phone. You then come across this app and find out what it has to offer.

Designing a product service system for smartphone repair

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 01 - 02 - 2021

02 - 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, ...).

Extending the lifetime of electrical and electronic equipment (EEE) will significantly reduce the ecological footprint of current consumption patterns. Such a life-time extension can be (partly) achieved through the repairability of products. This is especially true for smartphones, as they have been shown to be often replaced prematurely, more often than other products. Recent developments within the European Union under the umbrella of the “right to repair” show the important role repairability can play to achieve sustainability goals. Within the notion of the "right to repair", it should be easy for users to repair their own products. This should be doable for themselves, but it should also be easy for the users to let the manufacturer or a third party do this. As regulations will (have to) be changed in order to enforce the repairability of smartphones, all other stakeholders in the system will need to adapt to these regulatory changes, most notably the smartphone manufacturing company and the consumer. Making smartphones repairable does not currently pose an interesting option for manufacturing companies, because this could lead to lesser sales of new models and thus a decrease in revenue. The consumer might not be enthusiastic about repairability as well, because the act of purchasing a new smartphone fulfils psychological needs. Other stakeholders that are relevant within the repairability of smartphones, include consumers associations, third-party repair shops, retailers of smartphones, network providers, and all parties along the production chain of smartphones. Allowing a consumer to spend a longer time with one model of a smartphone will automatically make its consumption less resource intensive. More efficient production and use of materials will also allow companies to maximize their operational efficiency and reduce production costs. Additionally, a repair service might be an extra income stream for manufacturing companies. Next to advantages for the environment and companies, using a smartphone model for a longer time will also allow the consumer to spend less money and time on the purchase of a new model. Finally, when there will be greater willingness among consumers to repair their phones, third-party repair shops will benefit from having more potential customers. Despite the aforementioned advantages, there are major limitations to repairability. On the consumer side, there exist unawareness and unwillingness. Firstly, the consumer often doesn’t know how much impact it will have to use his smartphone for an extended period of time. Secondly, consumers are often unaware of the repair possibilities that exist when a smartphone has seemingly become (functionally) obsolete. Third, fulfilment of psychological and social needs does not come with the repair of old smartphones. Parties along the production and retail chain benefit the most from achieving a high number of sales, which is not maximized with repairable smartphones. Because sustainability and profitability are difficult to combine, it will be difficult for these companies to adapt and make smartphones more repairable.

In this project, I choose to design a Product-Service System that incentivizes consumers to choose for smartphone repair. This system will not primarily be designed for a smartphone company, but for consumers and consumers associations. The goal of this project is to help them understand what a Product-Service System for repairable smartphones can look like. This will help consumers make informed decisions on the purchase of smartphones and eventually, it gives consumers and consumers association information to force companies to adopt a similar Product-Service System.

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Initials & Name L. Platell Student number 4574923

Title of Project Designing a product service system for smartphone repair

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.

Currently, consumers are likely to discard their smartphone when it is still in a functional or repairable state. This is caused by many factors, of which the consumer and the smartphone manufacturer are the most important actors. In this graduation project, I will focus on the role of the manufacturer in incentivizing the consumer to repair a smartphone when it has failed. There is currently a lack of incentive that Product-Service Systems provide for consumers to choose to repair their smartphone instead of replacing it. The set-up of current smartphone retail systems poses a two-side problem; on the one hand, consumers are relatively more willing to replace a smartphone and on the other hand, consumers are relatively less willing to repair it.

The design of a Product-Service System that takes care of the two-sided problem discussed above, should support consumers, at the point of product failure, to decide to repair their current smartphone. When consumers know more about Product-Service Systems for repairable smartphones, they can make the right decision to purchase a smartphone within a given Product-Service System. This project will also produce knowledge for consumers associations by showing what components a repairable product service system can consist of. This will enable consumers associations to advise consumers and possibly force companies to adopt a similar Product-Service System.

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.

In this graduation project, I develop a smartphone Product-Service System that stimulates consumers to choose for repair over replacement.

RQ: What design of a smartphone Product-Service System stimulates consumers to choose for repair over replacement? Implementing a PSS that incentivizes consumers to choose for repair over replacement will lead to environmental benefits, as the use cycle of a smartphone is extended, which eventually leads to life cycle extension. Before I will be able to design this PSS, I must understand why consumers would want to replace their smartphone in the first place, and how repair can postpone this replacement decision. This project has four sub research questions:
1. What opportunities and barriers do consumers perceive when they decide to replace their smartphone?
2. What opportunities and barriers do consumers perceive when they decide to repair their smartphone?
3. What solutions do currently exist to stimulate consumers to choose for repair over replacement?
4. What opportunities and barriers do Product-Service Systems pose for stimulating consumers to choose for repair over replacement of their smartphone?

The design of this 'ideal product-service combination for repair' should allow consumers and consumers associations to gain deeper insight in what kind of Product-Service System works best for the repair of smartphones. As I will also study the effectiveness of the designed Product-Service System in supporting consumers to choose for repair, I will provide clear guidelines for consumer associations to assess the repairability of a smartphone Product-Service System. This way, consumers can gain knowledge about the possibilities in the market, and consumers associations can advise consumers with regards to the best possibilities.

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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 1 - 2 - 2021 2 - 7 - 2021 end date

	±4,5 days a week (30 EC, 22 weeks)																				
Calendar week	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Project week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Month	February				March					April				May					June			
Exploration																						
Literature review																						
Desktop research																						
Expert interviews																						
Research																						
Set-up																						
Execution																						
Analysis																						
Design																						
Requirements/KPIs																						
Idea generation																						
Prototyping																						
Concept development																						
Final evaluation																						
Review requirements/KPIs																						
Guidelines																						
Recommendations																						
Official meetings	Kick-off meeting								Mid-term meeting								Green light meeting				Graduation ceremony
Preliminary dates	01/Feb			22/Feb			15/Mar		29/Mar			19/Apr			10/May			31/May			21/Jun	02/Jul
Other meetings				Mentor + Chair			Mentor + Chair					Mentor + Chair			Mentor + Chair						Mentor + Chair	

As mentioned in the assignment description, this project has four sub research questions. I will first study these questions by conducting a literature review. In this literature review, I will look at the first two questions, and the theoretical part of the third and fourth question. In addition to these theoretical solutions, I will perform desk research and expert interviews to explore existing solutions, and the current PSSs of smartphone manufacturers. I will further explore the existing smartphone PSSs in a short consumer study. In semi-structured interviews, I will talk with consumers about their reasons for replacing or repairing a smartphone, by comparing the different existing PSSs of smartphone manufacturers. Interviews are chosen to gain a deep understanding of the consumers' opinions. Based on the findings, I adapt the framework and make a final problem definition. Then, I start the design process with the definition of the design requirements. After this, I will make several prototypes of concepts, which I will later test in a second consumer study. This time, I will use an online questionnaire with both closed and open-ended questions. Compared to interviews, a questionnaire will allow me to get relatively more generalizable information from more consumers. As both the generalizability and the deep understanding of consumers' opinions are needed, the questionnaire will consist of both closed and open-ended questions. Based on the findings from this research, I will further develop one prototype. Having developed this prototype, I will conduct another online questionnaire with closed and open-ended questions, to validate the prototype. Based on the findings from this study, I will discuss to what extent the developed prototype incentivizes consumers to choose for repair over replacement. I will then provide guidelines with regards to what factors constitute a PSS that incentivizes consumers to repair their current smartphone model, and what not. I will also discuss recommendations for further research into this topic.

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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.

I chose to set up this project, because I have developed an interest in designing sustainable solutions during the Master. I think, especially as a designer, it is important to always keep into account how a certain product or service will affect the environment and society at large. In addition to learning more about sustainable design and design for repair, I have several competences that I want to learn or improve:

- Integration of research with design
Something that I missed at times during both my Master and Bachelor is the link between theory and practice. There have been developed many academic theories and research experiments that could provide valuable insights for most projects. I think that applies to this project as well. Although I do not want my project to become a research-only project, I want to make sure that I use academic knowledge to design a fitting solution to a relevant problem. I still lack a lot of experience in making this link between academia and practice, but I think that this will be the perfect time to get this experience. In order to do this, I plan to use the findings from the literature review, desk research, expert interviews, and small consumer studies to develop and validate design requirements and ideas. This will help me throughout the design process to improve the design.

- Developing Product Service Systems
Looking at the innovations of recent years, like Swapfiets, I think that product-service systems and services will become even more relevant over the coming years. Especially in the circular economy, Product-Service Systems can be a relevant tool to allow consumers to minimize the ecological footprint of their consumption patterns. As I would like to work on product-service innovations after my graduation, I am very eager to learn more about how to design Product Service Systems. During the Master, most projects revolved around the design of product-service systems or services alone. This means that I do have some experience with the design of product-service combinations, but I think that my previous projects lacked a real integration of the product design and the service design, which is what I want to learn more about in this project.

- Repairability of products; smartphone infrastructure
Personally, I am very interested in the design of electronic products. I like to take them apart and see how they are designed. Although I am slightly familiar with the internals of a smartphone, it is still sort of a 'magic' black box for me. Therefore, I want to use this project to learn more about the design of a smartphone and understand why certain decisions have been made in the design and development of these products. I do not only want to learn more about the actual design of the phone, but also the service provision that companies provide with the phone. I think that these two components are highly linked. A good understanding of the product and service design of current smartphones will allow me to make informed decisions on the design of a Product-Service System that allows for the repair of smartphones.

FINAL COMMENTS

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