DESIGNING A WASHING MACHINE FOR THE SERVICE ECONOMY

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MSc Integrated Product Design
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PREFACE

This project marks the end of my Master studies, with which I hope I can start contributing and collaborating with others to deliver solutions that have a positive impact in people's lives and our planet, and improve the way we design, produce and consume goods.

I am extremely thankful to **TU Delft** and the **Justus van Effen scholarship committee** for giving me the opportunity of learning so much about the things I am passionate about these past two years.

Jotte, Mark and Emilia. Thank you for always taking the time, for sharing so many resources with me and for all your feedback, I learned a lot from it. But especially thank you for always doing it with a sense of humour and in such a caring way.

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My friends. For those here and there and for those back in Mexico. Thank you for all your love... for feeding me, cheering me up and motivating me throughout the project. Also, thanks for the last sprint motivation library crew.

LIST OF TERMS AND ABBREVIATIONS

Business to Business (B2B). Offer or commercial agreement from one company to other companies or business.

Business to Consumer (B2C). Offer or commercial agreement from a company to consumers.

Circular Economy (CE). Economic model that proposes the closure of material loops and aims to decouple profits from the use of resources.

Customer. A person that buys or acquires a product or service. In this report the user and customer could be the same person.

High-end or high quality washing machine. Washing machines that count with a high life expectancy (16 or more years) and have an energy efficiency score of A+++. .

Internet of Things (IoT). Physical objects that are wirelessly connected to a digital network where they are enabled to receive and send data, becoming 'intelligent' and giving them possibilities such as sensing, interacting and communicating with other 'things' and users.

Life cycle. In this report, it refers to all steps that constitute the 'life' of the PSS. From material extraction and manufacturing, to transportation, use, reuse, disposal etc. In this report the phases of the life cycle are referred to as pre-use, use and post-use.

Life Cycle Assessment (LCA). Life-cycle assessment is a form of assessing the environmental impact of all the stages of a product's life cycle.

Low-end or low quality washing machine. Washing machines that count with a low life expectancy (12 years or less) and have an energy efficiency score below A+++.

Maintenance. In this report it refers to the actions that can be taken during the use phase to prevent malfunctions and keep the machine in good state, e.g. cleaning.

Product Service System (PSS). Combination of a product and a service that together fulfill a customer need.

Recycling. Transformation of materials from used products to be used in new products.

Refurbish. Giving service to a product to return it as close as possible to a 'new' state in order to put it through additional life cycles.

Repairing. Action of returning a product to a state of function. It can include the replacement of components.

Total Cost of Ownership (TCO). The Total Cost of Ownership can be defined as the sum of costs associated with the acquisition, ownership, use (consumables, energy and water, in the case of a washing machine) and subsequent disposal of a good or a service.

Updating. Renewing the physical or digital components of a washing machine in order to extend its functional life.

Use cycle. In this report it is considered to be the period where the washing machine is in a user's home until the machine goes back to the provider for refurbishment.

User. A person that uses a product or service. In this report the user is the person who uses the washing machine.

EXECUTIVE SUMMARY

Product Service Systems (PSSs) are considered to be a promising approach towards a sustainable, resource efficient economy (Tukker, A., 2015) (defined as 'a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs' (Tukker, A. & Tischner, 2006)), because they make the delivery of satisfaction possible through functions and not necessarily through products, fulfilling needs with less resources and consequently with lower impact. This is especially true when they are specifically designed to provide high quality resource efficient products. Bundles is a Dutch company that is intending to do exactly that, making high quality home appliances accessible through a Use oriented PSS (Tukker, 2003) where they lease washing machines and other home appliances, maintaining the ownership over the washing machine and becoming responsible for all maintenance and repair costs.

Bundles has as a goal the reduction of waste and environmental impact caused by the use and disposal of low-end non efficient machines. They intend to increase the lifetime of their products, submitting them to several use cycles by recovering the appliance, refurbishing it and installing it in a new home. Supported by IoT technologies they currently monitor the use phase (to calculate the monthly fee based on the number of washing cycles) and are now interested in extending the possibilities of these technologies for refurbishment, reuse, and recycling processes. Additionally, with the advantage of maintaining control over the ownership of a great number of appliances, Bundles opens interesting opportunities for material and part recovery. For all of the reasons above Bundles has been recognized for having a business model that could benefit the circular economy.

In an attempt fulfill all of the above, Bundles exclusively works with washing machines from German manufacturer Miele due to their high content of recyclable materials, high quality and long lasting characteristics. However, these characteristics of the product represent today, limitations to achieve having several use cycles. Making processes like refurbishment and part replacement expensive or not possible at all. Because of this it is unclear for Bundles how to deal with the deterioration of the machines after several use cycles and how customers will perceive this deterioration. For this reason, although Miele establishes their products have a life expectancy of approximately 20 years, Bundles only considers approximately half of this life expectancy within their business model. Additionally, Bundles offer is bounded to a machine that is also available for customers to purchase, limiting their competitive advantages over product-based business models. A customer with the stability and economic possibilities of purchasing a Miele washing machine will most likely perceive Bundles' PSS as expensive in the long term.

Nowadays Bundles and Miele, design and deliver their services/products independently from each other and for different types of business models. This project focuses on finding opportunities to improve the synergy between Miele's product and Bundle's service to enhance the economic, circular and environmental possibilities of the current PSS. In order to do that, this project initiated with a literature and field research with all primary stakeholders, considering them individually and relationships with one another. This research delivered insights regarding the current limitations of the

components and delivery of the PSSs and potential opportunities for its improvement, within all phases of its life cycle (Pre-use, Use and Post-use). The insights were then translated into values or Focus Areas to guide the ideation and further development of the PSS: Personalization is identified as a relevant value for the Pre-use phase, to increase the perceived value of the user over the PSS and refurbished products and for the Use phase, as an opportunity for the reduction of the environmental impact. Likewise, communication is identified to be a value that can be used to positively influence the user behaviour to reduce the environmental impact of the Use phase (highest among all phases of the lifecycle of a washing machine (Öko-Institut, 2005)), and improve his/ her involvement in maintenance and caring procedures. Lastly, refurbishment is selected as a focus area for the Post-use phase since the improvement of the product in this aspect could not only reduce costs for Bundles but also increase the life expectancy of the product. These values were used as a guideline throughout the ideation process, which delivered a collection of several concepts that were further evaluated together with all main stakeholders, the final result of this process delivered a combination of a new concept washing machine and a personalization platform.

The new PSS proposes a washing service that allows users to personalize their washing machines inside and outside. The user can select a color for the front panel of the machine, thanks to the implementation of a replaceable layer and obtains a personalized 'Washing Package', which includes: a set of programs, number of washes per month (frequency) and set of tips. All three elements are defined by a system that considers the user's specific washing needs with information obtained through a digital platform (The Washing Test), and pairs them with identified recommendations for: the reduction of environmental impact of washing, the best care for clothes, and recommendations related to the care and maintenance of the washing machine. The personalization of the Washing Package allows users to take the best care for their clothes without an excessive use of resources (energy and water). The internet module of the washing machine and its sensors allow the monitoring of use and state of the components of the machine. The data collected from the monitoring of use is used by the system to constantly update the Washing Package to adapt it to changes in the user's needs or identified behaviour that increases the environmental impact. The design of the washing machine, allows it to have several use cycles without losing its aesthetic value, its quality or its resource efficiency. The construction, materials and finishings of the washing machine are proposed for the optimization of refurbishment processes as well as the improvement of access to its components for updates and repairs allowing the machine to increase its life expectancy within the PSS to the originally established expectancy of 20 years (defined by Miele).

As a final step of this project the new concept was evaluated first, together with the main stakeholders and then submitted to an assessment to identify its improvements in disassembly and ease of access as well as refurbishment processes and the reduction of the environmental impact in comparison with the current PSS. The new concept appears to have the potential of improving the implementation of the PSS throughout all of the phases of its lifecycle and is assessed positively by the stakeholders specifically considering its potential to reduce refurbishment costs, increase the life expectancy of the product, increase the perceived value of the user over refurbished products and PSSs, and the reduction of the environmental impact of the use phase.

The results of the validation and assessment allowed the identification of information gaps for further research and further development of the concept. These include for example, the development of test settings and prototypes for further proof of concept, a more refined and accurate Life Cycle Assessment to identify further specific points of improvement, further detailing and analysis of the product structure and construction to reduce its material input, and further study and analysis regarding the recovery of the product and the possibilities of the reintroduction of its materials and components in the manufacturing of new washing machines. To conclude, the new concept proposes a product service combination which characteristics enhance each other functions and overall envisioned processes towards the reduction of environmental impact and increase of circularity, whilst considering the involvement of Miele and Bundles in a new collaborative relationship for the achievement of all processes and successful implementation of the PSS.

CONTENT

Preface i

List of terms and Abbreviations ii

Executive summary iii

1. Introduction 02

1.1 Assignment 02

1.2 Introduction to the context 03

1.2.1 Today's PSS 03

1.2.2 Introducing the primary stakeholders 04

01 Research and analysis 06

2. Literature Research 07

2.1 PSSs and design for sustainability 07

2.1.1 Characteristics of PSSs 07

2.1.2 Potential benefits of PSSs 08

2.1.3 Challenges of PSSs 09

2.2 PSSs and Circular Economy 10

2.2.1 Circular Economy 10

2.2.2 Bundles' efforts in CE 11

2.2.3 Circular Product Design and the PSS 12

2.3 IoT in PSSs and Circular Economy 14

2.4 User acceptance of PSSs and refurbished products 16

2.4.1 Acceptance of PSSs 16

2.4.2 Acceptance of refurbished products 16

2.5 The environmental impact of washing 19

2.5.1 Env. impact of washing and recommendations for its reduction 19

2.5.2 Overall behaviour in European countries 20

2.5.3 Influences in the user washing behaviour 20

3. Field Research 22

3.1 The PSS System Map 24

3.2 The Pre-Use phase 26

3.2.1 The limitations of Bundles' offer today 26

3.2.2 Limitations of the current collaboration between Miele and Bundles 26

3.2.3 Current limitations of the product and opportunities for its improvement 27

3.2.4 User acceptance of refurbished products 30

3.3 The Use phase 32

3.3.1 Analysis of the user behaviour, creation of value and env. impact 32

3.3.2 Analysis of influences in user behaviour 34

3.3.3 Product characteristics that contribute to the user behaviour 35

3.3.4 The ideal washing experience 37

3.3.5 Context and user behaviour. Identified challenges for repair and maintenance. 40

3.4 The Post-Use phase 42

3.4.1 Current processes for refurbishment and repairs 42

3.4.2 Considerations for repair and update of the product 44

3.4.3 Repairability and ease of access of the product 44

3.4.4 Identified priority components 46

3.4.5 Recycling and recovery of parts and materials 47

02 Focus 49

4. Design scope and goal 50

4.1 List of requirements 50

4.2 Focus areas and goal 54

03 Development 59

5. Ideation 60

5.1 Approach 60

5.2 The possible concepts 63

6. Evaluation and concept selection 69

6.1 Feedback sessions 69

6.2 Comparison with the list of requirements and combinations 70

6.3 Concept selection 73

7. Final concept 74

7.1 The service blueprint 76

7.2 The platform 81

7.3 The product 90

04 Validation and conclusion 101

8. Evaluation and validation of new PSS 102

8.1 Evaluation with stakeholders 102

8.2 Validation and limitations 104

8.2.1 Refurbishment, repairability and ease of disassembly 104

8.2.2 Assessing viability 114

8.2.3 Assessing the env. impact of the PSS 118

9. Recommendations and conclusion 123

10. Personal reflection 128

11. References 130

12. Appendices (separate document)

1. INTRODUCTION

1.1. Assignment

This project is focused on the redesign of a washing machine for the service economy, specifically one for Bundles, a Dutch company that leases washing machines and other appliances to households through a variety of subscription models. Bundles currently exclusively leases washing machines from Miele, a German brand and manufacturer of high quality domestic and professional appliances. Bundles' service model aims to make high end appliances accessible (by reducing high initial investment costs), and reduce the negative environmental impact caused by the use and disposal of low-end machines. Bundles is recognized for having a business model that could benefit the circular economy. They are responsible for maintenance, repairing and installation processes and aim to increase the lifetime of the products by refurbishing them for reuse and lease them to another user. Additionally, Bundles has the advantage of maintaining control over the ownership of a great number of appliances, opening interest and opportunities for material and part recovery. Taking into account all this, they envision their business model to become more circular through a product that supports all procedures mentioned above, and the use of smart technologies (Internet of Things).

Nowadays Bundles and Miele, design and deliver their services/products independently from each other. Bundles is bounded by the characteristics of the available Miele products, since Miele's washing machines are not specifically designed to meet circular service models and were originally designed for a product based business model. Although high quality and long lasting products could suffice a big part of the service model, there are several opportunities to improve the synergy between Miele's product and Bundle's service to enhance the economic and environmental possibilities of the current PSS.

This project explores the current limitations that the product imposes for the successful implementation of the Product Service combination (or Product Service System, PSS) in order to propose a redesign that enhances it whilst also taking into account circularity and the reduction of environmental impact.

Identified design boundaries from the assignment

-The design* should be a combination of a product and a service.

-The design of the product should enhance the characteristics and proposed procedures of the service.

-The design should increase the possibilities for circularity.

-The design should consider the overall reduction of environmental impact of the PSS.

-The design should be supported by IoT technologies.

Wishes (the design could...)

-The design could deliver new opportunities for collaboration between Miele and Bundles.

** "The design" refers to the concept of a PSS to be delivered as part of the project.*

1.2 Introduction to the context

1.2.1 Today's Product Service System

A simplified version of a Product Service System Map (Figure 1) (Tukker, 2017) introduces the primary and secondary stakeholders that are involved in the production, management, delivery and secondary processes of the current product service combination. The primary stakeholders are described below in more detail, including their role and their interests in the PSS. Throughout this assignment the primary stakeholders are analyzed individually and collectively to obtain insights for the (re)design and improvement of the current PSS.
The primary holders are those who have a direct input in the manufacturing and delivery of the PSS components. The secondary stakeholders constitute the processes and services that support the PSS but do not directly deliver it, for example, communication companies, IoT module provider, investors and recycling company.

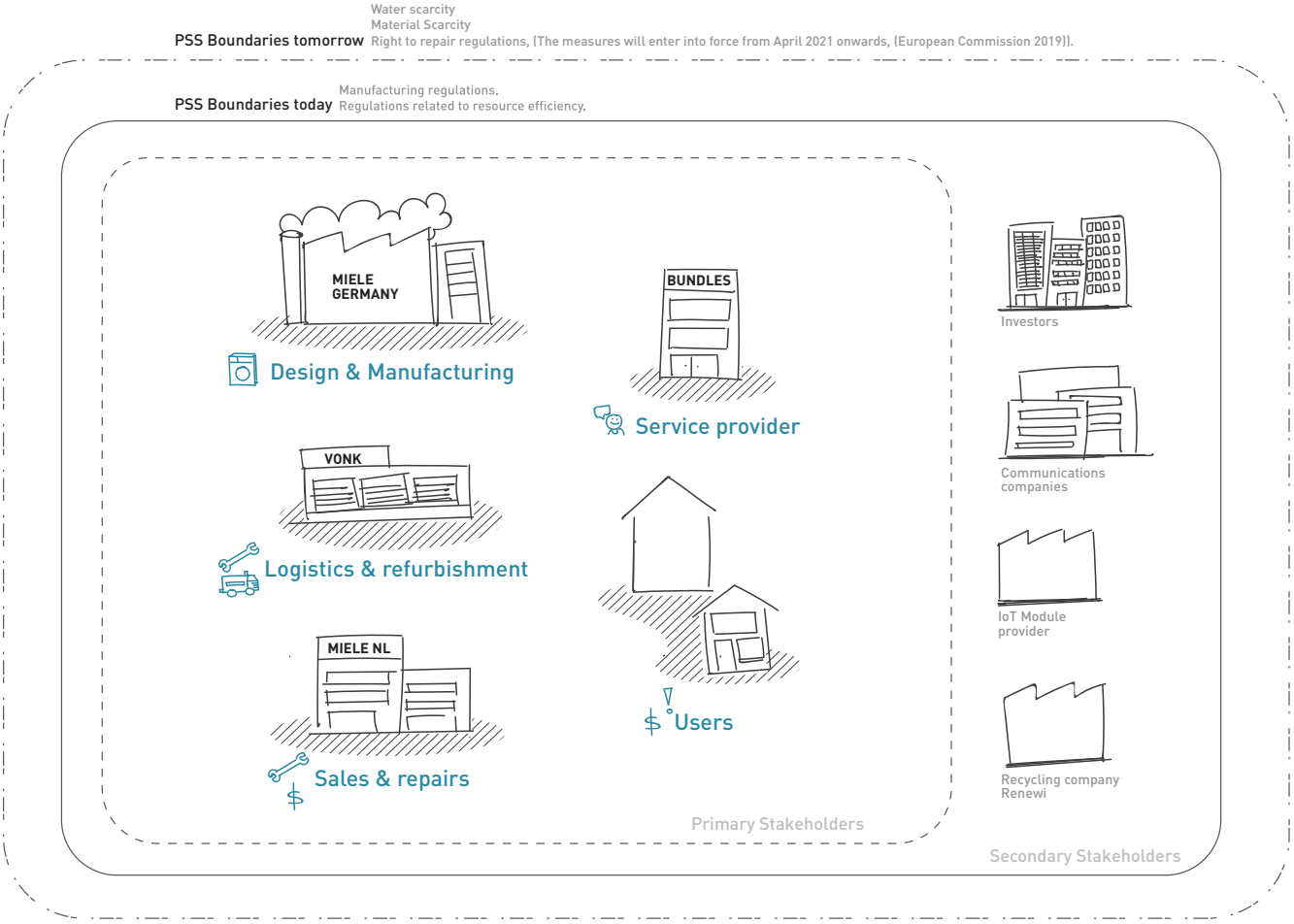


Figure 1. PSS System Map stakeholders. Based on Tukker's approach for PSS design (2017).

1.2.2 Introducing the primary stakeholders

Bundles

Bundles is the service provider. Bundles is a Dutch company, founded in 2014, that works through a Use oriented PSS (Tukker, 2003) where they lease washing machines and other home appliances (Image 2). As mentioned before, Bundles offer is to make 'the best appliances available as a service'. Bundles offers access to the product through a subscription with two options: 1. A monthly fee with unlimited number of uses per month or 2. A monthly base fee and pay per cycle separately (Image 1).

Bundles currently offers 2 different types of washing machines from manufacturer Miele, a basic model and a deluxe model. According to Bundles' founders, they chose Miele for a number of reasons, such as their quality and long lasting products, the content of recyclable high quality materials and the resource efficiency of their appliances. Bundles maintains the ownership of the washing machine and is responsible for all maintenance and repair costs. They intend to submit their appliances to several use cycles and do that by recovering the appliance, refurbishing it and installing it a new home. Bundles collaborates with another company, Vonk, for all logistics and refurbishment procedures.

Bundles offers advantages like the lack of initial investment of buying a high end machine (convenience), taking care of maintenance and repairs (comfort), the possibility to stop the contract at any time (flexibility) and extra services (Bundles App) that supports the use phase with tips. Additionally, Bundles highlights the long term benefits of using a resource efficient machine, reflected in the reduction of water and energy costs.

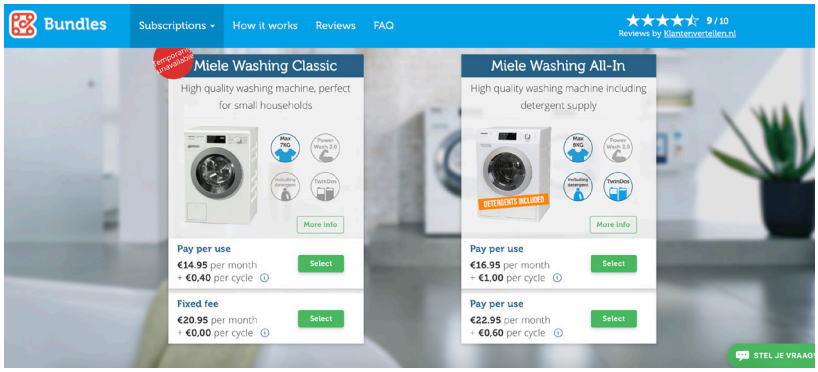


Image 1, Bundles offer of washing machine subscriptions. Bundles.nl.

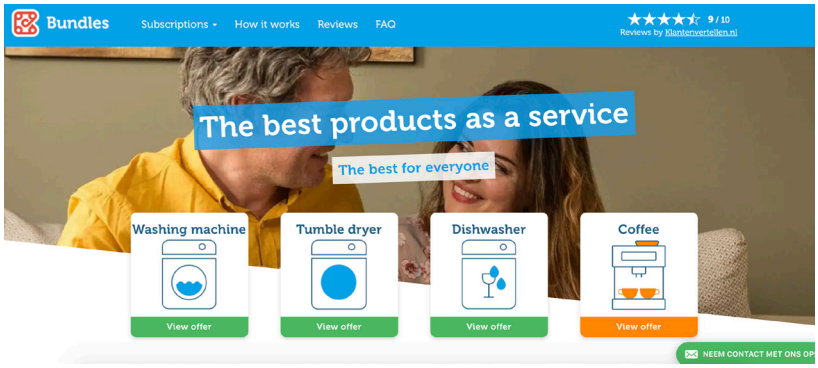


Image 2, Bundles slogan and offer. Bundles.nl.

Miele

Miele Germany is the manufacturer of the washing machines. Miele NL is the appliance distributor in The Netherlands and also the service supplier to Bundles. Miele is a family owned, traditional, German appliances manufacturer established in 1899, experienced in the design and manufacturing of appliances for domestic and professional (commercial) use. Miele focuses on durability, performance and energy efficiency and works on its positioning in the premium segment. In terms of sustainability, Miele focuses in the development and delivery of long lasting products, energy and water efficient use and a high degree of recyclable content in their products.

Vonk

Vonk is the logistics provider for Bundles services, contracted for all transportation, installation and refurbishment procedures. During refurbishment, Vonk technicians clean the machine and assess whether repairs are needed. Images 3 and 4 show the facilities where they operate. For these procedures, Vonk counts with a special area for Bundles' appliances to be refurbished and cleaned. Procedures that interfere with the interior components of the machine such as repairs and part replacements are done by Miele NL technicians since Vonk technicians do not count with the experience to do them.

Customer / User

According to Bundles, users attracted to acquire a subscription are typically driven by the elimination of the high initial investment of high end machines, the comfort of maintenance, installation and repairing support, and/or the flexibility Bundles provides when there is a lack of stability (E.g. students, people continuously moving from one place to another).

The user receives the washing machine and gets charged for the service according to the type of subscription they selected. In addition, the user is charged with an initial deposit fee. The user is in charge of communicating malfunctions to Bundles and is also in charge of maintaining the appliance in the best conditions possible. Bundles and the user communicate via phone or email, and the user can also receive tips and information through the Bundles app. The use of the washing machine is sometimes (not fully implemented and working nowadays) monitored by an IoT module to calculate the use for billing purposes. The user has the possibility of terminating the subscription at any moment. With this characteristic Bundles intends to provide the user with a sense of control.

Images 3 and 4, Vonk facilities and refurbishment room for Bundles' machines.

01

RESEARCH AND ANALYSIS

This part of the report includes all insights derived from research performed through literature and field studies and is composed of Chapter 2 and 3. Chapter 2 includes theoretical background to understand the characteristics and possible challenges of Product Service Systems, their potential positive impact on the environment and Circular Economy and the possible benefits and opportunities of the use of IoT technologies within them. Additionally, it includes available information of the user perspective in PSSs and more specific information of the environmental impact of washing.

Chapter 3 first explains in detail the design of the current product service combination of Bundles and Miele. Secondly, it includes a detailed analysis of the current PSS challenges and opportunities identified throughout the field research done with all main stakeholders. The information is organized considering the phases of the PSS lifecycle (Pre-use, Use and Post-use).

Research Questions

Considering the goal of designing a PSS for Bundles together with the goal of increasing circularity and the reduction of environmental impact, the following questions and sub questions were formulated in order to guide the performed research.

RQ 1. PSS implementation.
How is the existing product allowing or limiting the implementation of the PSS? How can this improve? How can the (re) design of the product deliver benefit/ value to all main stakeholders and facilitate a long term, sustainable, PSS implementation?

RQ 2. Increasing circularity
What opportunities exist to increase circularity in the PSS? What are the current challenges? What could be the potential benefits for the stakeholders?

RQ 3. User role and impact
What is the potential role and impact of the user in the PSS? Can the perception of value be enhanced? Can the user behaviour be influenced to improve processes of the PSS and reduce environmental impact?

2. LITERATURE RESEARCH

This chapter shows the analysis of current available information on Product Service Systems, their relationship to Circular Economy and the challenges they represent for user acceptance. The chapter also analyses available sources related to Circular Product Design, the use of IoT technologies in CE and the overall environmental impact of washing. The selection of these topics was meant to understand where Bundles' current PSS could have potential risks and where the opportunities for its improvement are. Additionally, the selection considered the goals set by the assignment of increasing circularity and reducing environmental impact.

2.1 Product Service Systems and Design for Sustainability

Bundles offers, as their slogan states, 'The best products as a service' which means they have decided to deliver a different way for customers to access home appliances. This corresponds to the definition of a Product Service System (PSS). PSSs can in fact be defined as 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).

2.1.1 Characteristics of PSSs

According to literature, PSSs have the potential of satisfying user needs by delivering functions instead of products and changing the way people consume, because people do not necessarily need to own things, but only acquire access to them instead, potentially reducing the amount of products they possess (Ceschin & Gaziulusoy, 2016). This reduction in material input is one of the key potential benefits of PSSs within sustainability. Additionally, PSS could be specifically designed to provide high quality, resource efficient products to reduce environmental impact and waste (Roy, 2000).

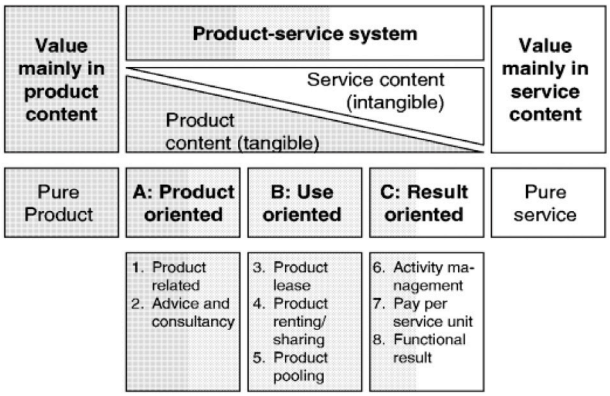


Figure 2 Types of PSS (Tukker, 2004)

Today Bundles provides access to high quality, resource efficient washing machines (Miele washing machines) through a subscription. By eliminating the high initial investment costs of a high end washing machine, they are an alternative for people who would normally purchase a low end washing machine which:
a) Deteriorates faster, as lifetimes for a high quality machine are approx 10,000 hours in comparison with 2,500 hours for a low end one (EMF, 2019).
b) Is not resource efficient, increasing the overall costs of water and energy consumption (EMF, 2019).

Considering this, Bundles' PSS is potentially reducing the number of disposed appliances and the overall impact of the use of resource inefficient appliances. However, since the appliances Bundles is using are meant to withstand several use cycles, it is important to consider the preservation of their resource efficiency throughout their lifetime.

As figure 2 shows, there are several types of PSSs according to literature and they can be classified depending on how value is delivered to a consumer (Tukker, 2004):

Product-oriented services. The business model is based upon selling products but companies provide extra services to consumers.

Use-oriented services. The business model is not oriented to selling products but the product plays the main role. The provider keeps control over the ownership of the product and the product is offered to the consumers through subscriptions.

Result-oriented services. The business model is not centered in a product. Value is delivered exclusively as a result.

Bundles PSS falls into the category of **Use-oriented services** and the subcategory of **Product lease**. The access to the product is individual and the ownership remains with the provider, who is responsible for maintenance, repair and other services. In the case of Bundles the consumer can choose between paying a fixed monthly fee for the use of the product or pay per use *(term used to define a situation where, in a service, the offered resources are measured and the customer only pays for the time he or she used said service (TechTarget, 2019)).*

Literature argues that result oriented PSSs could have the least environmental impact considering the delivery of results could be done collectively, making a more efficient use of resources (E.g. Laundry services and dry cleaners) (Tukker, 2004). However, since the effort to achieve the result relies exclusively on the service provider, these services tend to be expensive, making them inaccessible for some users. Bundles offers an affordable alternative for users to have access to quality and resource efficient laundry without disrupting the 'normal' scheme of owning a machine. Considering this benefit, and since redesigning the business model is outside of this assignment's scope, the proposed design should maintain the characteristics of a Use Oriented PSS, specifically, product lease.

Providers maintaining the ownership of products is yet another key for PSSs to be a more sustainable alternative over product based business models. Providers are incentivized to reduce the amount of resources, materials and energy needed to deliver value or satisfaction to the consumer since these represent costs to them (Ceschin & Gaziulusoy, 2016). In the case of Bundles, the washing machine is expected to complete several cycles of use. The lifetime of the product is prolonged as much as possible through processes like refurbishment and repairs, avoiding the purchase of new machines for every use cycle. An additional insight obtained from literature is that designing a PSS requires a systemic approach where products, services and related stakeholders are considered simultaneously (Dewberry et al, 2013). Also, when considering the economic and environmental dimensions of sustainability (PSS design for eco efficiency) it is important to contemplate the PSS whole lifecycle (Ceschin & Gaziulusoy, 2016; Roy, 2000). This means the elements that compose the PSS should correspond and support each other and should ideally be designed together as opposed to Bundles and Miele's case.

2.1.2 Potential benefits of PSS

PSSs deliver many opportunities for companies to create added value over product based business models: (Tukker, 2004)

-PSSs can help companies fulfill customer needs in an integrated and customized way.
-PSSs can help build unique relationships with clients, enhancing customer loyalty.
-Companies can innovate faster knowing and following client needs better which could become a competitive advantage.

According to Tukker, Bundles could become more competitive and benefit from becoming closer to their customers and delivering of customized solutions. Today Bundles is bound to an offer of a product that is also available for purchase, although they offer additional services like taking care of installations and repairs, they still lack an element that brings them closer to their consumers and offers a truly competitive advantage over a product based business model. Bundles is starting to implement the use of customer data and use tracking in order to deliver feedback and tariff adjustments. The potential of the use of this data is further explored ahead. In the case of Miele, PSSs could represent a competitive advantage as a manufacturer that provides machines suitable for the service economy. Additionally, they could benefit from information delivered by Bundles, result of closer relationships with the customers, and use it in their creative process to find new ways of delivering value.

2.1.3 PSSs Challenges

The implementation of PSSs challenges users' existing habits and behaviour, as well as companies, organizations and existing regulations, they can be difficult to design, test, implement and bring to the mainstream (Ceschin, 2013; Ceschin & Gaziulusoy, 2016). These challenges were researched further in order to identify potential risks and design opportunities to be considered throughout the following steps of the design process. Literature has identified a variety of design challenges for the successful implementation of PSS the following two were selected considering their relevance to the design of the product and the service (Other identified challenges consider organizational barriers or those related to the business model, which are out of the scope of this assignment):

User acceptance and satisfaction in PSS. According to Tukker (2015), customer experience could be at risk of being much lower in PSS when compared to product based models since it has been found that consumers desire to have control over things. For this reason, PSSs should look to enhance rather than limit customer experience. In order to achieve this, studies in user behaviour and socio-cultural factors are necessary to identify the factors that deliver satisfaction. Bundles needs to find new ways of delivering satisfaction to really differentiate themselves from product based models. Ways of giving the user a feeling of control should also be further explored.

Internal barrier for companies adopting PSS that are used to the traditional way of delivering products. Changes in corporate mindset, organisation and competences are required in order to support the creation and delivery of PSS (Vezzoli et al., 2015). This challenge involves the communication and collaboration between Miele and Bundles, product and service should be designed collectively considering both available expertise. The development and successful delivery of the PSS requires a strong collaboration from both companies (Vezzoli et al., 2015).

Takeaways and answers to research questions.

RQ 1. PSS implementation.
The current service and product were designed and developed independently from one another. According to literature (Vezzoli et al., 2015; Dewberry et al. , 2013), a true collaboration in the development and delivery of the elements of the PSS between Miele and Bundles could allow the PSS to be successfully implemented and allow the product design to be aligned with the service requirements.

Bundles prolongs the lifetime of the product through processes like refurbishment and repairs, however, these processes also represent costs and should be considered in the design of the PSS in a way that they do not interfere with Bundles profit.

RQ3. User role and impact
Bundle's PSS offers a product that is also available through product based business models without many competitive advantages. The product should be specifically designed to meet the characteristics of a service that increases the perceived value from the user instead of limiting it. According to Tukker (2015), this perception of value can be enhanced, for example, through the delivery of customized solutions and the delivery of a sense of control to the user, commonly lost when acquiring PSS as opposed to products.

Requirements derived from this section

- The design should increase the customers' perceived value of the PSS compared to the current one and Product based business models.

-The design should promote a longer and closer relationship with the customers.

-The design should maintain the Use Oriented PSS model of Bundles.

2.2 Product Service Systems and Circular Economy

Bundles business model is considered to portray efforts towards a Circular Economy (EMF, 2018). Bundles envisions to increase and improve these efforts. Because of this, it is relevant to understand the impact PSSs could have in CE and identify the potential areas of improvement.

2.2.1 Circular Economy

Circular Economy (CE) is an economic model that proposes the closure of material loops and aims to decouple profit from the use of resources, challenging today's linear (take, make, waste) way of consuming. The model intends to address the challenges that a continuously growing population and the unsustainable way of using and consuming finite resources will lead to (E.g. Resource scarcity, increased prices of resources and price volatility) (EMF, 2012).

The Ellen MacArthur Foundation (2014) proposes that the Circular Economy can achieve change through the creation of new business strategies that reduce material input, for example, via the servitization of products; and through the design of products that for example, last longer, or are designed to be reused or recycled. Some of the principles to consider when transitioning to the Circular Economy are: adopting the use of renewable energy sources, designing out waste and pollution, maintaining products and materials in use and regenerating natural systems. Figure 3 shows the separation of the biological cycle from the technological cycle and the proposed cycle loops or alternatives to the end of life in each one of them. Bundles can be considered to be on the technological cycle.

As mentioned before, PSSs have the potential of fulfilling user needs with less resources and consequently lower impact. Because of this PSSs are considered to be a promising approach towards a resource efficient, circular economy (Tukker, 2013). Within Use Oriented PSSs, the use of materials and resources becomes a cost factor, incentivizing companies to design to minimise production and use products more efficiently (Tukker, 2015).

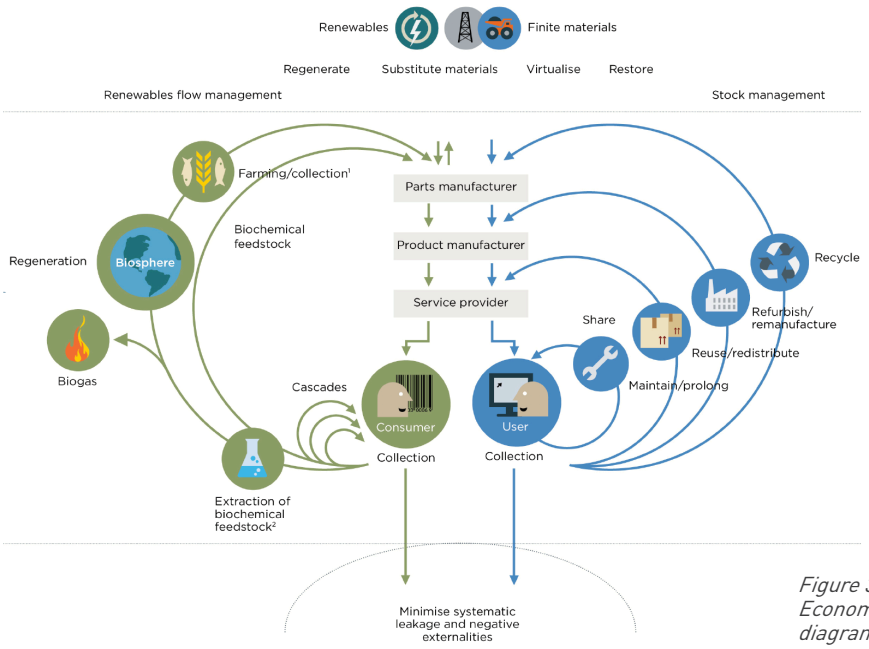


Figure 3 Circular Economy System diagram. (EMF, 2019)

2.2.2 Bundles efforts in CE

Bundles envisions to be circular through the servitization of high quality home appliances. Bundles has been following several strategies in order to become a Circular and Sustainable alternative for laundry. Table 1 shows Bundles current efforts to fulfill those strategies and shortly mentions identified limitations that are described in detail in Chapters 3.2.3 and 3.4.1. It can be observed from the table that in order for Bundles to fully meet the strategies and procedures within their circular product service system, they are in need of a product that supports it and all the envisioned efforts.

	Efforts	**Limitations**
Prolong/ Maintain	Bundles aims to extend the life of the machine by giving a long lasting high quality product several use cycles.	It is unclear how to deal with the deterioration caused with each use cycle.
Refurbish/ Re manufacture	Bundles attempts to refurbish their appliances before a new use cycle.	Today, the machine is not designed to go through these types of procedures and generates high costs to Bundles.
Re use/ Re distribute	Bundles reuses and re distributes their machines.	Due to the limitations for refurbishment and remanufacture (Explained ahead, Chapter 3.4), it is unclear how the used products should be commercialized in comparison to new ones.
Recycle	Bundles wants to reduce waste generation caused by the dispose of low quality appliances and use appliances with high contents of recyclable materials.	Bundles machines are properly disposed in recycling facilities, however, this material is not being recovered to produce new machines. Having control over the ownership of a great number of appliances, Bundles could become a recovery point of materials and parts for Miele.

Table 1. Efforts proposed by the Circular Economy System diagram (EMF, 2019) and Bundles' strategies and limitations towards CE (Bundles, 2018).

2.2.3 Circular Product Design and the PSS

Researchers have created guidelines for product designers to follow when designing a product that could potentially fit the Circular Economy (Van den Berg & Bakker, 2015). Figure 4 and figure 5 show the Circular Product Design Vision and a summary of Circular Product Design guidelines, both of which are to be used as references during the (re)design of the product.

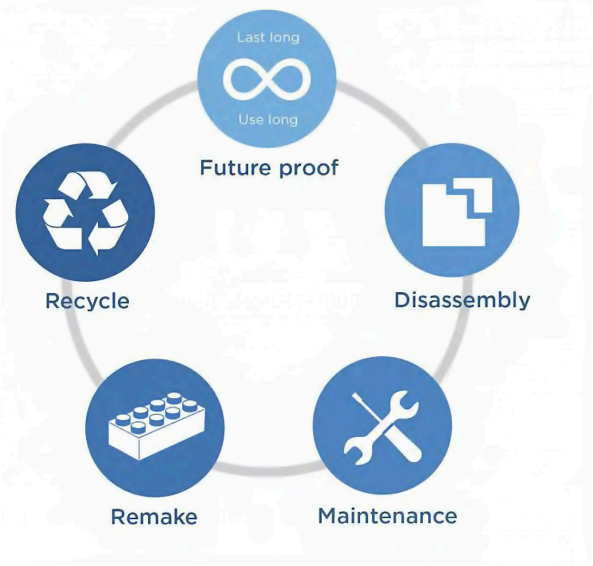


Figure 4. Circular Product Design Vision (Van den Berg & Bakker, 2015).

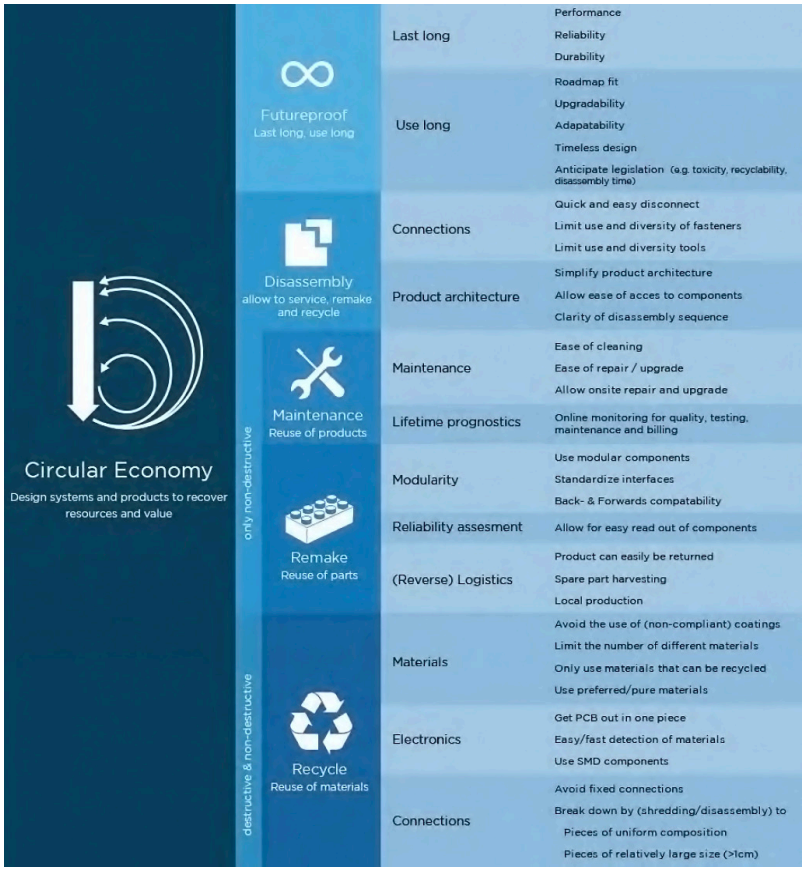


Figure 5. Circular Product Design Guidelines (Van den Berg & Bakker, 2015).

Takeaways and answers to research questions.

RQ 1. PSS implementation.
As shown in the table above regarding Bundles' efforts towards CE, today, the product design makes refurbishment processes expensive and it is unclear for Bundles how to deal with the deterioration of the product in order for it to have several use cycles. To improve this, the design of the new product could consider some of the strategies proposed within Circular Product Design. Not only designing for the product to be long lasting but improving it for disassembly to facilitate maintenance and refurbishment processes.

RQ2. Increasing circularity
In order for Bundles to fully meet the strategies and procedures within their circular product service system, they are in need of a product that supports it. Refurbishing or remanufacturing processes need to be improved in order for the product to be reused and prolong its lifetime. The Circular Product Design guidelines provide a clear structure of possible strategies that can also be implemented in different phases of the lifecycle of the product. In addition to improving the disassembly of the product for its refurbishment and repair, the recovery of the materials of the washing machine for their recycling can be considered. Although today the machine has a high content of recyclable material, none of it is being recovered or reintroduced in the manufacturing of new machines since it would be an expensive procedure for Miele once they lose control over the machine to track and collect them.

Both the recovery and improvement of refurbishment processes could benefit both Miele and Bundles, creating for example, new business strategies that involve service and spare parts packages as well as Bundles becoming a recovery point for Miele parts and materials.

Requirements derived from this section

-The design should allow for several use cycles of the product. The design should aim to maintain most components in use for a longer period of time.

-The design should consider the use of recyclable materials and finishings in order to facilitate their recovery.

Wishes (the design could...)

-The design could reduce material input by facilitating reusing and recycling processes.

2.3 IoT in PSS and CE

IoT, or Internet of Things, is a term used to describe physical objects that are wirelessly connected to a digital network where they are enabled to receive and send data, becoming 'intelligent' and giving them a wide range of possibilities, sensing the environment that surrounds them, interacting and communicating with other 'things' and users (Bocken, 2019; Whitmore, 2015).

According to literature, IoT has the potential of supporting Sustainable Business models. Specifically when applied in Use Oriented PSSs, when intending to reduce the environmental impact generated throughout the use phase. Smart products, enhanced with sensors and communication technology, have the potential to, for example, interact with users to stimulate and induce a sustainable behaviour (Bocken, 2019). Table 2 shows an overview of the IoT capabilities that are considered to be useful for sustainable PSS. (Porter, 2014; Bocken, 2019). According to the Ellen MacArthur Foundation (2016), IoT is also considered to have the potential to support and enhance Circular business models, where the data collected by the product and its environment becomes a component for value creation. The identified sets of information that could deliver value creation are the knowledge of the location, the condition (technical performance), and the availability (the activity status and use information) of a product or component. This knowledge has the potential of enhancing the four identified value drivers of the Circular Economy: Extending the life cycle, Increasing utilization, looping and cascading through additional use cycles and regenerating natural capita (Preserving the productivity of natural systems such as soil, oceans, forests, etc.).

Bundles is in the process of improving the implementation of smart functions and finding other ways to use the connectivity of their devices and collected data to improve their service, reduce the environmental impact of the use phase and augment circularity. The new design could consider the opportunities for the implementation of IoT capabilities throughout the whole PSS lifecycle.

IoT Capability	What is it?	Examples of application in PSSs
Monitoring	Use of sensors and data to monitor, product's condition, usage and external environment.	Providing the user and provider with feedback and information related to use and performance.
Control	Software embedded in the product that allows the control of product functions and the personalization of the user experience.	Allow the remote control of devices to users and or providers.
Optimization	The use of algorithms resulting from monitoring and control to allow the optimization of the product performance.	Tracking use history and provide information to optimize the use of the product or for preventive measures through failure prediction.
Autonomy	Autonomous product operation and communication with other products and systems.	The product can make autonomous decisions. Running self diagnoses and updating itself, for example.

Table 2 Useful Capabilitites of IoT for Sustainable PSS (Porter, 2014; Bocken, 2019)

Takeaways and answers to research questions.

RQ2. Increasing circularity
The implementation of IoT technologies in Bundles' PSS could have potential benefits in several of its procedures related to the Circular Economy, specifically considering processes that allow the machine to have several use cycles. The monitoring of Bundles' appliances, supported by internal sensors could also provide them with information to identify and predict failures and promote preventive maintenance or replacement. Monitoring could also help to measure the resource efficiency of their washing machines in order for it to be preserved through several use cycles. Diagnosis, refurbishing and repairing processes could also be optimized if information and historical data is made available.

RQ3. User role and impact
Today, Bundles is using IoT by equipping their washing machines with an external plug that measures the energy use of the washing machine and collects this data for the monitoring of use for payment purposes. The tracking device also gives Bundles the possibility of addressing the environmental impact of the use phase, through the use of a pay per use model, having the possibility of economically incentivizing the reduction of the use. Bundles also intends to deliver feedback to the user regarding their laundry behaviour. These intentions and actions could be further explored considering the monitoring of additional values to the energy consumption in order to find more opportunities of influencing the users' behaviour to reduce their environmental impact. These strategies could also be further explored to identify opportunities to augment the attractiveness of PSS through IoT, delivering personalized information to enhance the user experience. However, it is important to consider societal questions and concerns regarding data security and privacy that arise with the implementation of sensing and IoT technologies (EMF, 2016).

Requirements derived from this section
Wishes (the design could...)

-The design could monitor the user activities through IoT technologies in order to deliver a better experience.

-The design could monitor the user behaviour through IoT and use the information to deliver feedback related to maintenance and care of the washing machine.

-The design of the PSS could monitor the user behaviour and use the information to reduce the environmental impact of the use phase.

-The design could monitor the intensity of use through IoT for repair and refurbishment purposes.

2.4 User acceptance of PSSs and refurbished products

As mentioned in the previous sections (Chapters 2.1 and 2.2), PSSs may represent challenges regarding user acceptance specifically when competing with product based business models. It is important then to further understand what are the limitations and the possibilities to improve this acceptance. Additionally, considering that Bundles is aiming to submit their washing machines to several use cycles, it is important to consider the circumstances in which a user is willing to accept a refurbished product instead of a new one.

2.4.1 User Acceptance of PSSs.

PSSs challenge the way people consume, their existing habits and behaviour. Researchers have found that consumers value having control over things and life itself (Tukker, 2015).
Tukker states that it is a big challenge to overcome the customer's feeling of being in a dependent controlled position when acquiring a PSS in contrast with product based business models. And recommends that a big part of a successful implementation of a PSS relies on enhancing rather than limiting the customer experience. Other identified challenges for the acceptance of PSSs are that consumers may not be aware or completely understand the benefits, risks or responsibilities they may have with PSSs in comparison to ownership (Vezzoli et al., 2015). The PSS can be perceived, for example, to be more expensive compared to the purchase of products like the case of Bundles.

The PSS is also subject of cultural barriers, for example, the lack of value over something a customer does not own. Consumers are subject to cultural barriers where many of the goods are part of their identity (Vezzoli et al., 2015).

2.4.2 User Acceptance of refurbished products.

The implementation of PSS and the intention of having several use cycles with a single product arises concerns related to the challenges of user acceptance of refurbished products.

According to Van Weelden (2016), there are several barriers for the acceptance of refurbished products Figure 6.

Within the misconception of refurbishment, customers do not count with information about the product condition and hence it is likely to be perceived as less valuable, since it has been used by another person and could even be damaged or dirty. In order to overcome this, it is important to be transparent about the state of the product and inform the customer (Van Weelden et al, 2016). As for the lack of thrill of purchase, customers purchase decisions are in cases driven by emotion and not entirely by functional motivations (Van Weelden et al, 2016).

It is also important to consider the balance between risks and benefits (Figure 7) the customer thinks of when deciding to obtain a refurbished product. The consumer should be convinced of the value of a refurbished product through transparent and accessible information (Van Weelden et al, 2016). The specifics of the perception of Bundles' users regarding refurbished products are discussed ahead as part of the field research.

Figure 6. Barriers for the acceptance of refurbished products (Van Weelden et al, 2016).

Figure 7. Perceived benefits and risks of refurbished products (Van Weelden et al, 2016).

Takeaways and answers to research questions.

RQ2. Increasing circularity
Although the refurbishment of the product could extend its lifetime through several use cycles it is still unclear how to deal with its deterioration. With this, several barriers regarding the user acceptance of refurbished products arise. The two most relevant to the current PSS include the misconception of the concept of refurbishment and the lack of thrill of newness (figure 6). Meaning the users could perceive refurbished products as less valuable and less exciting in comparison with purchasing a new product. In the case of Bundles, the thrill of newness could be enhanced through the delivery of specific value to a specific customer, personalization. Bundles should also look into improving the shopping experience (building a closer relationship with the customer) and the product presentation and delivery.

Considering the misconception of refurbishment, monitoring the use of the product through IoT, and creating guarantees approved by Miele (considering their high quality reputation) could be good strategies to provide transparent and reliable information to the customer.

Finally, as for the user's perception of potential risks (Figure 7), In the case of the Bundles' PSS, many of the perceived risks are taken care of by the company (necessary repairs, part replacement and even machine replacement), it is important however, to highlight this information, as well as the economic and environmental benefits of acquiring the PSS.

RQ3. User role and impact
The use of guarantees provided by Miele considering their reliable reputation as well as highlighting the economic and environmental benefits of acquiring a PSS could also be a good strategy for Bundles to increase the perceived value.

Bundles could address cultural barriers as identified by Vezzoli, (2015) considering for example personalization, which could allow the user to regain the feeling of ownership and identity. Additionally, literature suggests to look into motivating users through emotion to regain the feeling of newness and excitement.

Today, Bundles' offer is limited to a product that is also available through a product based business model but through a pay per use model, which could be perceived as restrictive as opposed to the recommendation of enhancing the user experience for the successful implementation of the PSS (Vezzoli et al., 2015) . In order to avoid this, Bundles should find ways to deliver a stronger value offering that defines a competitive advantage over ownership models additional to the relief of risks and responsibilities offered to the user.

Requirements derived from this section
Wishes (the design could...)

-The design should consider the user acceptance of refurbished products.

-Providing added value (Personalization)

-Providing transparent information.

Wishes (the design could...)

- The design could attract customers through emotion.

2.5 The environmental impact of washing

2.5.1 The environmental impact of washing and recommendations for its reduction

Since the reduction of environmental impact caused by the use of the PSS is considered in the assignment, it is important to further analyze how this impact is being generated and what opportunities are out there to reduce it in addition to Bundles' current efforts through the use of high resource efficient appliances and use conditioning through pay per use models.

According to several studies (Koerner et al., 2011; Öko-Institut, 2005; A.I.S.E., 2013) the use phase accounts for the largest environmental impact of a washing machine lifecycle with 92% of all water consumption, 60% of all energy consumption, 73% of the overall global warming potential and 62% of fossil fuel depletion.

The impact during the use phase is directly influenced by the way the product is used. Most of this impact is a result of the energy needed to heat the water and during the wash cycle, as well as water used for washing and rinsing cycles (Koerner et al, 2011).

In an LCA performed to washing machines it was determined that environmental impacts increase exponentially as washing machine loading decreases, regardless of the level of resource efficiency of the machine and automatic loading detection were it is assumed to only reduce water and energy consumption by 15 % at a loading of 60% (Öko-Institut, 2005). The following quote can be noted, "When considering the environmental impacts associated with the use of washing machines, results from the study suggest that in general, energy use impacts are more closely linked to machine size than energy rating" (Koerner et al, 2011).

These studies suggest the importance for users to choose the appropriate size (capacity) of washing machine, in response to the volume of clothes they have, the frequency of washing and whether or not they separate their clothes.

The following is a summary of the identified recommended actions for the reduction of environmental impact of washing machine: (Koerner et al., 2011). (A.I.S.E. 2013).

a) Increasing the wash load as much as possible without overfilling (following indications from the machine manufacturer). This action results in an optimal use of resources.

b) Decreasing wash frequency. According to the studies, pay-per-use models have the potential to nudge the user into reducing the frequency of washing. More information and opportunities to decrease washing frequency can be found below (Influences on use behaviour).

c) Consumers should be encouraged to check the care symbols on the textile labels to obtain information on the possibilities of washing at different temperatures and combining textiles. Considering this, recommendations could be done to the user towards combination possibilities that don't harm their clothes and help them achieve larger loading volumes.

d) Soap. Consumers are encouraged to read the label of the soap packaging and pay attention to the type of water hardness of their area for proper dosing. Overdosing has implications in water use and increased rinsing cycles as well as increased environmental impact related to the manufacturing of detergent chemicals. If collaborating with soap manufacturers is possible, Bundles could facilitate the delivery and accuracy of this information.

e) Using low temperature settings. As mentioned before, energy consumption is largely related to the heat needed to warm up water. Bundles could provide users with information regarding ways of achieving good cleaning results without the use of higher water temperatures. More related to this topic can be found below (product characteristics).

f) Consumers should be encouraged to read the booklet of instructions of their washing machines to find the facts on energy and water consumption of the various programmes. This could allow users to make the best decision related to environmental impact and their clothes. However, Users do not necessarily need to read the booklets if they count with a service that constantly communicates this information to them.

*In an additional note, it is important to highlight that the drying of laundry (with a dryer) has more impact than the whole life cycle of a washing machine (by a factor of 2.5) (Öko-Institut, 2005). Within the goal of reducing the environmental impact of the use phase it would be important to recommend to the user alternatives to using dryers, or implementing additional features in the product to reduce the water content of clothes and or accelerate the drying process.

In order to understand the origin of the environmental impact of the use phase it is necessary to analyse and identify where the users are failing to fulfill the recommendations provided above.

2.5.2 Overall behaviour in European countries

In a study from the A.I.S.E. (International Association for Soaps, Detergents and Maintenance Products), (2013), several characteristics of washing user behaviour within the Europe were identified.

It was found that the average wash frequency in the European Union is 3.2 times per week and that 68% of European loads are washed at 40°C or above, of which 17% are washed at 60°or above. Considering this data it could be assumed that users believe they are cleaning their clothes better by using higher temperatures and that users have created routines and continuously wash their clothes Additionally, it was found that 60% of all consumers claim to use the full capacity of their machine but this number depends directly on the type of load meaning that If people separate, they have variations between small and large loads and are still prone to underloading their machines.
As an important note, it was identified that 72% of European consumers look for advice on sustainability of washing. According to the study, many consumers are not aware of the measures they can take to have a more responsible behaviour.

2.5.3 Influences in user behaviour of washing identified by literature. The social layer of washing.

In order to propose potential solutions to positively influence user behaviour and reduce the impact of washing it is important to understand the origin of this behaviour. This section shows available information in literature in relation to the social influences of washing behaviour. Further findings of other identified influences from the field research are available ahead in this document (Chapter 3.3.2)

According to literature, users have the tendency of developing routines and habits, washing clothes can become part of the user's daily life routine. 'Routines help to navigate everyday life by automating and easing decision-making' (Gram-Hanssen, 2007). However, routines cause a lack of reflection and in the case of the use of appliances like the washing machine, it can have negative consequences in the excessive consumption of energy and water. (Gram-Hanssen, 2007). In order to reduce the environmental impact of the use phase and over use of resources, it is important for users to receive support with the decision making of 'when to wash'; through products and services that promote reflective decisions and promote the exclusive use of what is needed and not what is assumed to be needed.

In relation to the frequency of washing, it is necessary to point out that users lack information to measure how dirty their clothes are and rely on routines and 'cultural norms of clean' when deciding 'what needs washing'. Cleaning practices have become something periodical, causing users to consume resources un-reflexively (Shove, 2003). Users are subjects of "hidden" social norms regarding cleaningness. Collective conventions of cleanliness are not explicit or measurable, however, people have an intangible sense of 'clean' or 'presentable'. (Tullia, 2013). Products and services could provide the user with tangible, measurable elements or information that promotes a better decision making and generates a feeling of security or acceptance.

Takeaways and answers to research questions.

RQ 3. User role and impact
The use phase represents the highest environmental impact of the PSS, the user washing behaviour has the highest influence on this impact. As mentioned above in this chapter, there are several recommendations of washing habits that could reduce the impact of the use phase. In many cases, these recomendations are not followed because of a number of reasons, which include misinformation (lack of reading of manuals or labels) a non reflective automatic decision making and lack of measurable information or references.

The identified recommendations for the reduction of the environmental impact of the use phase can be considered by Bundles in order to guide and/or nudge the user to improve their behaviour during the washing process and reduce environmental impact without stopping to consider their specific washing needs. These recommendations, together with the identified overall European washing behaviour and insights derived from the field research (Chapter 3.3.1) could define the data that needs to be collected through IoT regarding use conditions and frequency as well as the guidelines to formulate recommendations, measurable feedback and advice.

It was found that users would appreciate counting with reliable sources of information that indicate them how to reduce their impact when washing. The information should be made available in a different form from manuals and labels since these are not successfully delivering the information.

By delivering tangible and measurable information Bundles could provide the user with a feeling of control and security over their decisions potentially adding value to the PSS while giving them references to positively modify their behaviour.

Requirements derived from this section

-The design should promote the reduction of the overall environmental impact compared to other products and current PSS. Specifically the impact derived from the use phase.

-Through functions.

-Promoting a positive user behaviour.

Wishes (the design could...)

- The design could be resilient to misuse.

3. FIELD RESEARCH FINDINGS

Field research findings. Today's PSS Challenges and Opportunities

This chapter presents all findings obtained through the field research done with all main stakeholders. The chapter first shows a detailed version of the PSS Map in order to visualize all processes and characters involved simultaneously. Secondly, it displays all insights organized by the different phases of the PSS lifecycle: pre-use, use and post-use. This, in order to run the analysis of the findings with a systemic approach that considered the lifecycle of the PSS per phase and as a whole.

Methods used to obtain insights

The research questions (previously shown in Part 1) were used as a guideline to perform field research, specifically considering the gaps left unanswered by literature related to this specific PSS. Additionally, several methods were used to perform the field studies according to the type of stakeholder or process that would be researched. These include semi-guided interviews, visits, and observation sessions (a detailed version of all information obtained during these activities is available in Appendixes A, B (confidential) and C). The obtained information was interpreted in the form of insights that lead to the identification of design opportunities.

The insights presented are the result of a visit to Miele's central office in Guetersloh, Germany, several visits to Bundles in their office in Amsterdam, several visits, observation sessions and phone interviews with users, visits to Miele Netherlands in Vianen and a visit to logistics partner Vonk. In order to identify the source of the insights presented the following codes are provided: Miele Germany visits and interviews (Mg), Miele Netherlands visits and interviews (Mn), Bundles visits and interviews (B), Vonk visit and observations (Bv), User interviews and Observations (Ui), User workshops (Uw).

Personas and workshop with students

In addition to the field research, and, in order to understand the user experience better and find more opportunities to add value through the PSS, three personas were developed. The personas were created based on the people interviewed and their answers and generated 3 characters that represent the extreme behaviour possibilities in users. The personas included the description of washing needs considering number of members, type of activities, schedules and availability and personal characteristics such as being messy. Additionally they included a fictional summary of their ideal washing experience and potential future changes in their lives. Each pesona was then developed through a fictional user journey map for each one of them. In addition to the Personas, a creative workshop with students (acting like users) was organized in order to receive external input about what the 'Ideal Washing Experience' could be. The results obtained from these methods are presented ahead in this Chapter and details of the personas, the user journey maps and workshop procedure and results can be found in Appendix E and F.

Images of different forms of field research done throughout this project.

3.1 The PSS Map

Figure 8 shows the PSS system map, a tool used to simultaneously visualize the PSS processes, value flows and involved stakeholders. This tool helps with the identification of all the processes and with the organization of insights derived from field studies and analysis. Figure 8.1 provides the code to read the PSS map.

The boundaries of the system are briefly mapped, these include two layers: 1. Today's boundaries, regulations regarding manufacturing, repairing and recycling and current resource availability. 2. Future boundaries, future trends, changes in resource availability and future upcoming regulations e.g. Right to repair legislation, expected to be implemented in 2021 in several appliances and electronic products (European Environmental Bureau, 2019). These boundaries are especially important in order to foresee future requirements and possibilities that directly affect the implementation of the PSS and its stakeholders. Considering information could allow the (re)design to be suitable and sustained in future scenarios.

The different lines and arrows show differences in the flow of materials, services, money and information. The system map also makes a distinction between the different phases of the lifecycle of the PSS and divides the steps into their corresponding phase. Re-use includes all that happens before Bues' customers acquire the machine, use is all processes related to the product's lifecycle in a customer's home and post-use relates to further use cycles and end of life.

The following is a detailed description of the steps of the PSS.

Pre-Use Phase.

1. The user signs up for a membership.
2. Bundles purchases machine from Miele NL. (Or alternatively uses an already refurbished machine in their inventory, if this is the case, the following step is 4).
3. Miele Germany delivers the washing machine in Vonk.
4. Bundles pays Vonk for logistics, transportation and refurbishment processes.
5. Bundles purchases the IoT modules from the supplier.
6. Bundles delivers IoT modules to Vonk.
7. Vonk delivers and installs the washing machine and the IoT module in the user's home.

Use Phase

8. Use of the washing machine (referred to as 'washing journey' in the following chapters of this document).
9. Use data is obtained from the IoT module.
10. The user pays the monthly invoice.
11. User communicates to Bundles any problems with the washing machine or their service through phone with customer service or email.
12. Bundles notifies Miele NL of any repairs needed.
13. Miele NL technicians repair the washing machine in the user's home.
14. The user terminates the contract.

Post-Use Phase

15. Vonk picks up the machine and takes it to its facilities.
16. Vonk refurbishes the machine which consists of an external and internal analysis and cleaning. In some cases small repairs (E.g. scratches on the panels) are repaired by Vonk technicians. Vonk notifies Bundles if any repairs are needed so they can notify Miele NL. Miele NL repairs the washing machine and replaces any necessary parts.
17. Bundles pays Miele NL for all services done to the washing machine.
18. Vonk delivers the refurbished washing machine to a new user.
19. If the machine is in bad conditions and is not possible to repair it, Vonk delivers the washing machine to the recycling company.

The system map serves as a tool to visualize and consider all elements of the PSS collectively and was used as a base for the research conducted with the different stakeholders to identify and pinpoint the insights found within each lifecycle phase of the PSS.

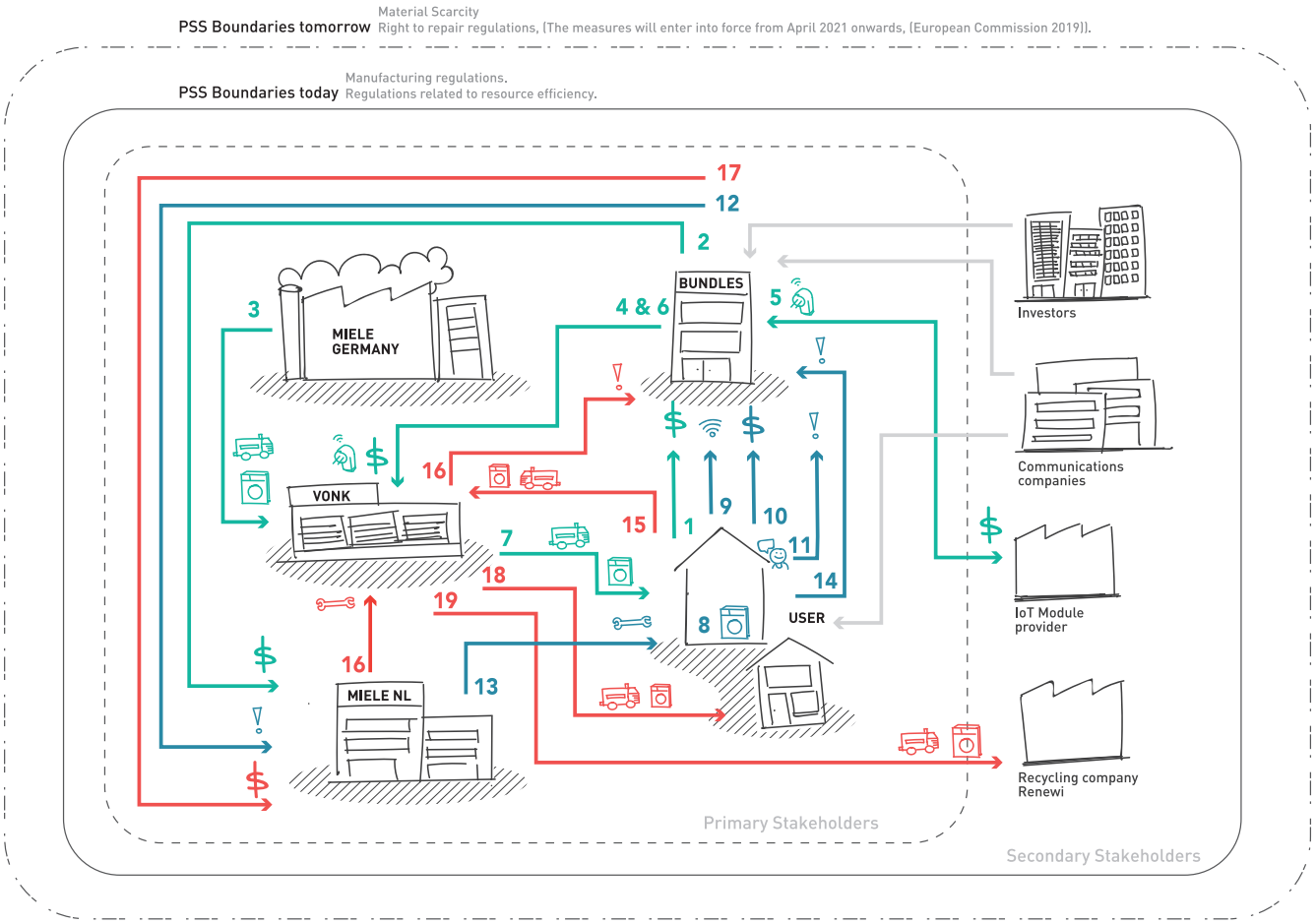


Figure 8, Today's PSS System Map. Based on Tukker's (2017), approach for PSS design.

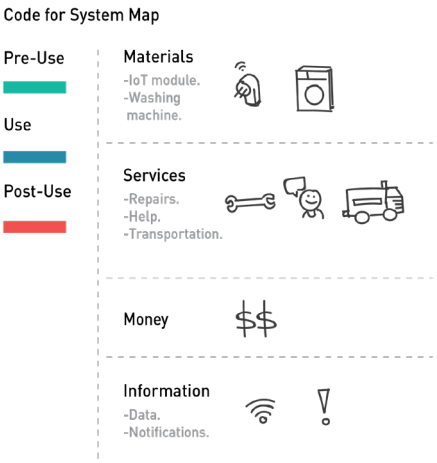


Figure 8.1. Code to read system map.

3.2 The Pre-use Phase

This section lists down relevant insights identified within processes belonging to the Pre-Use phase. The insights below highlight some of the limitations of the implementation of the current PSS, specifically those related to the current offer and the proposed delivery of value. The analysis first dives into the limitations presented in the service, the relationship between the service provider and product manufacturer and the development and characteristics of the product itself.

3.2.1 The limitations of Bundles' offer today

Bundles current delivery of value is limiting their offer to a very specific segment, to people who perceive Bundles as convenient in comparison to the TCO (Total Cost of Ownership) of a low-end machine or to people who are not willing to or can not pay the high initial investment of high-end machines(B). *The Total Cost of Ownership can be defined as the sum of costs associated with the acquisition, ownership, use (consumables, energy and water, in the case of a washing machine) and subsequent disposal of a good or a service (Saccani N., 2017).*

This limits their advantages against product based business models of high end machines. Today, people who have the economical possibilities of acquiring a Miele machine are very unlikely to consider the purchase of a membership with Bundles, because they don't perceive any added value and consider it to be very expensive in the long term (Ui).

Bundles could also have disadvantages against low end machines because people may prefer ownership or may not consider the disadvantages of the TCO of a low quality machine. Bundles should explore new possibilities of delivering value through their service to generate new competitive advantages against product based business models in general in order to keep growing and extend their target groups.

When acquiring a membership with Bundles, customers have, as mentioned before, different options. By acquiring the fixed monthly fee with unlimited number of washes, users get more security of what they will pay. However, the purpose of nudging the reduction of use of the pay-per-wash model is lost (B). Bundles needs to find ways to deliver that feeling of security to the user while promoting the reduction of excessive use.

Bundles is looking to improve and diversify their offer through a larger diversity of plans, considering for example, the duration of the contract or the state of the machine. By doing this and through a better implementation of IoT to provide additional services through connectivity, they are expecting to augment their delivered value (B). However, today, any addition of value has to be done externally (outside of the machine itself) since they are limited by the washing machine offer of Miele and have no intervention in the product itself.

3.2.2 Limitations of the current collaboration between Miele and Bundles

As we learned previously from literature, the successful delivery of PSSs requires a strong collaboration from the involved companies. Today, the development of the elements that compose the PSS are designed and developed separately. Although Miele's machines are long lasting, these do not fulfill all processes envisioned by Bundles for the PSS. Specifically for repairability and refurbishment, the overall long lasting construction and high quality characteristics of the product cause excessive costs to Bundles (B) (Bv). For example, replacement of components, such as the rubber ring (which deteriorates easily during use) can cause excessive costs related to working hours of Miele technicians (Appendix B & Chapter 3.4).

For the PSS to grow and achieve all envisioned processes, it is necessary to go from an almost B2C relationship were

Miele exclusively acts as the supplier and delivers repairing services, to a B2B relationship where both parties collaborate in the development, delivery, maintenance and recovery processes of the circular PSS.

In order to achieve this change in the relationship, benefit opportunities must also be identified for Miele to be interested in developing and manufacturing products and processes for circular PSSs (Mg) (B). Miele's experience through their professional line could be a good example of how the relationship with Bundles could change through, for example, parts and service packages for refurbishment, where Miele's profit is based on refurbishment processes and not exclusively on the machine acquisition. Another example of benefit opportunities could be the recovery of Miele materials and parts, with Bundles becoming a recovery point for them. Today, with approximately 1000 appliances installed (Appendix B), Bundles may not represent today, enough volumes for Miele to develop a new product or processes for their business model (Mg)

3.2.3 Current limitations of the product and opportunities for its improvement

Bundles uses Miele products because of their long lasting, high quality characteristics. However, the concept of longevity is approached differently by both companies. As figure 9 shows, Miele designs a product to last 10,000 cycles (Approximately 20 years considering an average of 5 programs of approximately 2 hours each per week) within the same user and not to go through several life cycles like Bundles envisions as part of the PSS (Mg) (B).

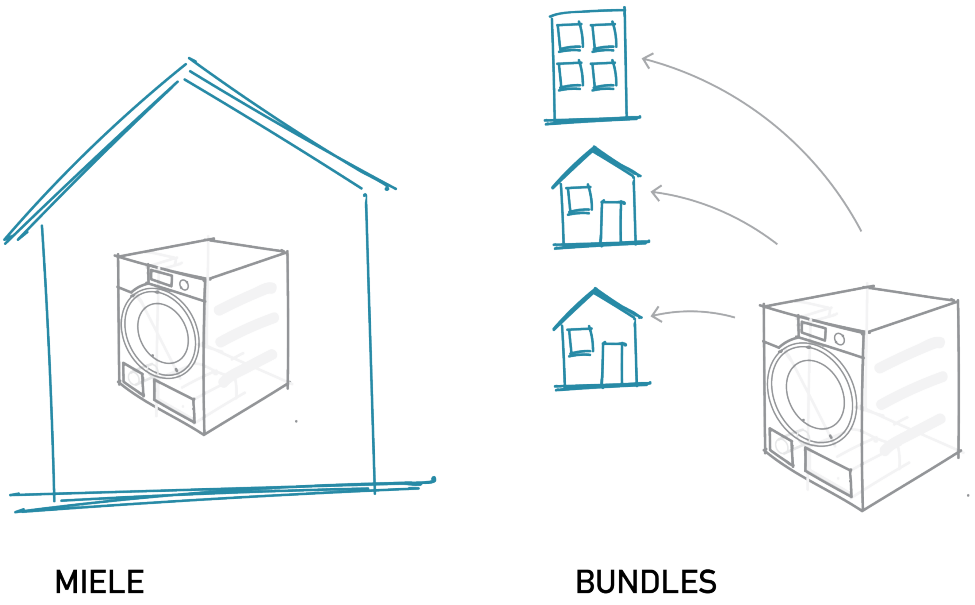


Figure 9. Today's product vs envisioned model of longevity.

This difference brings several topics to the discussion. Although Miele washing machines are one of the most efficient machines in the market, this efficiency depends on the intensity of the use of the product (Mg). Going through different users could cause variations in the intensity of use causing uncertainty on the preservation of the efficiency overtime, affecting consecutive users of the service. In addition to the PSS being able to monitor the state of the machine, the product should be enabled for updates to enable an increase in the number of use cycles that don't decrease the offered value to consecutive users.
Within the same concept of several use cycle longevity, it is important to consider that although the product today, is made with high quality materials and finishings, it will still look outdated and deteriorated after the first or more use cycles.

Because of the reasons above, Bundles' business model considers that the machine will be able to be put to use for a maximum approximate of 10 years, considering 2 use cycles (or subscriptions) if an average of 5 years is estimated. The current characteristics of the product limit its use up to half of its expected lifetime when put through several use cycles (B). Bundles and Miele should explore possibilities to address this, through a product that looks timeless or through a product that can be updated (Ui) (B).

Furthermore, Miele counts with a wide knowledge of professional and commercial products. Within washing machines, Miele counts with a Semi-professional and Professional line. Many characteristics of the way they approach this specific market, could be applicable to the Bundles PSS.

Professional and semi-professional machines are designed to have a longer lifespan with a sturdier construction and use of long lasting materials, however, due to this construction they are larger than the domestic machine standard size. Professional machines are also designed to be quicker, however, this has a negative impact on their resource efficiency. Domestic machines on the contrary, are designed to be as resource efficient as possible since they are made to meet the best score possible (A+++) within the Energy Efficiency label (Appendix A) (Mg).

Professional machines are also designed in a way that they allow a certain level of customization through the programming and control board of the washing machine to meet specific needs of their customers (E.g. mop cleaning machine). Images 5 and 6 show examples of these machines and personalization options. Additionally these machines are designed to optimize repairing and customer service procedures within B2B relationships. Bundles new washing machine could consider using long lasting materials, personalization and service facilitation characteristics without sacrificing the standard size and resource efficiency of domestic machines which could have negative implications in the use phase and become difficult or unattractive to install in people's houses.

In an additional note, Miele counts with variations in manufacturing volumes along their factories.The manufacturing of their professional machines is designed for lower volumes allowing more flexibility for the design of the product (Mg). This is an important consideration that could be related to the PSS, since the proposal of maintaining the product as long as possible in the loop through several use cycles may have consequences in the necessary manufacturing volumes.

Images 5 and 6 .
Examples of professional washing machines and options for the personalization of the control panel.

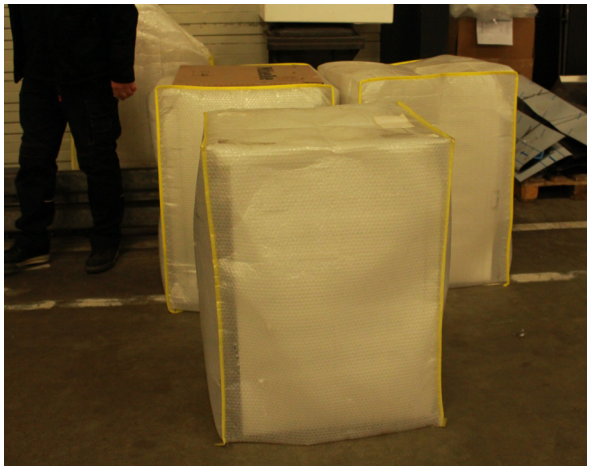
3.2.4 User acceptance of refurbished products

As mentioned in Chapter 2.4 the implementation of PSSs and the intention of having several use cycles arises concerns related to the challenges of user acceptance of refurbished products. The specific identified insights for Bundles' PSS regarding refurbished products are explained below.

Today, the perspective towards refurbished machines within Bundles customers is still unclear, the results of previous survey exercises (done by Bundles) show it is not of relevance to the user (Appendix B). However, through the field research it was found that some of Bundles customers do request a new machine when acquiring a subscription, contradicting the basic principle of the proposed circular PSS (B). Bundles has also highlighted concerns towards whether users with refurbished machines should pay the same as users that receive a new machine (B).

In fact, it was found that during installation, Vonk technicians take off any wrapping before showing the machine to the user. This wrapping can be from a new machine or a reusable plastic cover Bundles uses to protect refurbished machines (Images 7 and 8). They mentioned they do this to reduce the perception or expectancy over the machine being new or refurbished. Today, this is a possibility considering the oldest Bundles machine is five years, however, with time, deterioration an outdate will be more visible. This situation should be addressed by Bundles in order to be able to continue reusing the machines, possible strategies to do so and further findings in the topic are discussed in Chapter 3.4.

Additionally, users have mentioned that washing machines could be well received as long as quality, hygiene and correct functioning are guaranteed (Ui). This coincides with the recommendations found in literature (Chapter 2.4) regarding the delivery of transparent information and guarantees to the user, to augment trust.



Images 7 and 8. Bundles' cover for refurbished machines.

Takeaways and answers to research questions.

RQ 1. PSS implementation.
In today's PSS any addition of value has to be done through the service. The product value offer is the same as product based business models, limiting the competitive advantages of the PSS to a specific segment; people who value the lack of high initial investments and the comfort of maintenance being the responsibility of the company. The product should be designed to become a part of the delivery of value to the user. Additionally, the current product construction for longevity represents high costs and limits the implementation of several use cycles model. How to deal with deterioration after several use cycles is unclear to Bundles today, which forces them to base their entire business model in an expected lifetime of the machine of 10 years, instead of the 20 years it was originally made for. The product design should allow several use cycles without lowering the quality standards set by Miele.

RQ 2. Increasing circularity
In order to improve refurbishment and repairing processes, knowledge from the professional line of products of Miele can be implemented. Such as spare parts and service packages, as well as the design of a product that makes components more accessible to make repairs and updates more efficient.

RQ 3. User role and impact
Knowledge from professional lines can also be implemented to increase the perceived value of the PSS through the use of personalization to meet specific user needs and requirements.

Requirements derived from this section
Wishes (the design could...)

- The design could increase the opportunities for a Miele and Bundles collaboration through refurbishment and part replacement.

- The design could increase the volumes and value for Bundles and Miele. The increase in volumes could increase interest in CE procedures as a business strategy. Considering the recovery and recycling of materials as well as service and spare parts services.

- The design could aim to expand the pool of targeted customers.

3.3 The Use Phase

This section lists down all relevant insights identified within the use phase. First, this section focuses on the environmental impact and creation of value for the user during the use of the product (referred to as the Washing Journey in this chapter) including insights derived from research conducted with Miele Germany and users. This analysis first contemplates the user actions (user behaviour), second, the reasons behind those actions and third, the product characteristics that contribute to them. User actions are presented in the Washing Journey Map, which considers every step the user goes through while doing laundry. Second, this section displays additional findings related to augmenting the perceived value of the current washing experience obtained from interviews and the formulation of Personas. Finally, insights related to the current limitations of processes like repairing and maintenance and their relation to the user, are presented.

3.3.1 Analysis of the user behaviour and its relation to the creation of value and environmental impact

In order to gain further insight related to the user behaviour, seven different users were interviewed from which five were also observed while doing laundry. The group of interviewees consisted in a combination of different living conditions and occupations and well as differences in ages and types of washing machine facilities (ownership, leased two current Bundles users included, shared, etc).

The insights that were found relevant for the reduction of environmental impact or identified as opportunities for the increased delivery of value through the Bundles PSS were mapped in a 'Washing Journey Map' (figure 10) (Ui). The most relevant identified actions or situations are indicated in grey and Bundles' possible actions and opportunities for design are highlighted in green. The Washing Journey Map indicates all steps related to the activity of washing clothes, including first, preparatory steps: **planning** and **collecting** which define when are people washing and the frequency with which they are doing it. The following steps (How are people washing? How long does it take?) include: **Separating**, which refers to whether a user does or not separate clothes and how he or she does it. This value could also have consequences in the frequency of washing. **Loading**, which refers to the action of putting clothes in the washing machine and defines the volume of the load. **Set up**, refers to the selection of the program. **Soap**, which defines the amount and type of soap the user puts in the machine. **Cycle**, refers to the time it takes (defined by the program) to wash the clothes. **Unload and next steps**, refers to the action of taking the clothes out and considers when this action is done and if other steps follow, such as consecutive cycles or drying.

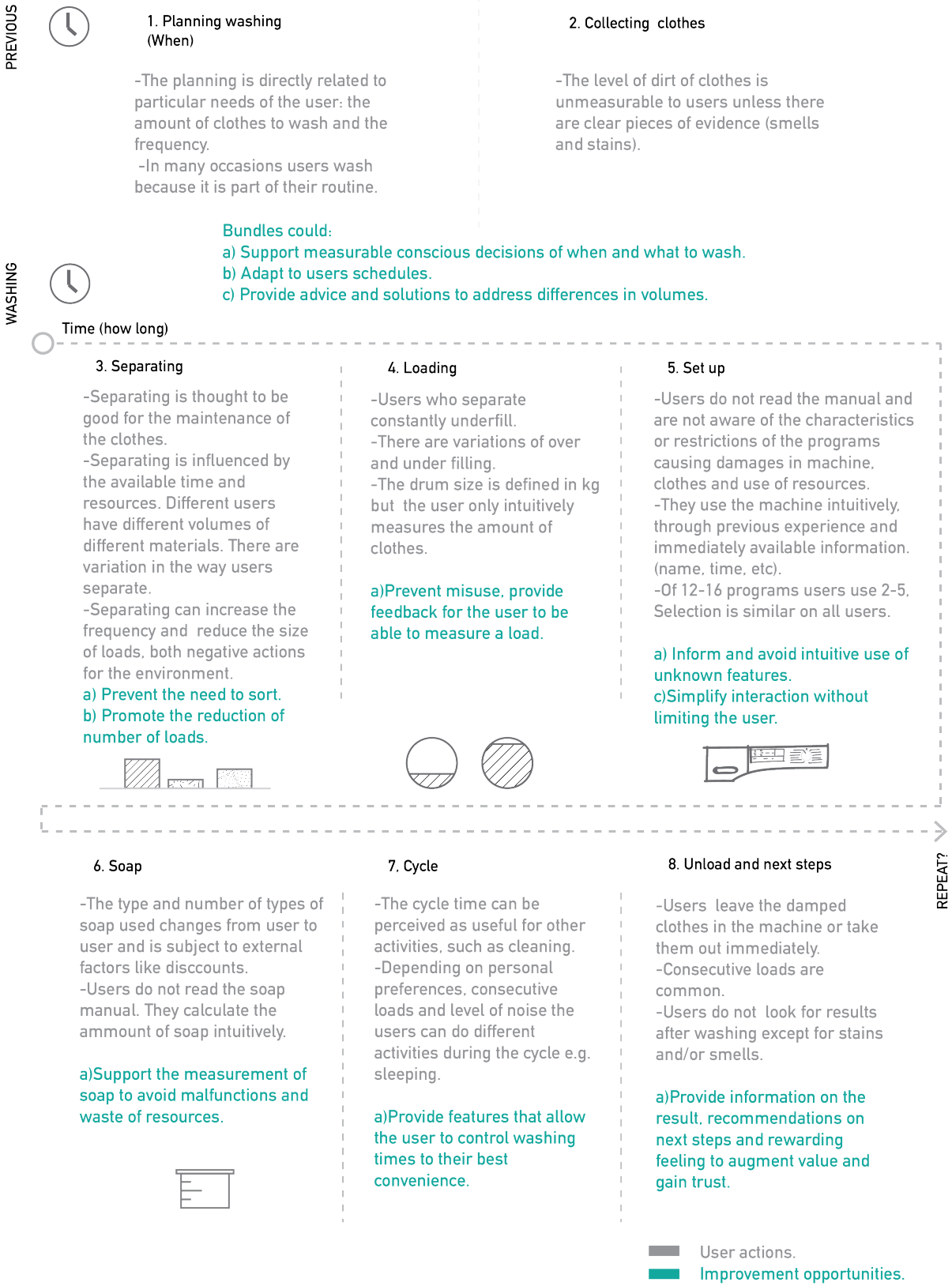


Figure 10. Washing Journey insights of actions and opportunities for design. (Ui)

3.3.2 Analysis of the influences on user behaviour.

As mentioned before (Chapter 2.5.3), in order to propose potential solutions to the effects of user behaviour, it is important to understand its origin. Some of the insights listed above highlight that the decision making of what and when to wash is based on intuition, immeasurable information and users' routines.

The identified influencing factors through the user interviews include:
The users' living situation. Many of the characteristics that define a user's living situation (input) defines his or her laundry needs, behaviour and circumstances (output). Table 3 lists down the values for Input and Output (Ui).

This information is an important indicator of the diversity of needs and potential failures to fulfill environmental recommendations (Chapter 2.5.1) that can be found among possible customers and users of the PSS. Although a challenge, Bundles could tackle this diversity of user needs through their services through for example, personalization, generating a unique competitive advantage when compared to product based business models based on new value propositions and the reduction of the environmental impact of the use phase.

A second identified big influence in people's washing behaviour are their sources of knowledge, past experiences and culture (input). These define many of people's washing habits and decision making (output). Table 4 shows the values for input and output (Ui).

These findings are relevant to the implementation of the PSS when considering the delivery of information to the user since they indicate tested successful sources of information the users usually follow and trust (Ui). These insights could be used for the redesign of the PSS to deliver reliable information to positively influence user behaviour.

Input (Living situation characteristics)	**Output (Needs, behaviour and circumstances)**
-Type of house. -People they live with and relationship to them. -Age. -Occupation and activities. -Stability. -Available resources and time. -Value of clothes and attachment to them	-Type of washing machine or available washing facility. -Amount of clothes. -Frequency and schedule for washing. -Types and amounts of materials. -Level and type of dirt. -Type of soap. -Programs.

Table 3. User's living situation influence.

Input (Sources for knowledge, experiences and culture)	**Output (Washing habits and behaviour)**
-Word of mouth. "My mom says". -Previous experience with other washing machines. -Collective norms and conventions for cleaningness and hygiene. -Immediate feedback and information delivered by machine or clothes through the control panel, display and tags.	-Sense or evaluation of dirt levels. -Frequency of washing. -Size of loads (influenced by separation). -Types of soap. -Used of programs. -Inconsistent or incorrect measures to reduce environmental impact.

Table 4 . User's sources of knowledge and information.

3.3.3 Identified product characteristics that contribute to the user behaviour.

The following are the characteristics of the current PSS washing machine identified to represent limitations to the user interaction with the product and to have an influence in the behaviour mentioned above.

The washing machine displays a control panel that provides a variety of at least sixteen programs (this number changes from model to model). The sixteen programs (figure 12) have different available variations (not all variations are available for all programs), such as time and temperature. Programs have loading limitations and are meant to take the best care of a specific type of cloth. The programs are predefined in relation to the Sinner's Circle (Figure 11) for optimal washing, which balances the proportions of four elements, mechanical input, temperature, cleaning agent or detergent and time. The balance of these elements is what defines a program. If for example, the time variable is reduced, it has to be proportionally reflected in the augmentation of another variable, like temperature. It is important to note that as mentioned before, these variables have differences in the environmental impact they generate, temperature and cleaning agent having the most negative consequences (Mg). This is why Eco programs are designed to be so long, by augmenting the time and mechanical input variables, it is possible to achieve good cleaning results without heating up water (Mn).

*A specific note to make here, is a recommendation highlighted by Miele: mixing is a possibility and good results of washing (Hygienic results, no color transfer or damage to fabrics) can be achieved by long periods of mechanical input. Reducing the use of high temperatures and achieving complete (full) loads (Mg).

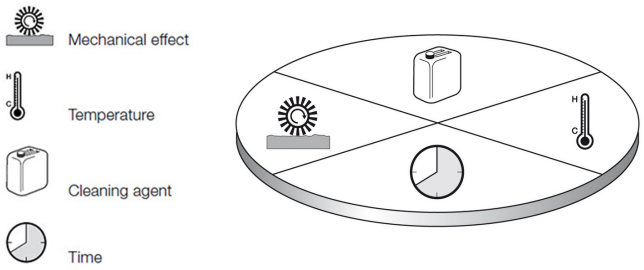


Figure 11. Sinner's Circle for washing Retrieved on April 11th, 2019 from: https://www.hhands.co.uk/blog/cleaning-sinners-circle-chemical-and-the-right-equipment-n15

Delicates	**cold to 40 °C**	**Max. load 2.0 kg**
Use for	Delicate garments made from synthetic fibre, mixed fibre, rayon and viscose. Curtains, including net curtains, specified as machine-washable by the manufacturer.	
Notes	– Dust in curtains usually makes a programme with pre-wash advisable. – Deselect the spin for items which crease easily.	
Woollens	**cold to 40 °C**	**Max. load 2.0 kg**
Use for	Machine-washable or hand-washable wool or wool blend fabric. If the care label does not specify a temperature, wash using the cold setting.	
Note	Reduce the spin speed for items which crease easily.	
Silks	**cold to 30 °C**	**Max. load 1.0 kg**
Use for	Silks and other handwashable fabric with no wool content.	
Note	Place tights, bras etc. in a laundry bag.	
Shirts	**Cold to 60 °C**	**Max. load 1.0 kg/2.0 kg**
Use for	Shirts and blouses made of cotton and mixed fibre.	
Notes	– Pre-treat collars and cuffs if necessary. – Wash silk shirts and blouses in the *Silks* programme. – If the preset *Pre-ironing* option is switched off, the maximum load capacity is increased to 2.0 kg.	
MobileControl		
The Miele@mobile app is used for selecting programmes and operating the machine.		

Sportswear	**cold to 60 °C**	**Max. load 3.0 kg**
Use for	Sportswear such as singlets and leggings as well as microfibre and fleece garments.	
Notes	– Do not use fabric conditioner. – Observe the manufacturer's care label.	
Automatic plus	**cold to 40 °C**	**Max. 6.0 kg**
Use for	Mixed loads of garments suitable for the *Cottons* and *Minimum iron* programmes.	
Note	The wash parameters (e.g. water level, wash rhythm and spin speed) are adjusted automatically in this programme to ensure the best possible care and wash result for each item.	
Separate rinse/Starch		**Max. load 8.0 kg**
Use for	– Rinsing hand-washed items – Starching table cloths, serviettes and workwear.	
Notes	– Reduce the spin speed for items which crease easily. – Laundry that is to be starched should be washed but not treated with fabric conditioner. – Items will be rinsed very effectively using two rinse cycles by activating the *Water +* option.	
Drain / Spin		**Max. load 8.0 kg**
Notes	– Drain only: Select 0 rpm for the spin speed. – Make sure you select the appropriate spin speed.	

Figure 12. Example of the programme selection available in a Miele machine.

The variety of programs is extensive and complex. Information about this complexity does not typically reach the users, even though it is available in a manual, the information also fails to be delivered through the direct interaction with the product (Ui) (Mg). Users are not aware of all the characteristics and restrictions of the programmes and typically simplify their interaction with the machine by selecting a favorite group of 2-5 programs (See Washing Journey Map, Chapter 3.3.1) in a poor attempt to 'best' cover their needs (Ui). This selection is similar from user to user, reduced to cotton programs, wool and delicates, fast programme and, at times, Eco program (Ui).

The users select programmes based on immediately available information (display), previous experiences or recommendations from other people and immediate needs. The complexity of the system, the misinformation caused by the failure of delivery of information and the overall user behaviour (See Washing Journey Map, Chapter 3.3.1) consequently deliver misuse (Mg). Misuse has consequences on the excessive use of resources, damage of the washing machine and damage of the clothes. All of which are in the PSS best interest to address, considering they have consequences and opportunities for value delivery within all phases of the PSS lifecycle.

The machine provides a wide selection that intends to meet a wide variety of needs and responds to the characteristics of the clothing industry (materials and care labels, see Appendix A). In order for the user to make use of the washing machine as recommended, he or she would have to read the washing machine manual, all care labels in their clothes and label on the soap they use. It has also been found that users have a feeling of control and appreciate having so many different options (Ui) (Mg), however, this variety is having more negative effects than positive. The variety doesn't have to be eliminated, but it can be administered differently by Bundles. The service could give control to the user, for example, through personalization (See Chapter 2.4.2, User acceptance of PSSs). Simplifying the interaction, eliminating intuition and misinformation, and equipping the machine to meet specific needs could have a positive impact in the rational use of only the needed resources and better care of clothes and machine. This is seen as an example, in the personalization of

Load	Unit		**5 kg**	**3.75 kg**	**2.5 kg**	**1.5 kg**
Water (suds)	Litre		11	8,5	6	4
Water (per rinsing cycle)	Litre		8	6,25	4,5	3,1
		Temp				
Total energy consumption	kWh	*20°C*	0,25	0,23	0,22	0,21
	kWh	*30°C*	0,29	0,27	0,25	0,23
	kWh	*40°C*	0,47	0,41	0,35	0,30
	kWh	*60°C*	0,83	0,70	0,57	0,46
	kWh	*95°C*	1,34	1,10	0,87	0,68

Table 5, Energy and Water consumption with a future automatic load detection, (Öko-Institut e.V. , 2015).

Miele's professional and semi professional washing machines (Mg).

Additionally, the recommendations for washing included in the manual in relation to capacity, ideal programming and separation for best clothing and machine care do not correspond with the recommended actions for best sustainability practices when washing (Mg), encouraging the use of high temperatures and underfilling. Even considering that machines now count with an automatic load detection system (which measures the amount of water needed to wash a certain load), LCA studies in washing machines (Koerner et al, 2011; Öko-Institut e.V. , 2015) indicate that energy and water consumption is optimized with larger loads. Table 5 shows an example of this.

These elements need to be put in balance to best meet the user needs in the most resource efficient way. Bundles should look into providing the user with possibilities of constantly being as resource efficient as possible and to fit their needs accordingly. Instead of limiting the user experience to a single predefined program (or set of programs) or bound it to specific model of washing machine. This could add new possibilities of delivery of value and add on to their already proposed value of becoming more resource efficient.

Another observed limitation from the product is related to longevity, washing machines are expected to stay in a house for a long period of time, a lot of things can change in a user's life during that time, like having children or involving in sports or other activities (Ui). However, the machine and way of washing do not change accordingly. Bundles and Miele could also find this as an opportunity to deliver value to the user by offering and allowing updates or changes that respond to their customers. There is a possibility to implement this through the use of IoT and monitoring of the user actions and activity with the washing machine, for example.

3.3.4 Findings on what users find valuable during the washing journey - The ideal washing experience.

This section briefly describes additional findings related to the creation of value for the user during the washing process and focuses on describing opportunities and limitations to address user needs and desires. First, findings from user interviews and observations are listed, followed by the results of the creation of Personas and a workshop with users to find the 'Ideal washing experience'

Interview results show that the user typically trusts the machine will do a good job cleaning the clothes. The user does not look typically look for results after washing unless there was a clear previous problem like a stain or a smell. However, the machine needs to be trustworthy in order for the user to feel secure about the washing results. Miele users buy a Miele machine due to the good high quality reputation of the brand (Ui). Bundles needs to deliver a similar feeling of trust through their service. This could be achieved by generating as literature recommends (Chapters 2.1.3 and 2.4.1) closer personalized relationships with the user, and in an initial phase (specially if a new product or features is involved) offer demonstrations, trial periods and guarantees.

Another important observation from the interviews is that the machine is not perceived as an important object, it is only considered a means to an end. Additionally, the procedure of washing is perceived as a time and effort consuming, a chore (Ui). Bundles and Miele could both explore possibilities to enhance the value of the washing machine considering it shouldn't only be a means to an end but, together with the service, a facilitator for such a consuming task. This could also be added to the goal of reducing the frequency of

washing, if the user is well informed and supported by the PSS they can reduce the amount of times they have to go through the chore.

A final important value to highlight from the interview results is time. The user highly values time and typically looks for either making the process as short as possible (with negative impacts for the environment) or looks to make good use of the cycle time by doing other activities. Today, those activities are bounded by the predefined cycle times and in the case of people who separate, by the need of doing consecutive loads (Ui). Considering this, Bundles and Miele could explore the possibilities of adapting the cycle times to the user and environment best convenience.

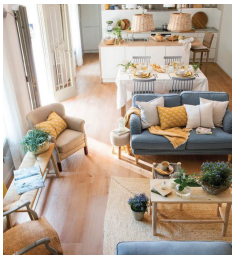
As a result from the creation of Personas (with a fictional User Journey Map for each one of them (Appendix F)) in combination with the results obtained from the definition of the 'Ideal washing experience' during the user workshop three values were identified for the users as most important: Seamless effort and time, Personalized and Informed (Communication).
Although the Personas indicate a great diversity of needs, the identified values or interaction keywords have similarities from one Persona to another. These values could be expected to have a positive impact in all of their washing experiences. Additionally, the created Personas consider future changes potential users could go through throughout their lives and the places where these fictional users live. These inclusions support the ideation processes to consider how to adapt the PSS to changing needs and differences in spaces where the machine could be installed.

Figure 13 shows a summary of the identified Personas and values, a complete version can be found in Appendix F. Images 9 and 10show an example of the results obtained from the workshop and the workshop itself.
The identified values and the consideration of the possibilities for future changes can be implemented by Bundles and Miele into the PSS to increase its perceived value and competitive advantages. These values can be interpreted in many different ways and implemented further in the development of the PSS either as services or characteristics of the product.

Image 10. Workshop participants, Ideal washing experience.

PERSONA 1

Family of 4 with kids



4 bedroom house

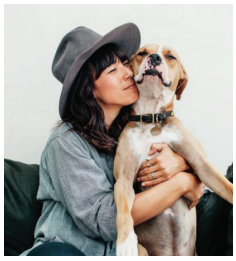
Ideal interaction key words

Seamless effort.
Organized.
Reflective and caring.

Future changes

-Mom get a promotion. Starts wearing more formal clothes.
-One of the kids moves out.

PERSONA 2



Single woman

Small loft

Ideal interaction key words

Informed and caring.
Seemless time.
Effortless.

Future changes

-She starts living with her partner.

PERSONA 3

Young couple

Small 1 bedroom studio.

Ideal interaction key words

Seamless time.
Informed and caring.
Enjoyable.

Future changes

-She goes on a 6 month research trip.
-They move to a larger home.

Figure 13 . Personas Summary .

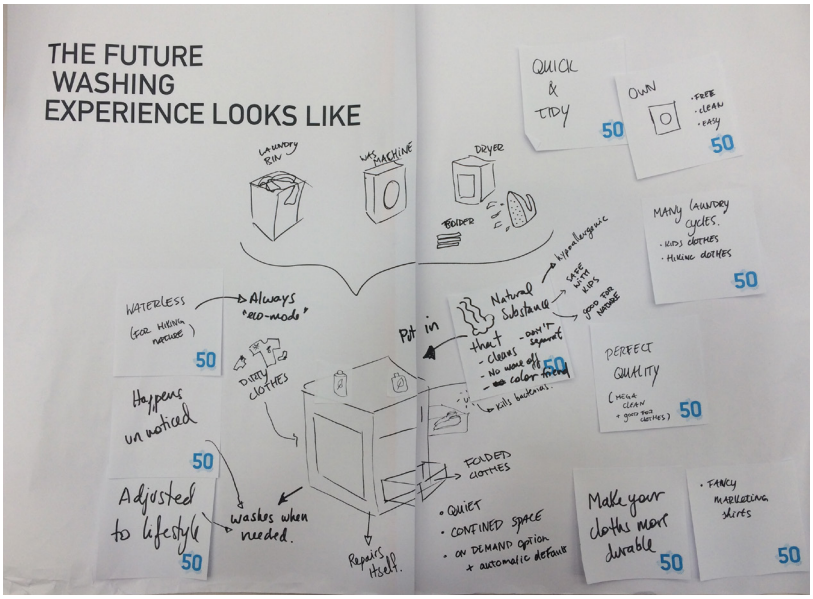


Image 9. Example of Workshop, Ideal washing experience.

3.3.5 Context and user behaviour identified challenges related to repair and maintenance.

This section focuses on the insights found through Bundles and user interviews related to the role of the user in the maintenance and care of the washing machine. Possible risks that should be addressed by Bundles in order to guarantee the correct use and care of the product to increase its lifetime and prevent additional costs during repairs and refurbishment are highlighted. The listed risks consider conditions that are consequences of both the context and the user behaviour.

Observations with users showed that the positioning of the washing machine can have a strong impact on its deterioration. Machines are typically positioned somewhere in the house where it is accessible and, when the location allows it, the machine is positioned somewhere "hidden" since it is not commonly aesthetically appreciated by the users. Some of the places include laundry cabinets, bathrooms and kitchens. Bad positioning of the machine due to limited space or just lack of care, can cause greater deteriorations to the machine. An example of these is the rusting caused by positioning the machine in bathrooms or any humid area (Ui).

These insights arise opportunities to augment the visual value of the washing machine, so it becomes more desirable and is as a consequence better placed and taken care of. Augmenting the sense of value of the product could nudge the customer into being more careful and paying more attention to it. Bundles could also generate more points to deliver information and feedback to the user. When starting a subscription, for example, they could use the installation as an important point to inform the user about maintenance procedures and better care of the washing machine. Today, the installation process is limited to some basic pieces of information provided by Vonk technicians due to tight logistics schedules. However, a higher investment of time during installation could not only inform the user but also augment the perceived value of the service just as it is done today with Miele's professional line (Mg). Additionally, Bundles could also offer the possibility of personalising the washing machine to meet the spatial needs of the user, enhancing value and care towards the machine and making it more attractive.

As previously mentioned, most users do not read the user manual, which also includes important information about maintenance procedures. Additionally, the user does not perceive the machine as an important object that requires continuous cleaning and maintenance. This has negative implications in the performance and deterioration of the machine due to maluse and lack of maintenance. (Mg) (Ui). As mentioned in Chapter 3.3.1 users constantly respond to direct feedback and pieces of information. In fact, some of Miele's higher end machines include messages that remind users to perform maintenance procedures such as the 90C machine cleaning program and cleaning of the soap tray. Users indicated they do follow these instructions and appreciate having information on what to do (Mg) (Ui).

Bundles could continue with the delivery of information and reminders through their service for users to learn and take care of the washing machine. Some of the points to highlight on these reminders are due to their effects on the condition of the machine are: positioning of machine, soap overdosing, lack of cleaning and maintenance, installation of other accessories (such as supports for dryers and other pieces of furniture that users like putting on top of the washing machine and could damage it).

Interview results also found that in case of malfunction users intuitively look for feedback and evidence in order to be able to provide a diagnosis to Bundles or the responsible =service provider. Users most typically have a problem solving approach, however, they will assess the severity of the situation and decide to fix it themselves or not, depending on their background and experience and the perceived potential risks of trying. Repairing is overall perceived as dangerous and difficult (Ui). Today, the machine is designed to avoid the user from intervening in the repairing process, and only allows repairs to be performed by a Miele technician. Bundles could however, in order to prevent excessive logistics costs and safely involve the user in the process of maintenance, have a guiding problem solving information system to guide the user into performing simple repairs and even diagnosis themselves. Through this and the monitoring of the machine components, Bundles could facilitate and optimize repairing processes through the prediction of malfunctions and the obtaining of information related to the status of the machine before hand.

Takeaways and answers to research questions.

RQ 1. PSS implementation.
Users' washing needs and behaviour are very diverse since they are defined by a great variety of factors such as living conditions, number of people in a household, occupation, etc. The product is designed to deliver a great variety of predefined programs in order to try to cover this variety. However, this characteristic together with the lack of information, causes the user to intuitively use the machine. Intuitive and misinformed use has negative consequences in the machine itself, increases the amount of used resources (water and energy) and has negative consequences in the care of the clothes. The machine does not provide any type of measurable information or feedback for the user to know the consequences if his or her actions. For example, when filling up the machine, which capacity is indicated in kg, there are no indicators or ways for the user to measure if he or she is over or underloading. Additionally, many of the characteristics of the predefined programs contradict the recommendations found to reduce the environmental impact of washing. In some cases, programs suggest to have half loads or use high temperatures.

RQ 3. User role and impact
Users highly value a washing experience that can take less time and effort. In addition the value having suitable functions for their specific needs. Users also value being informed on how to take better care of their clothes and reduce their impact. Having knowledge gives them a sense of control. Finally, it was found that people's lives are subject to constant change, while the machine and its functions remain static. Adaptation and personalization are values to be considered to overcome this.

Monitoring of use and the personalization of the washing machine characteristics could be strategies to reduce the environmental impact of the us phase. Eliminating intuitive use while best meeting specific user needs. The user should also be informed considering the good care and maintenance of the machine in order to avoid malfunctions caused by misuse and reduce the need for repairs. Immediate pieces of feedback on the product with indications of necessary processes could be a strategy to improve the sense of care for the product. Additionally, knowledge from Miele professional lines could be implemented considering their personalized user trainings, where they explain and give personalized tips in relation to the user's specific needs.

Requirements derived from this section

-The design should be able to adapt to the customers' specific washing needs.

-The design should be able to adapt to the customers' space needs.

-The design should promote a positive user behaviour to avoid damages and promote maintenance.

-The design should deliver functions and information that improve the customers' washing experience and clothes' caring.

Wishes (the design could...)

- The delivery of customized washing solutions could be a strategy to avoid overuse of resources or materials, and reduce overall environmental impact.

3.4 The Post-use Phase

This section focuses on all insights gained from observations with Miele and Bundles related to all processes within the Post-Use phase. It first dives into the current processes, complications and overall recommendations related to the repair and refurbishment of the washing machine to submit it to several use cycles. Secondly, it considers insights found in other studies performed by researchers regarding priority components, their repair and update. Finally, it details the current situation and opportunities regarding the end of life of the washing machine in the PSS.

3.4.1 Current processes for refurbishing and repair for several use cycles.

The current processes of Bundles for refurbishment consists of cleaning the machine, exterior and interior (running 90C program), small repairs like putting plaster on the exterior panel if there are any scratches and testing/analysis of further repairs or part replacement needed. These procedures are done by Vonk technicians, however, if the repair needed is internal, or parts need to be replaced, Vonk will notify Bundles so they can call Miele NL technicians to do them (Bv). Observations and interviews show that the use of the machines is generally good, only one in 50 machines received by Vonk for refurbishment are considered to have been mistreated by the user (Bv).

Today, Bundles has approximately 700 washing machines installed in customer's houses, considering this number and 5 years after they started (their longer subscription period is then 5 years), the volume of machines to be refurbished is still low. However, this number may increase soon, requiring higher investments in repairs and larger facilities to do so. Bundles highest investment point is the purchase of the appliance itself, additionally, and even though the machine is very high quality, high costs also derive from any repairs (from Miele NL) or spare parts are needed. This needs to be addressed considering that the machines will need more investment in refurbishment and repair after several use cycles and this should not interfere with Bundles profit.

There are several reasons for the high costs related to repairs and refurbishment. The first, as pointed out before, is the almost B2C relationship between Miele and Bundles which will need to change to a B2B one if the PSS is to grow and bring benefit to both of them. Miele has great attention to detail in customer service within their professional line, the product is designed for optimized repairs, replacement parts and services (service or repair hours) are offered ase packages and long term contracts, and the user is informed during installation about functions and proper maintenance (Mg). All of this knowledge could be extrapolated into the relationship between Miele and Bundles and analyze what level of involvement would be necessary from Miele since it could be proposed that Miele could even become a second refurbishment facility.

Another reason related to the high costs of refurbishment and repair is that domestic machines are designed for a highly automated mass production, which means many of the qualities and characteristics of the product are defined to optimize this production. Domestic machines are more and more designed to be perfectly integrated to maintain their durability and reduce manufacturing costs, an example of this is the use of side panels as part of the structure of the machine and the use of plastic of some of the external components, such as the control panel and top section of the top panel.

Additionally, due to the complexity of their construction extensive knowledge is needed to repair them and the access components is complicated, augmenting the number of service hours (of Miele technicians), which are coincidentally the highest cost for Bundles considering repairs (B). A good example of this is the rubber ring (Images 11 and 12), which deteriorates and stains easily and would ideally be easily replaced. The rubber ring is not an expensive part (approximately

50 Euros) however, to replace it, a Miele technician is necessary, making the replacement very expensive (Bv). The PSS needs a product that facilitates refurbishment and repair procedures for it to be submitted to several use cycles in an affordable way.

Image 11. Deteriorated and stained rubber ring

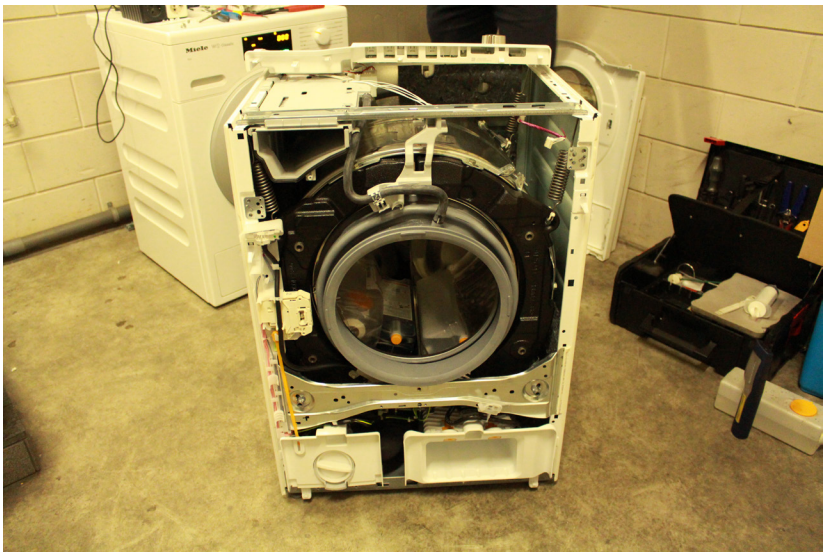


Image 12. Access to rubber ring.

3.4.2 Considerations for the repair and update of the washing machine

When submitting a domestic appliance to several or long cycles of use, concerns regarding the preservation of their original resource efficiency arise. An LCA study on Miele Washing machines (Öko-Institut e.V. , 2015) researched the resource efficiency and impact of long operating lives (20 yrs) vs the early replacement of the appliance and concluded that the early replacement of washing machines does not pay off in comparison with the sum of the impact of the other phases of the Lifecycle of the machine necessary for replacement. However, the loss in resource efficiency does not necessarily implicate the replacement of the product as a whole. The PSS should count with a product that supports updates as well as a system that monitors said efficiency and allows the generation of diagnosis and even predictions of malfunctions or deterioration to optimize the refurbishment process. Updates in the product should not be exclusively considered for resource efficiency. Developments in the user interface as well as updates and trends related to finishes and exterior should also be considered.

3.4.3 Repairability and ease of access of the washing machine

In order to improve the washing machine machine to make it more suitable for repairs and refurbishment it is necessary to analyze it considering several parameters. A great variety of methods are available for this analysis of appliances in relation to repairs, the European Commision (Cordella et al, 2019; Vanegas et al, 2016) has created assessment tools and scoring systems for the repairability, upgrade and ease of disassembly of products. The tools consider different parameters for the assessment including, technical, behavioural, economic, organizational and legal factors.

Since technical parameters are directly reflected in the design and architecture of the product, they are considered of most relevance for this project. The report of the European Commission (2019) categorizes the technical parameters into two thematic areas, a) Design for disassembly b) Repair/ Upgrade process. Ease of disassembly is considered separately and it can include identification and access to components as well as visibility, tools and manipulation of the product during the process. The publication defines disassembly as "the non-destructive (reversible) taking apart of an assembled product into constituent materials and/or parts, in such a way that they could subsequently be reassembled and made operational". The following are the technical parameters the publication recommends for the assessment of products.

Although the scope and time limit of this assignment does not allow the deep study and application of the assessment parameters for the Miele washing machine or the future concept, it is important to keep them into consideration for the development of the concept and its validation.

a) Design for disassembly.
These parameters are further analyzed and illustrated in the validation section of this document.

-Disassembly depth sequence. This refers to the number of steps to access a component. A step consists of an operation that finishes with the removal of a part and/or with a change of tool (Commission Decision (EU) 2016/1371, 2016). This number is ideally reduced and the process should proof to be reversible.

-Fasteners. The assessment considers the number and type of fasteners as well as their visibility and accessibility. Additionally, fasteners should be reusable and not cause damage to the product.

-Tools. It refers to the type and number of tools needed for the process. The use of available and common tools is preferable over product specific or tailored tools.

-Disassembly time. This parameter could be defined by the combination

of the previous three parameters. Its measurement can be complex due to the number of additional external factors that could affect it. Time can also be used as an indicator of service costs.

b) Repair/Upgrade process.
-Diagnosis support and interfaces. This parameter considers the information that helps to identify a problem with a component. It can be made available by the manufacturer or it can be displayed on the product itself. In the case of Miele, their technicians count with special manuals and a specific service interface they can access to in every machine (Mn).

-Type and availability of info. It refers to the availability of information that facilitates and supports the repairing and disassembly process. The assessment is based on how comprehensible the information is and whether or not its availability is restricted. This information has not been obtained throughout this assignment.

-Spare parts. It refers to the availability, delivery time and costs of spare parts. Specifically for the priority components (defined below). Spare parts in Miele are made available for up to 7 years after purchase (Mn). The delivery time is not clear for every component but as mentioned before, spare parts and their availability could become part of a new business relationship between Miele and Bundles.

-Software and firmware. The parameter refers to the availability and upgradability of the controlling software of a device. This has not been clarified throughout this assignment.

-Safety, skills and working environment. This assessment is based on the necessity for specific technical skills for the repair process. This can be an indicator of the complexity and costs of the process. As mentioned before the construction of the machine requires a high level of expertise to perform repairs and disassembly (Mg) (Mn).

-Data transfer and deletion. This parameter is related to the security and deletion of user's data. It is relevant for products that will change ownership like the case of Bundle's PSS.

-Password reset and restoration. In line with the previous parameter it refers to the ability of restoring the product to factory settings and is also specifically related to products that will be reused.

-Commercial guarantee. It refers to the relation between the length of the guarantee and the reliability of the product and its effect in limiting or allowing the repair operation. As well as the spare parts, the generation of guarantees prior and after refurbishment processes could become a part of the new business relationship between Bundles and Miele since it can become an important source of transparent and reliable information for the user.

3.4.4 Identified priority components of the washing machine

Within the washing machines some components are more prone to deteriorate than others depending on their function, exposure and intensity of use. When augmenting repairability of a product it is important to identify which are the components that deteriorate the most or most often and facilitate access to them as mentioned above. These are called priority components and in order to identify them two sources were used:

Tecchio et al (2019) and the European Commission (Cordella et al, 2019) propose this list for priority components of a washing machine.
- Motor brushes
- Shock absorbers and springs
- Washing drum, drum spider and related ball bearings
- Printed circuit boards
- Electronic displays
- Door, door hinges and seals, door locking assembly.

These results are, however, generic to all washing machines that participated in the study. In order to be more accurate Miele NL (2018) provided the following list of the fifteen top parts reported to be most repaired in the last quarter of 2018 (Figure 14).

The combination of the two lists indicates coincidences in the following priority components: the shock absorbent, the door seal and lock, the motors and drive belt, and the electronic module for the power control. This list should be considered throughout the improvement of repairability and refurbishment processes of the new concept. Figure 15 shows the estimated positioning of the priority components in the machine.

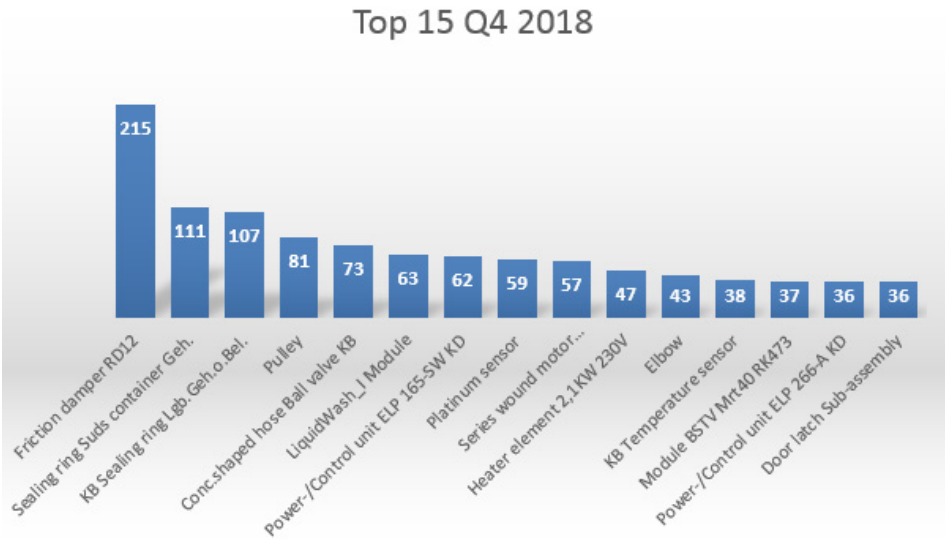


Figure 14. Top 15 repaired parts in domestic washing machines in the NL.

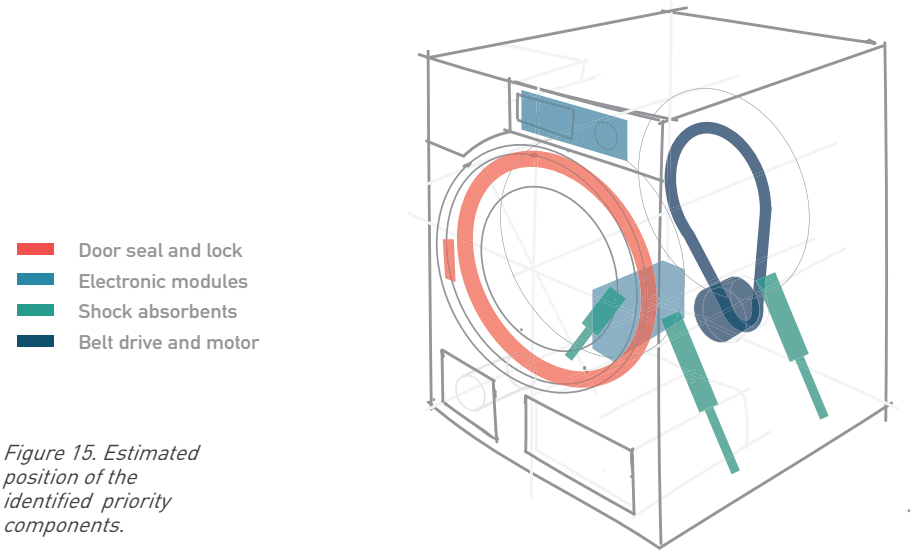


Figure 15. Estimated position of the identified priority components.

3.4.5 Recycling and Recovery of parts and materials in the PSS

As mentioned before (Chapter 3.2.1), Miele machines were also chosen by Bundles for they high content of recyclable materials. Today, the washing machines that are used in the PSS are responsibly disposed, Miele is only involved in this process through the payment of the Extended producer responsibility fee, by regulation (Mg) and Vonk sends all non functioning washing machines to the recycling companies Renewi and Coolrec in the Netherlands (Mn).

However, for the PSS to become circular, the recovery of materials and parts and their recycling and upcycling should become a reality. 85% of a domestic Miele washing machine is recyclable (Mg) but none of it is recovered because recovery costs are too high since Miele loses control over the ownership. Bundles has the advantage of remaining control over the ownership of their machines, and, as mentioned before, could become a point for recovery for Miele. If Miele wanted to start reintroducing materials into the loop in the future, they would not have to acquire these materials over recycled material suppliers but reuse their own. Allowing then to maintain control over organization and quality of the materials and components. However, Bundles' volumes would have to grow to interest Miele in this procedure.

In the past Miele was recovering the cast iron counterweights from their washing machines and recycling the material to make new parts (Mg). Further study of other possibilities for recycling and reuse should be done considering current and future regulations and restrictions, including the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) and Restriction of Hazardous Substances (RoHS). (Mg)

The new design should consider the use of recyclable materials and make use of Miele's current construction knowledge in order to preserve or augment the 85% content of recyclable materials. Additionally, and considering what was mentioned above, the disassembly of the components should also be taken into account to facilitate the recovery of materials.

Takeaways and answers to research questions.

RQ 1. PSS implementation.
The current washing machine is designed to be mass produced and long lasting, these characteristics make the machine highly integrated. This becomes a complication when attempting to submit it to several use cycles. Refurbishment and repairing procedure become very expensive for Bundles because spare parts are costly, any repairs and part replacements have to be done by a professional Miele technician (since a high level of expertise is necessary), and the integrated construction of the machine makes the disassembly and access of components more difficult increasing service times. Ease of access and disassembly have to be implemented into the new product considering priority components which deteriorate faster or are prone to encounter a malfunction. Additionally, processes for the refurbishment of the machine should be considered when selecting materials and finishings.In addition to the redesign of the machine, the relationship between Miele and Bundles should consider a new business strategy that includes service programs and packages, where Miele could become fully responsible for the refurbishment of the machine.

RQ 2. Increasing circularity
The Miele washing machine has 85% content of recyclable materials which could be recycled and reintroduced into the manufacturing of new machines. Bundles could become a recovery point for Miele since they maintain control over the ownership of several machines. However, in order for this to be feasible and interesting for Miele, the amount of machines Bundles manages would have to increase.

Requirements derived from this section

-The design should be optimized for refurbishment.
- -Facilitate the disassembly and reassembly of components.
- -Use of refurbishable materials and finishings.

-The design should be optimized for repair and improve component access compared to the current washing machine.

-The design should allow the product to remain resource efficient, through updates and/or the replacement of components.
- -Measurable intensity of use.
- -New developments.

02

FOCUS

This part of the report includes the formulation of a list of requirements and a set of focus points or values that serve as guidelines and define the limitations for the ideation and development steps of the design process. The definition of the requirements and values is a result from all identified insights from the literature research and field studies. The list of requirements is presented first, followed by a set of focus areas and the rationale behind their selection. This part of the report finalizes with the formulation of the design challenge.

4. DESIGN SCOPE AND DESIGN GOAL

4.1 List of requirements

The following is a list that includes the initial boundaries established by the assignment and additional requirements that derived from the analysis. These requirements are considered to be the design criteria that the concepts created during the ideation phase should follow. The requirement list also serves as a tool for evaluation and selection of ideas and concepts. The order in which the requirements is presented indicates their priority based on their relevance to the initial assignment statement.

This project explores the current limitations that the product imposes for the successful implementation of the Product Service combination (or Product Service System, PSS) in order to propose a redesign that enhances it whilst also taking into account circularity and the reduction of environmental impact.

Additionally, they include identified values (highlighted in green) derived from the analysis phase that will serve as a reference for the following steps of the design process. These values are further explained in Chapter 4.2 Focus Areas.

	SHOULD	COULD
Initial Design boundaries defined by the assignment. Introduction Chapter 1.1 Assignment	a. The design should be a combination of a product and a service. b. The design of the product should enhance the characteristics and proposed procedures of the service. c. The design should increase the possibilities for circularity. d. The design should consider the overall reduction of environmental impact. e. The design should be supported by IoT technologies.	The design could deliver new opportunities for collaboration between Miele and Bundles.

	SHOULD	COULD
Analysis Requirements. **PRE USE. Personalization.**	A1. The design should increase the customers' perceived value of the PSS compared to the current one and Product based models. Chapter 2.1. and 3.2 A2. The design should promote a longer and closer relationship with the customers. Chapter 2.1. A3. The design should consider the user acceptance of refurbished products. Chapter 2.4 and 3.2 -Providing added value. (Personalization) -Providing transparent information. A4. The design should be able to adapt to the customers' specific washing needs. Chapter 3.3 A5. The design should maintain the Use Oriented PSS model of Bundles. Chapter 2.1. A6. The design should be able to adapt to the customers' space needs. Chapter 3.3	The delivery of customized washing solutions could be a strategy to avoid overuse of resources or materials, and reduce overall environmental impact. Chapter 3.3 The design could increase the volumes and value for Bundles and Miele. The increase in volumes could increase interest in CE procedures as a business strategy. Considering the recovery and recycling of materials as well as service and spare parts services. Chapter 3.2 and 3.4 The design could aim to expand the pool of targeted customers. Chapter 3.2 The design could attract customers through emotion. Chapter 2.4 and 3.3

	SHOULD	COULD
Analysis Requirements. **POST USE. Refurbishment.**	B1. The design should allow for several use cycles of the product. Aiming to maintain most components in use for a longer period of time. Chapter 2.2 and 3.2 B2. The design should be optimized for refurbishment. Chapter 3.4 and 3.2 -Facilitate the disassembly and reassembly of components. -Use of refurbishable materials and finishings. B3. The design should be optimized for repair and improve component access compared to the current washing machine. Chapter 3.4 B4. The design should allow the product to remain resource efficient, through updates and/or the replacement of components. Chapter 3.4 -Measurable intensity of use. -New developments. B5. The design should consider the use of recyclable materials and finishings and their recovery. Chapter 2.2	The design could increase the opportunities for a Miele and Bundles collaboration through refurbishment and part replacement. Chapter 3.2 The design could monitor the intensity of use through IoT for repair and refurbishment purposes. Chapter 2.3 and 3.4 The design could reduce material input by facilitating reusing and recycling processes. Chapter 2.2 and 3.4

	SHOULD	COULD
Analysis Requirements. **USE. Communication.**	C1. The design should promote the reduction of the overall environmental impact compared to the current PSS. Specifically the impact derived from the use phase. -Through functions. -Promoting a positive user behaviour. Chapter 2.5 and 3.3 C2. The design should deliver functions and information that improve the customers' washing experience and clothes' caring. Chapter 3.3 C3. The design should promote a positive user behaviour to avoid damages and promote maintenance. Chapter 3.3	The design of the PSS could monitor the user behaviour and use the information to reduce environmental impact of the use phase. Chapter 2.3. And 3.3 The design could monitor the user activities through IoT technologies in order to deliver a better experience. Chapter 2.3 and 3.3 The design could monitor the user behaviour through IoT and use the information to deliver feedback related to maintenance and care of the washing machine. Chapter 2.3 and 3.3 The design could be resilient to misuse. Chapter 2.5

4.2 Focus Areas and design goal

The analysis of the current PSS delivered insights within the different phases of the PSS lifecycle. In order to keep into consideration all of these findings during the following steps of the design process, specifically during ideation, Focus Areas have been created for each phase. The focus areas serve as a structured overview of all findings.

Figure 16 shows an overview of the defined focus areas and explain the rationale behind their selection. The core values, highlighted in blue, mark the guidelines for the focus of the ideation. The values marked in grey are considered to be of second priority and are assumed to eventually become a consequence of the development of the core values. The values in white are of third priority, they provide relevant insights but they may or may not be considered for the for the ideation and development. These last could also be useful for the detailing phase of the selected concept. The values' prioritization is equivalent to the requirements list displayed above.

A detailed overview of the selected values for each phase of the lifecycle of the PSS and an explanation of the rationale behind the selection is shown ahead.

Figure 16. Focus Areas.

PRE-USE PHASE

Personalization (Needs and space)
Personalization was chosen as a core value because it has the potential to add to the perceived value of the PSS over a product based business model in different levels. Through the service, and assuming the product also allows it, the user could purchase a washing PSS that is customized to their washing needs and even to the characteristics of their home. This customization could allow for a closer relationship with the customer and for the product to become part of the customer's identity (Chapters 3.3.1 and 2.1.1).

Personalization could also increase the acceptance of refurbished products since it could maintain the thrill over newness and give the user a sense of control over the decision making (Chapters 2.4.2 and 3.2.4).

The reduction of environmental impact could also be possible through personalization. Starting with the decision of purchase, users could be motivated to buy the right size of machine and even software for their needs. Investing more time to make a more conscious decision, based on fulfilling what they really need. Additionally, the service could provide personalized feedback by tracking customers' behavior (Chapters 3.3.1 and 2.3).

Updatable
Just like the PSS could adapt to the customers initial needs, it could also be of value if the PSS could change together with the consumers' needs and life. This could mean for example, adapting to changes in activities or number of family members making it a unique selling point in comparison with current existing products (Chapters 3.3.1 and 3.3.3).

Aesthetics and Emotional value
Consumers could be attracted to be part of a PSS purely from an emotional point of view. It could be a motivation to be a part of something and become a consumer of sustainable solutions. (E.g. Dopper bottle, Swapfiets). This value also has the potential to increase the acceptance over refurbished products. (Chapters 2.4.1, 2.4.2 and 3.2.4).

USE PHASE

Communication
The use phase has the most environmental impact of the overall livecycle of the PSS. Constant provision of information to the user to improve their washing habits and overall behavior could have a positive effect in the reduction of the environmental impact (Chapters 2.3, 2.5.1 and 3.3.2).

Information could influence the decision making of the customer to make it more reflective and measurable. Better decision making and improved behavior could also have positive effects in the sense of care for the washing machine and better care of the clothes. This could increase the value of the overall user experience and improve Post-use procedures such as refurbishment and repair (Chapters 2.5.3 and 3.3.2).

Research shows that user's are currently highly influenced by direct feedback and word of mouth. Direct feedback could be provided through touch points in the product, while word of mouth could be transformed into a feedback system delivered by the service (Chapter 3.3.2).

Seamless time and effort
Research showed that needing less time and effort for washing defines, for most users, an ideal washing experience. This value could be targeted by the PSS considering the advantage of having a closer relationship with the user and being able to monitor and use data to build said relationship. The PSS could be adapted to the specific needs of a user considering times, schedules and washing needs (Chapters 3.3.1 and 2.1.1).

Enjoyable
A second identified value to improve the washing experience is enjoyable. This value is very well explored in coffee makers for example, through smell. A similar approach could be taken for washing machines. At the same time, the overall perception of washing and washing machines is not very positive. Washing is a chore and washing machines are typically placed in hidden areas. This could be something interesting for the PSS to address. (Chapter 3.3.1).

POST-USE PHASE

Refurbishing
The post use phase of the PSS is defined by the premise of having several use cycles. In order to achieve this, the product has to consider refurbishment from the perspective of the different stakeholders. On one hand, the PSS should guarantee the user will accept refurbished products, personalization is one strategy to achieve this (Chapters 2.4.1, 2.2.2 and 3.2.3).

On the other hand, focusing on refurbishment could also open more opportunities for Bundles and Miele to collaborate in a B2B relationship. Refurbishment could become a new business strategy and result in agreements that include service and replacement parts packages (Chapters 2.2.2, 3.2 and 3.4.1). From Bundles perspective, the PSS should consider reducing costs of repairs and refurbishing procedures by making it easier and faster to access components for replacement and repair (Chapters 3.4.1).

Updatable
Submitting the product to several use cycles could have implications on the resource efficiency of some components. The product should foresee the ease of replacement or update of these components to guarantee resource efficiency throughout time. In order to achieve this, it is also important for the PSS to be able to track and measure the use intensity and performance specifically in critical components.

If new developments become available the product should not be replaced as a whole, it should be updatable and future proof (Chapters 2.2.1 and 3.4.2).

Recycling
Given that Bundles represents an advantage of maintaining control over the ownership of several appliances, the recovery of materials and components becomes a more interesting and affordable possibility for Miele. This will only become true if the volume of appliances increases. The design should, in any case, facilitate the recovery and make use of recyclable materials (Chapters 2.2 and 3.4.5).

As a conclusion of this analysis the Design Goal can be defined as:

-Designing a PSS where the user experience is improved and the environmental impact of washing reduced through communication and personalization; and the product is future proof, optimized for several use cycles and the recovery of materials.-

03

DEVELOPMENT

This part of the report includes a description of the process of development of the concept for a new PSS. It first presents the ideation process and its results in the form of 9 concepts. Second, it presents the selection process of a concept to further develop, which was done through the evaluation of the 9 concepts with the list of requirements and feedback from the stakeholders. It then presents the selected concept combination, and finally, it includes a full description of the final PSS concept and its components.

5. Ideation

This chapter describes the ideation process carried out for this assignment, it describes its different stages and the methods used for each stage. The chapter finalizes with the description of nine resulting concepts, which were submitted for evaluation during the selection process.

5.1 Approach

The ideation process, visualized in figure 17, can be separated into four stages:

Stage 1, Creating the Ideal Washing Experience. During the analysis phase, the importance of understanding the user to provide value through a PSS as opposed to a product based model was highlighted. During stage 1, the three developed personas with their respective user journey maps were used as a base for a first ideation (Images 13 and 14). The priority of this stage was to identify opportunities in each one of the steps of the user journey to increase value. The ideas generated were very focused on the use phase and the three values identified as most important during the personas and workshop exercise; Seamless effort and time, Personalized and Informed (Communication). As a supporting method for this stage, moodboards *(set of images that represent certain characteristics of a value. It is used as a creative tool as a source for references and inspiration)* for each one of the identified values and for circular products were made. Ideas from stage 1 can be found in Appendix I.

Stage 2, Step back, focus areas and morphological charts. The ideas resulted from stage 1 were mostly focused on the user and the use phase, and did not consider the other stakeholders involved in the PSS or many of the other processes from the Pre-use and Post-use phases. Because of this, the ideation process took a step back to reorganize the focus areas of the project.
Based on the Focus Areas (Chapter 4.2), three morphological charts *(ideation method that generates a matrix where the functions or components of a product are listed vertically and the possible solutions horizontally)* (Van Boeijen, 2014) were developed, considering the three core values; Personalization, Communication and Refurbishment. The morphological charts were used to diverge and resulted in a scattered set of ideas for each one of the intended values. More details of the results and derived ideas form this stage can be found in Appendix I.

Stage 3, Design directions or points of interest. From the morphological charts some directions or points of interest could be observed, where more or stronger ideas had been developed. In order to start converging, three points of interest were selected from each morphological chart to continue the combination of ideas and their development.

A) Refurbishment: Access and disassembly. Replacement of parts. Fewer components or lighter configuration.
B) Communication: Automation. Light and color. Graphic data.
C) Personalization: Number of components. Materials and Color. Size and position.

This stage served as a draft for the following development stage. Details of the results of this stage can be found in Appendix I.

Stage 4, Creating the possible concepts. Using the drafts obtained from the previous stage, nine concepts were developed with a higher level of detail, considering the interaction with the user and/or the different processes of the Pre-use and Post-use phases. The concepts are explained with more detail in the following section.

Images 13. Ideation with Personas and User Journey Maps.

Image 14. Ideation session with students.

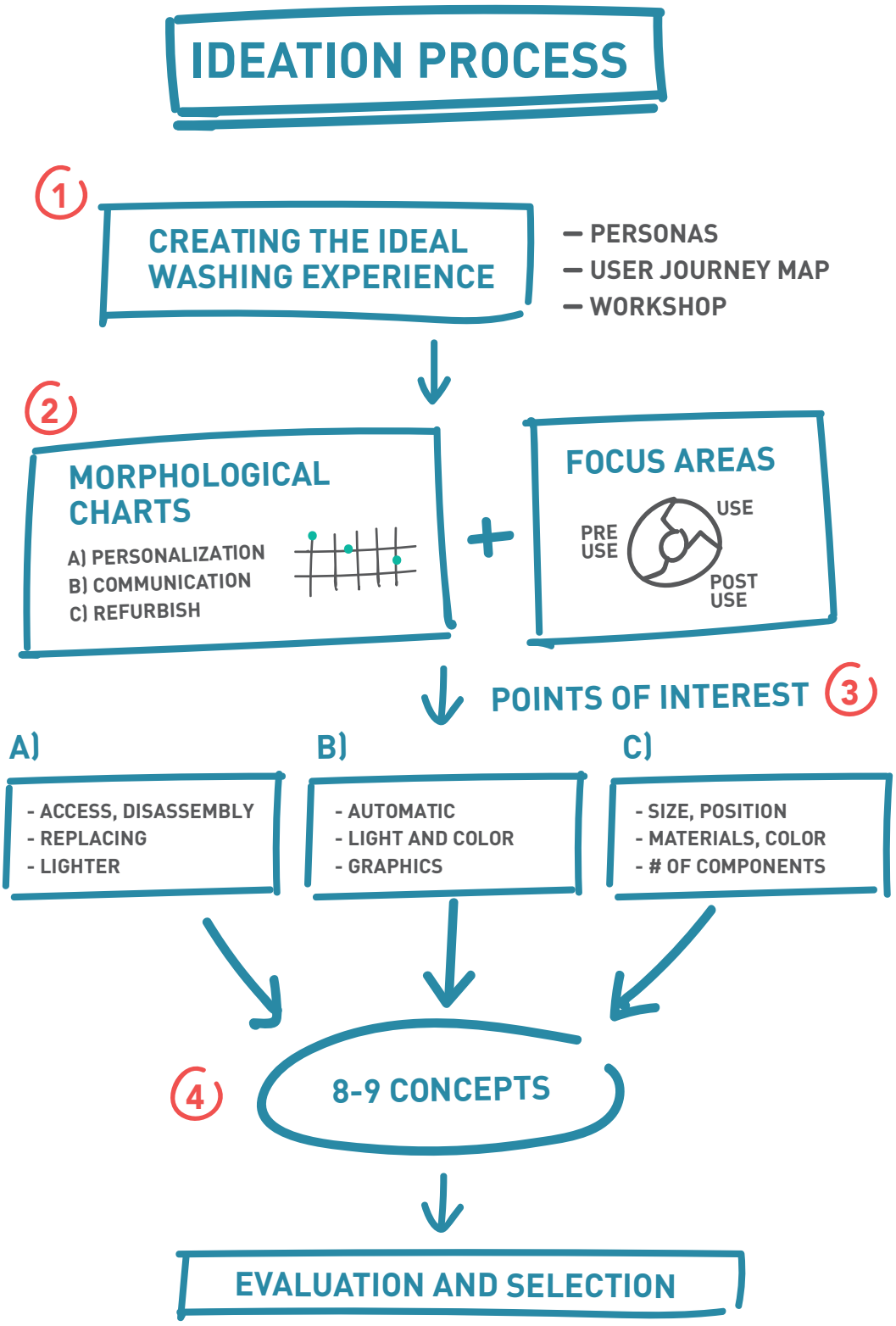
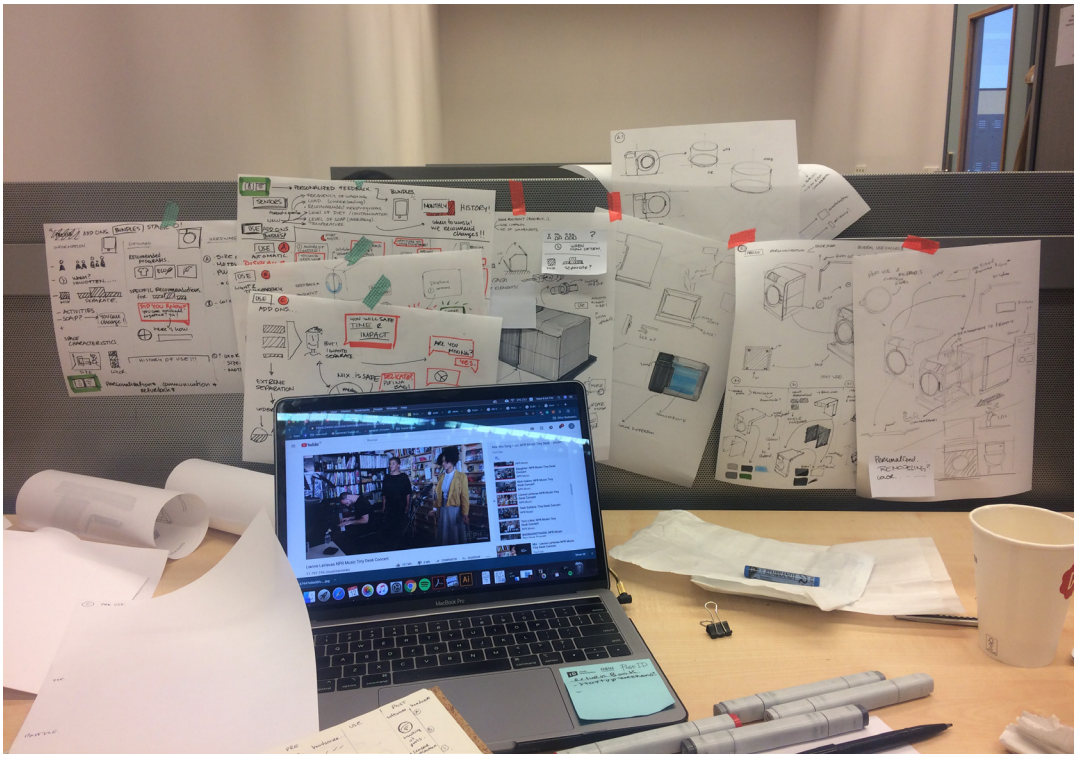


Figure 17. Ideation process.

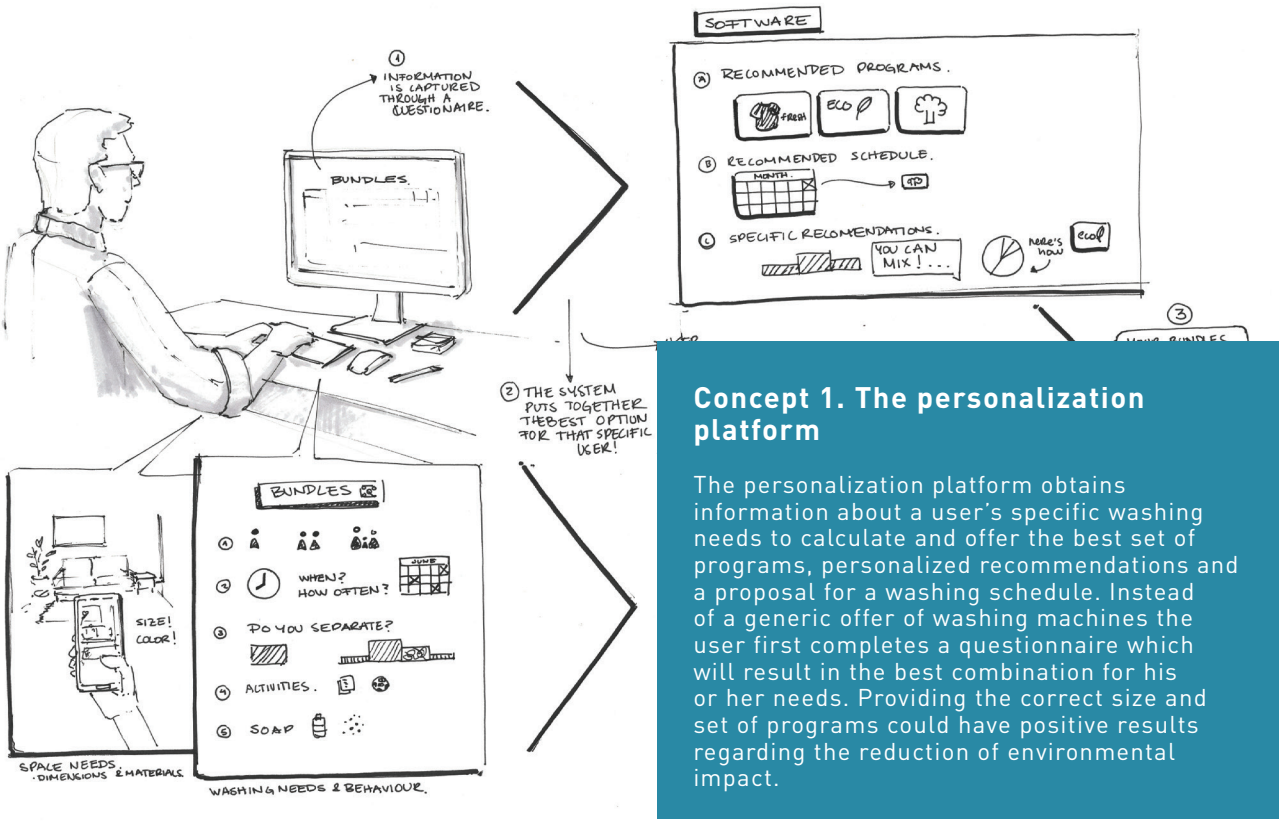
5.2 The possible concepts

Nine possible concepts were the result from the different ideation phases (Figures 18-27). These concepts were developed to a comparable detail level in order for them to be evaluated during the concept selection. Since the ideation process followed the structure defined by the Focus Areas (Chapter 4.2) it is natural to see some of the concepts are more oriented towards a specific phase of the life cycle of the PSS.

In order to develop the concepts, several sketches, paper models and quick 3D printed models were made to visualize and make the proposed functions more tangible for further exploration. The following pages describe each one of the nine resulting concepts.

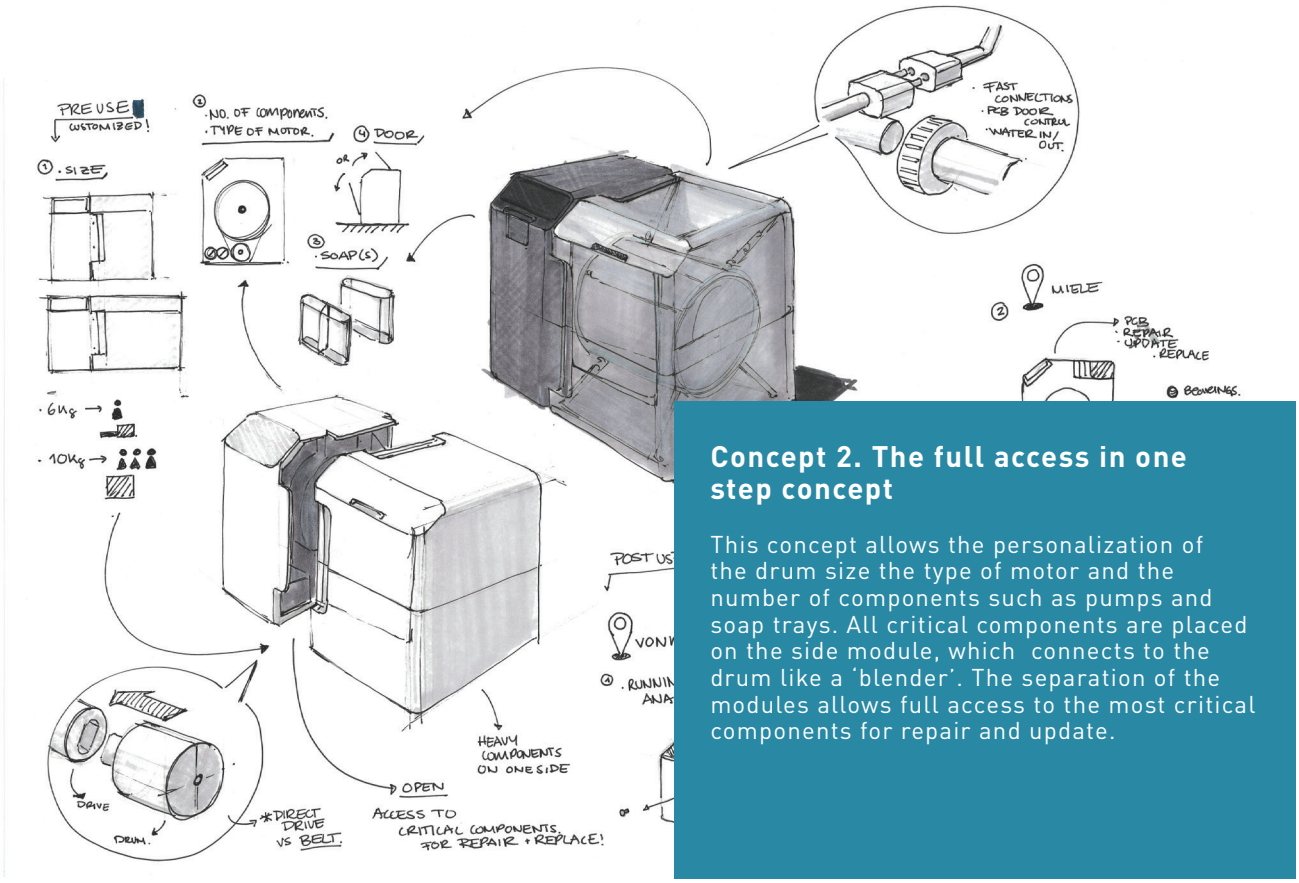


Development of the concepts



Concept 1. The personalization platform

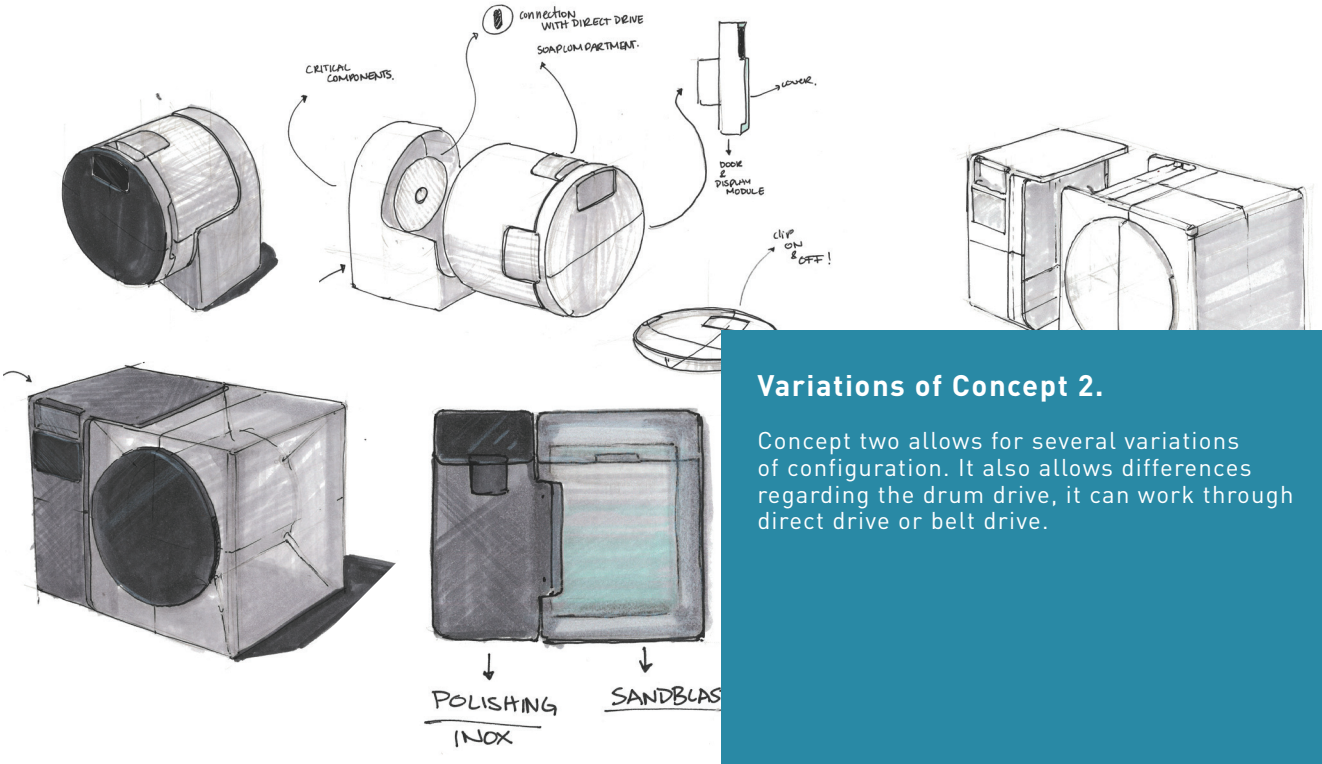
The personalization platform obtains information about a user's specific washing needs to calculate and offer the best set of programs, personalized recommendations and a proposal for a washing schedule. Instead of a generic offer of washing machines the user first completes a questionnaire which will result in the best combination for his or her needs. Providing the correct size and set of programs could have positive results regarding the reduction of environmental impact.



Concept 2. The full access in one step concept

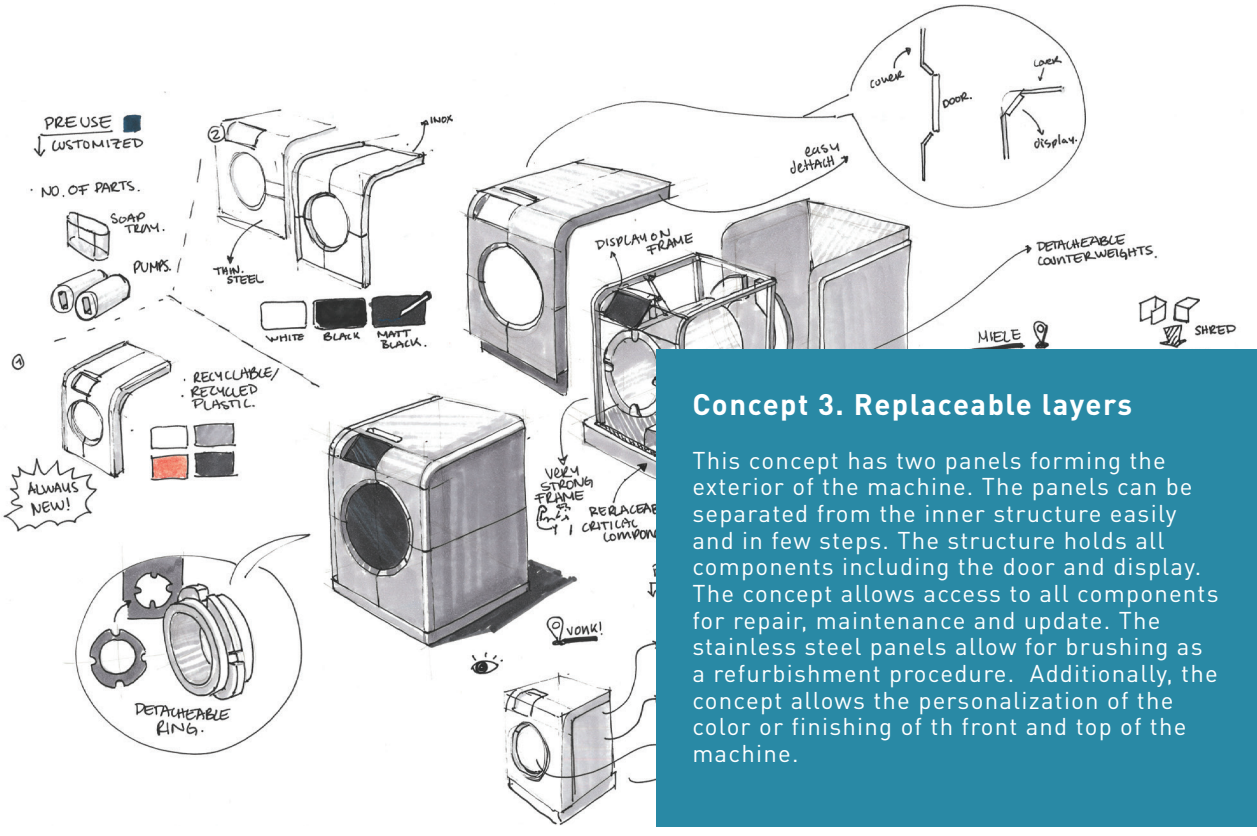
This concept allows the personalization of the drum size the type of motor and the number of components such as pumps and soap trays. All critical components are placed on the side module, which connects to the drum like a 'blender'. The separation of the modules allows full access to the most critical components for repair and update.

Figures 18 and 19.
Concepts 1 and 2



Variations of Concept 2.

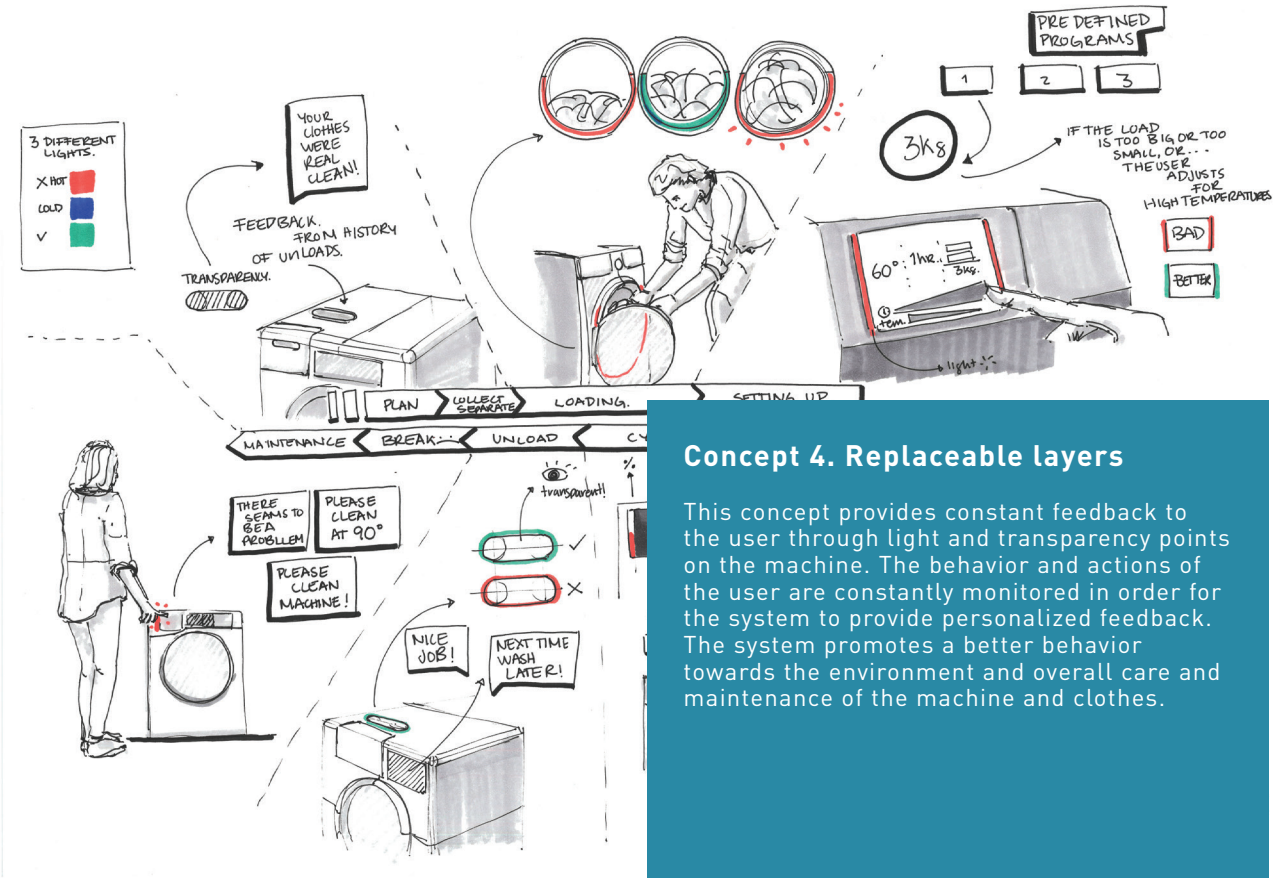
Concept two allows for several variations of configuration. It also allows differences regarding the drum drive, it can work through direct drive or belt drive.



Concept 3. Replaceable layers

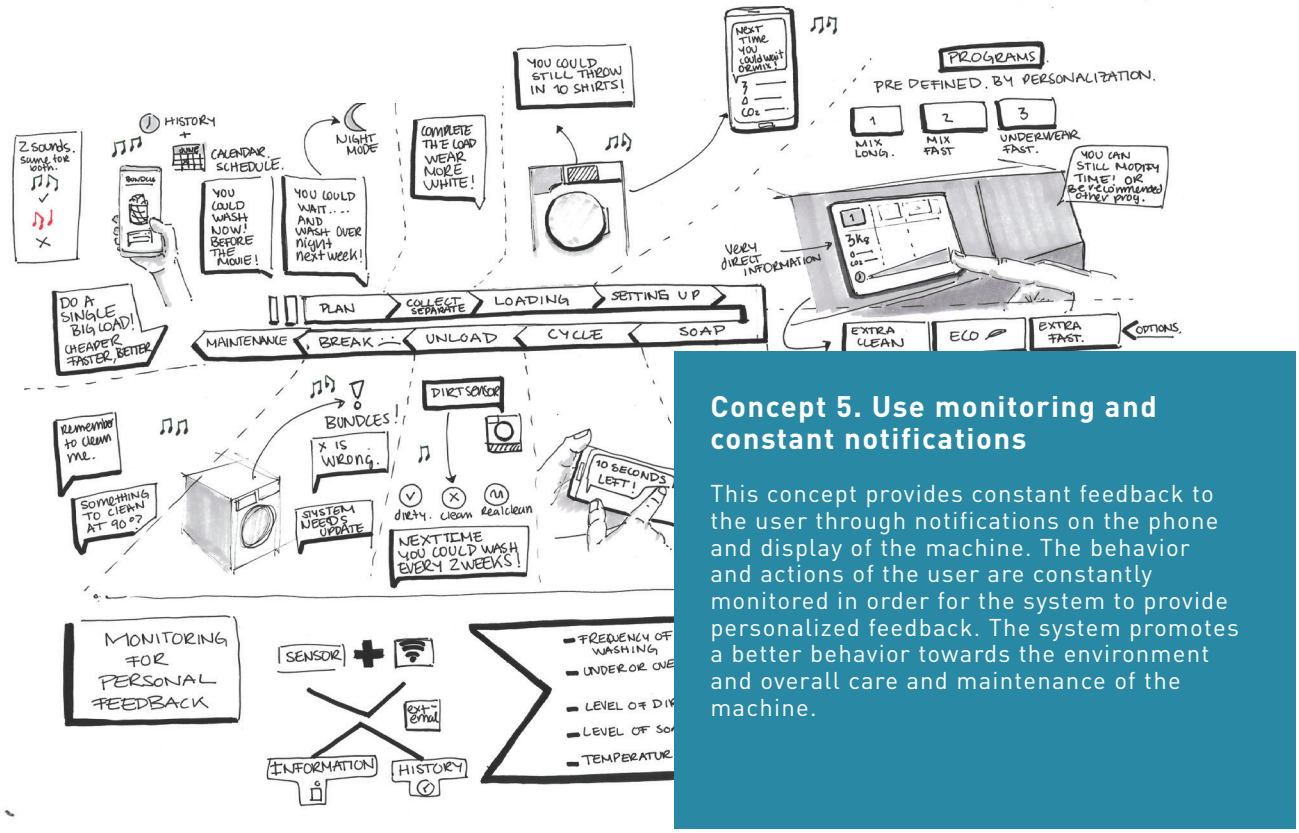
This concept has two panels forming the exterior of the machine. The panels can be separated from the inner structure easily and in few steps. The structure holds all components including the door and display. The concept allows access to all components for repair, maintenance and update. The stainless steel panels allow for brushing as a refurbishment procedure. Additionally, the concept allows the personalization of the color or finishing of th front and top of the machine.

Figures 20 and 21.
Concepts 2 and 3



Concept 4. Replaceable layers

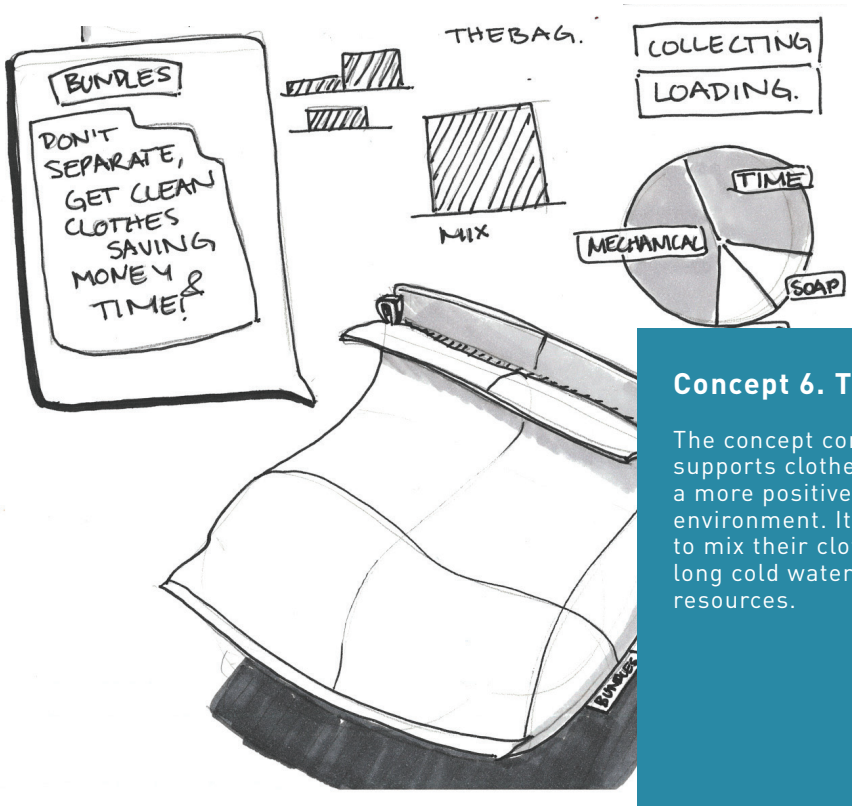
This concept provides constant feedback to the user through light and transparency points on the machine. The behavior and actions of the user are constantly monitored in order for the system to provide personalized feedback. The system promotes a better behavior towards the environment and overall care and maintenance of the machine and clothes.



Concept 5. Use monitoring and constant notifications

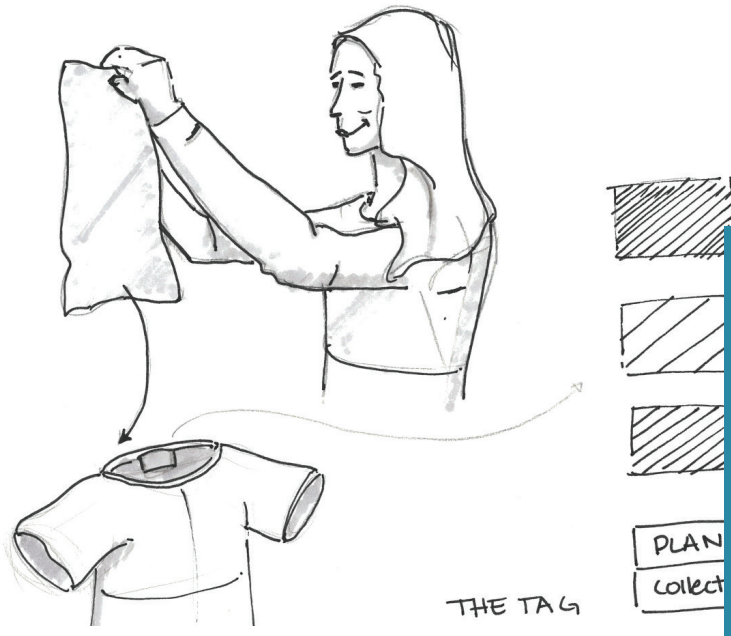
This concept provides constant feedback to the user through notifications on the phone and display of the machine. The behavior and actions of the user are constantly monitored in order for the system to provide personalized feedback. The system promotes a better behavior towards the environment and overall care and maintenance of the machine.

Figures 22 and 23.
Concepts 4 and 5



Concept 6. The bag

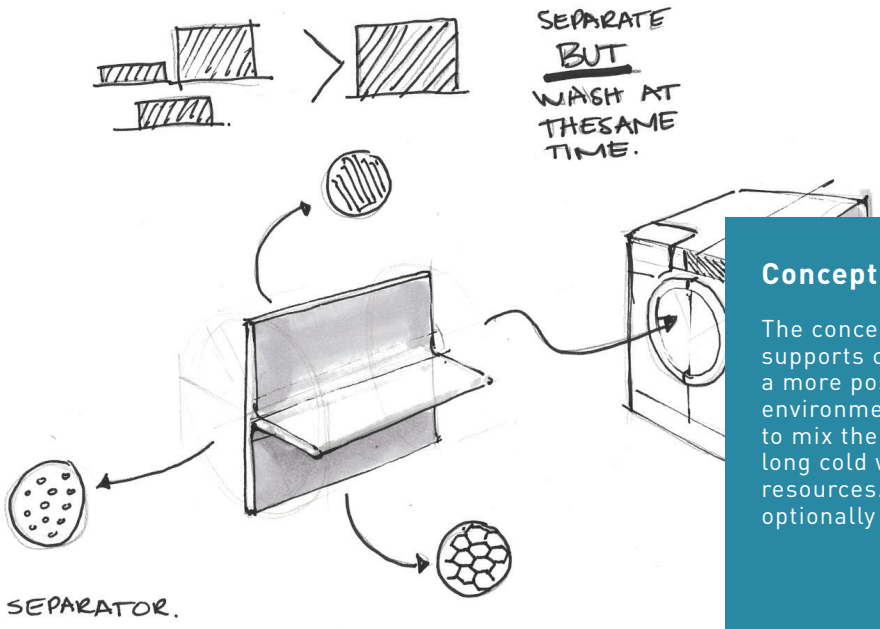
The concept consists on an accessory that supports clothes' care whilst promoting a more positive behavior towards the environment. It allows people to mix their clothes and wash them through long cold water cycles, saving time and resources.



Concept 7. The tag

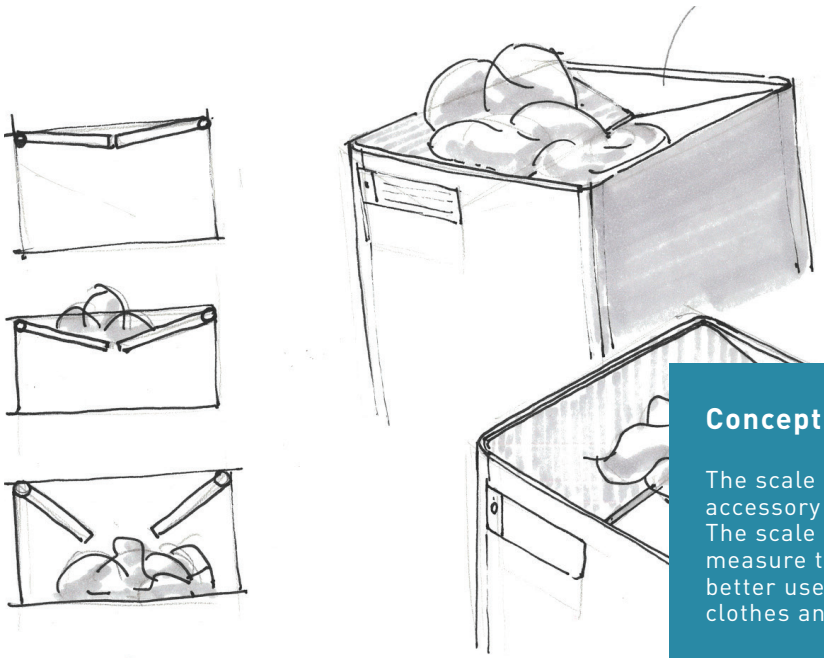
This concept consists on an additional product, a tag. The tag supports the user with visually measurable information when deciding which clothes must be washed. The tag is positioned in the user's clothes and it changes color according to the level of dirt it has. Conscious, measurable decision making that saves time and resources.

Figures 24 and 25. Concepts 6 and 7



Concept 8. The separator

The concept consists on an accessory that supports clothes' care whilst promoting a more positive behavior towards the environment. It allows people to mix their clothes and wash them through long cold water cycles, saving time and resources. The additional accessory is optionally placed inside the drum.



Concept 9.The scale

The scale is meant to be an additional accessory to the current washing machines. The scale allows the users to properly measure the size of a load. It promotes a better user behavior and better care of the clothes and machine.

Fugures 26 and 27 .
Concepts 8 and 9

6. EVALUATION AND CONCEPT SELECTION

This chapter explains the evaluation and selection process of the final concept from the pool of 8 concepts that resulted from the ideation sessions (Chapter 5.2). In order to do the evaluation, several methods were used: feedback sessions with fellow students and an expert, a comparison with the list of requirements using the 'weighted objectives' grading method (Van Boeijen, 2014), and feedback from the involved stakeholders.

6.1 Feedback sessions

Session with students
Feedback sessions with other students (Image 15) were organized to obtain external input and further analyse the eight concepts to support the selection. After the different concepts were presented, the participants were asked to select one concept from the consumer point of view and a second one from the service provider point of view. Preferences from the user point of view were in their majority for Concept 4 (Communication through light and transparency), considering it a strong point for continuous feedback and information that adds value not only to reduce environmental impact but also for the user to take better care of their clothes and machine. As for the service provider point of view, the participants showed preference for concept 1(Personalization platform) and concept 2 and 3 (The two modules and Replaceable covers). The Personalization platform was chosen because it seemed to be the best option to really come closer to the user and fulfil their needs in a more personalized way. Concept 2 and 3 (The two modules and Replaceable covers) were chosen because they represent a more convenient alternative to accelerate and facilitate the refurbishment and update of the product. Concept 3 was also considered to deliver more value to the user through the personalization of materials and/or color, and a good alternative to allow updates of the looks of the machine. The material presented to the students during these sessions is detailed in Appendix J.

Session with expert
Since concepts 2, 3 and 4 (The two modules, Replaceable covers and Communication through light and transparency) seemed to highly interfere with the current product architecture, it was necessary to consult an expert (Bram van der Grinten, Product Architecture, IDE) in order to discuss the feasibility of each concept. Although all concepts appear to be feasible, there are differences between them regarding complexity and potential risks. For example, the 'Two modules' concept would require a very specific and special connection point between the drive and the tub, while the 'Communication through light and transparency' concept could require additional electronic components that are prone to break. The replaceable cover concept seems to be a simple way of approaching the refurbishment together with personalization, however, it needs more exploration towards accessibility of components and potential vibration problems caused by the intention of easing the disassembly of the panels.

Image 15, Evaluation with students.

6.2 Comparison with list of requirements and combination of concepts

Method
In order to have all 8 concepts evaluated equally and in a quantifiable way, the 'Weighted Objectives' grading method (Van Boeijen, A, 2014) was used to compare them against the list of requirements.

As explained earlier, the list of requirements was organized considering the different phases of the PSS lifecycle (Pre-Use, Post-Use and Use). The method allowed to prioritize the requirements of each phase. A total of 100 points was assigned to each phase, which were then unevenly distributed to define the weight of the different requirements in it. A score system was then defined to assign a value in which a concept meets a certain requirement:
0 : The concept does not meet the criteria.
1 : The concept meets or could or meets the criteria to a certain degree.
2 : The concept meets the criteria.

Results
Because the ideation was also done under the Pre-Use, Post-Use and Use organization, it was expected to have some concepts score better in one phase than the others which gave good insights towards which concepts could be combined to complement each other.

The concepts that better met the established requirements (The maximum grade possible being 800 points) were, Concept 4 'Communication through light and transparency' with 649 points and Concept 3 'Replaceable covers' with 592 points. The runner ups were Concept 1 'Personalization Platform' with 587 points, and Concept 5 'Communication through notifications and monitoring' with 577 points (Table 6) (A complete table of the calculations and results of the comparison is available in Appendix M). Although the rest of the concepts are interesting they seem to lack connection with most of the requirements and even fail to respond to the design challenge or original brief.

Original brief:
This project explores the current limitations that the product imposes for the successful implementation of the Product Service combination (or Product Service System, PSS) in order to propose a redesign that enhances it whilst also taking into account circularity and the reduction of environmental impact.

Design challenge:
-Design a PSS where the user experience is improved and the environmental impact of washing reduced through communication and personalization, and where product is future proof, optimized for several use cycles and the recovery of materials.-

A comparison with the list of wishes (the design could...) was also done, using only the 0, 1, 2 scoring system. Concept 3 (Replaceable cover) and Concept 4 (Communication through light and transparency) scored highest in this exercise with 20 and 21 points respectively. The results show the areas where both concepts could meet other identified design opportunities (Table 7) (A complete table of the calculations and results of the comparison is available in Appendix M).

Having eliminated half of the concepts after the evaluations, the two best scored concepts (considering the results from the comparison exercises and feedback provided by students and expert) were further analyzed to understand their strengths and weaknesses and find opportunities for combinations that would complement them (Table 8).

As a result of all the previous analysis, two overall combinations of concepts were created and presented to Bundles and Miele in order to evaluate them and select one for further development (Figures 28 and 29).

Requirements

Concept 1 Platform	Concept 2 Full access	Concept 3 Covers	Concept 4 Light	Concept 5 Notifications	Concept 6 Tag	Concept 7 Bag	Concept 8 Separator
587	478	592	649	577	467	402	402

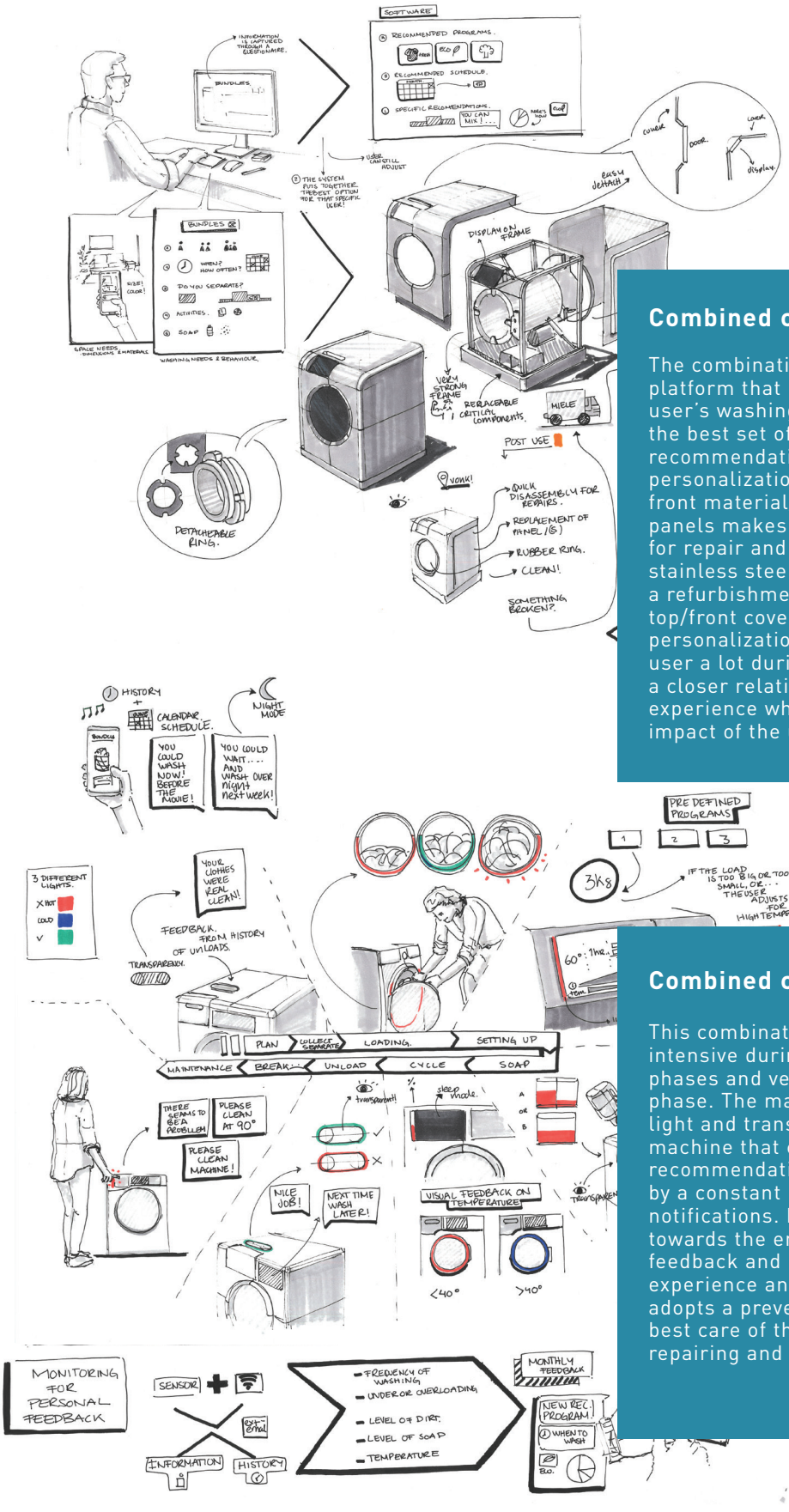
Wishes

Concept 1 Platform	Concept 2 Full access	Concept 3 Covers	Concept 4 Light	Concept 5 Notifications
15	17	20	21	18

Tables 6 and 7. Results from the comparison with the list of requirements and wishes.

	Weakest points	Strongest points	Possible risks	Opportunities
Concept 3	Does not provide opportunities for customization of washing needs. It does not provide enough input during the use phase to: Reduce environmental impact and improve overall experience.	It has a lot of potential to improve refurbishment and repairing procedures, provide more value to customers and create closer relationships with them through personalization.	Users could want to constantly replace the cover. The disassembly proposal could overcomplicate the product architecture and generate problems due to vibration.	There is an opportunity to combine it with Concept 1 in order to add to the personalization value and generate a closer relationship to a service.
Concept 4	The concept does not provide any input to facilitate and optimize the refurbishment or repair of the washing machine and does not truly fulfil the requirement for several use cycles.	The concept provides a very strong feedback touchpoint that promotes a better user behaviour to reduce environmental impact and promote better care for clothes and maintenance of the machine.	The concept could be adding electronic components to the current machine. Components that could be prone to break complicating repair and refurbishment.	There is an opportunity to combine it with the monitoring features of Concept 5 to improve the user experience and take preventive measures towards the post use phase promoting better care of the machine.

Table 8. Comparison of the two concepts.



Combined concept A

The combination of the concepts provides a platform that obtains information about the user's washing needs to calculate and offer the best set of programs and personalized recommendations, together with the personalization of the washing machine front material/color. The configuration of the panels makes access to components easier for repair and part replacement/update. The stainless steel panels allow for brushing as a refurbishment possibility and the thinner top/front cover is highly replaceable allowing personalization. The concept involves the user a lot during the preuse phase creating a closer relationship that delivers a better experience whilst reducing the environmental impact of the use phase.

Combined concept B

This combination of concepts is less intensive during the preuse and post use phases and very intense during the use phase. The machine provides several light and transparent touchpoints on the machine that constantly give feedback and recommendations to the user supported by a constant monitoring of use and phone notifications. It promotes positive behaviour towards the environment, and personalized feedback and information for a better experience and better care of clothes. It adopts a preventive profile to ensure the best care of the machine to avoid excesive repairing and refurbishment costs.

Figures 28 and 29. Combination of concepts A and B

6.2 Concept selection

Combination concept A was selected to be further developed for this project. The combination considers many of the insights found during research related to the creation of value for thePSS, the reduction of environmental impact of the use phase and the implementation of several use cycles of the product. Successfully considering the previously defined core focus areas Personalization (Pre-use), Refurbishment (Post-use) communication (Use phase). On the contrary, combination B, although interesting, focuses too much on Communication (Use phase), only influences the refurbishment (Post-use phase) through prevention and is limited considering the Personalization in the (Pre-use phase).

Bundles and Miele both concluded combination concept A to be a good direction. Miele was positive about having the possibility to always deliver a 'new' looking machine and suggested to offer the personalization of the front panel as well.

Miele also highlighted the importance of the monitoring of the components to optimize and even automate part replacement and refurbishment. Bundles noted that it is useful to focus on the physical parts to consider how the optimization of refurbishment and update procedures could look like, in order to make steps towards circularity.

7. THE FINAL CONCEPT

This chapter introduces the new PSS concept for Bundles. The new PSS proposes a washing service that allows users to personalize their washing machines inside and outside. Allowing them to select a color of their preference for the exterior of the machine. Additionally, the user obtains a personalized 'Washing Package', which includes: a set of programs, number of washes per month (frequency) and set of tips. All three elements are defined by a system that considers the user's specific washing needs with information obtained through a digital platform that can be accessed by a computer or smartphone. The personalization of the Washing Package allows users to take the best care for their clothes without an excessive use of resources (energy and water).

Additionally, the PSS supporting elements and the design of the washing machine, allow it to have several use cycles without losing its aesthetic value, its quality or its resource efficiency. The PSS concept is composed by a new washing machine and a supporting platform and database (figure 30). The processes envisioned for the PSS lifecycle and its components are further explained in this chapter.

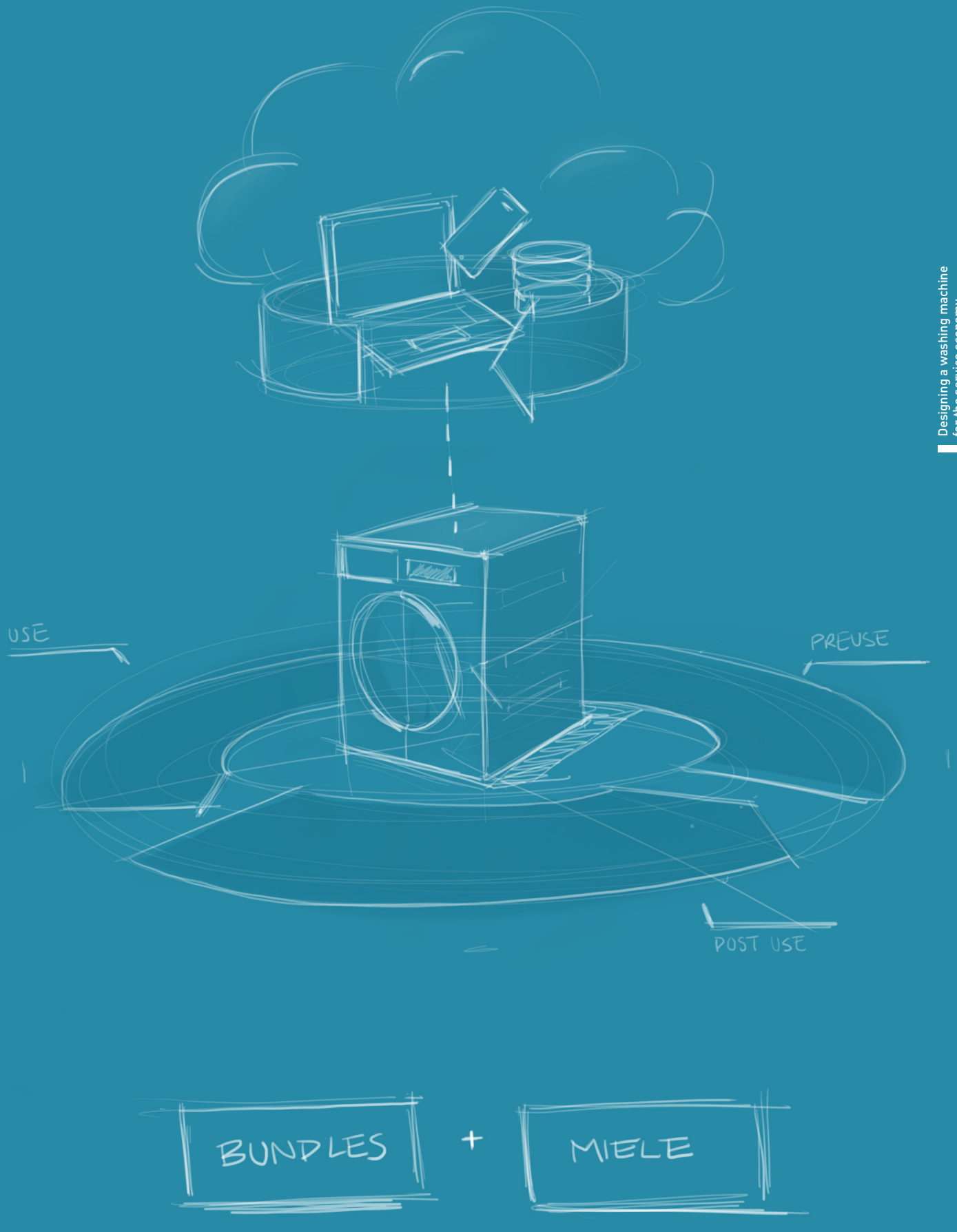


Figure 30. A new PSS for Bundles.

7.1 The Service Blueprint

This section explains in detail the PSS concept lifecycle through a service blueprint (Figure 31) that includes all processes from all stakeholders within the Pre-use, Use and Post-use phases.

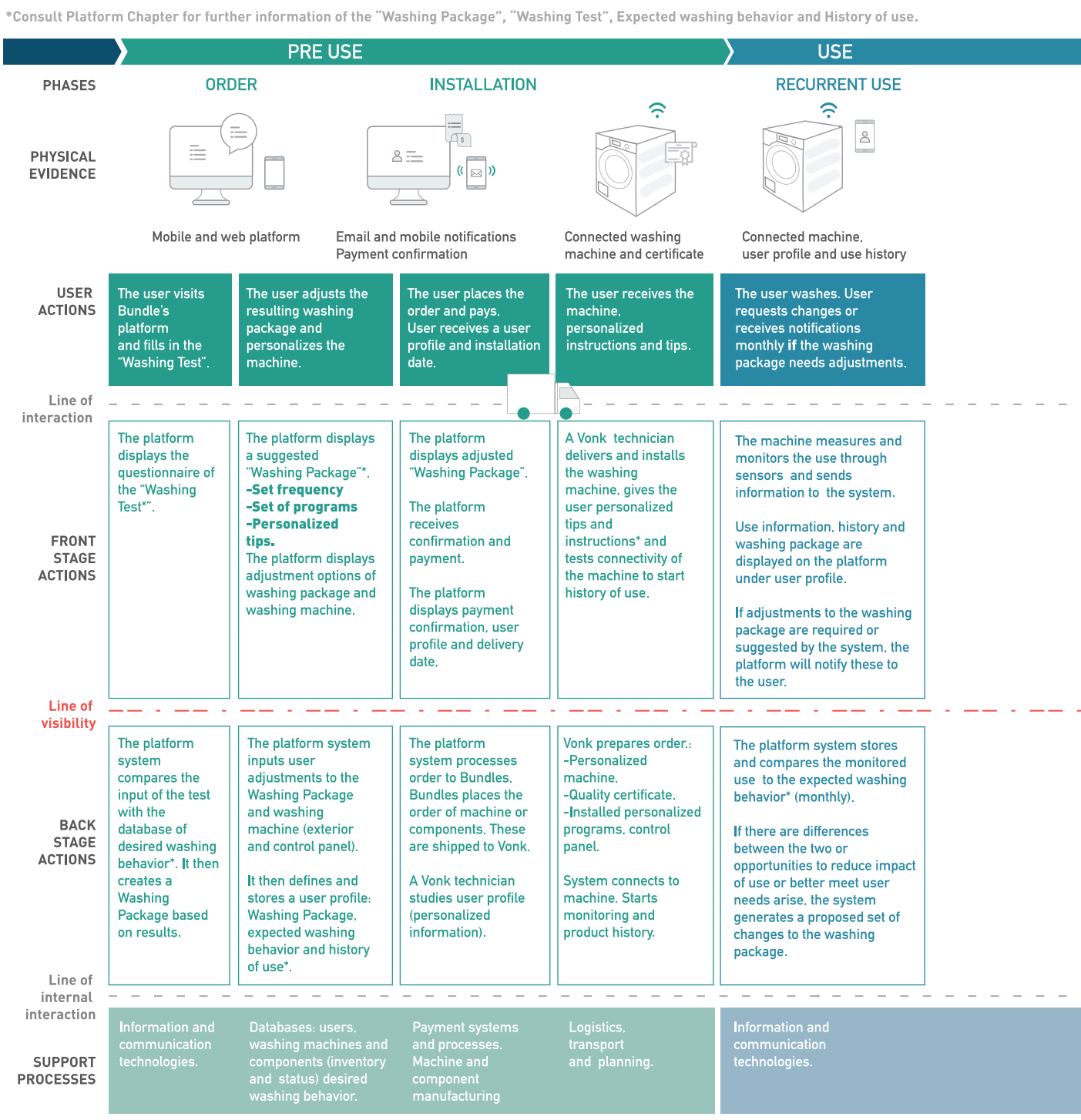


Figure 31. Concept PSS for Bundles. Service Blueprint.

POST USE

+ MONTHLY ADJUSTMENTS

Email and mobile notifications
Payment confirmation

The user agrees (or not) to adjustments and pays monthly for service.	Adjustments can be done monthly. If adjustments are approved by the user these are loaded into the machine. If they are not needed or approved, the system will only notify for monthly pay confirmation.
The platform system stores all changes to the washing package and uses the new information for future comparisons. It also stores information about the machine use history and status*.	Databases: users, washing machines and components, use history, desired washing behavior.

REPAIRS

Repaired machine

The user notifies or gets notification of malfunction.	The platform displays notifications of detected malfunctions or receives a malfunction inquiry. The platform displays a date for the technician to repair the machine.
The stored information about history of use is used by the system to monitor the state of components and predict malfunctions.	Payment systems and processes.

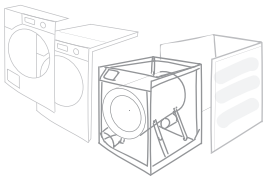
CANCELLATION & PICKUP

Mobile and web platform

The user receives appointment for repair and receives the technician on the set date.	The Miele technician visits the user and repairs the machine. The Miele technician inputs the repairing information and results into the system.
The Miele technician receives the profile of the machine with the history of use, status and possible diagnosis of the malfunction. The system stores all repair information into the machine use history and status.	Information and communication technologies.

The user cancels subscription and receives pickup appointment.	The platform displays cancellation options and inputs the cancellation into the system. It also displays a pick up time notification. The machine is transported back to Vonk facilities.
The system receives and registers the cancellation. The system eliminates the user profile. The system prepares an overview of the machine history and status.	Databases: users, washing machines and components status and use history.

REFURBISHMENT



Vonk technicians first observe and diagnose the machine to define next steps for refurbishment.

Internal: Using the overview of the machine status they check component state and run test program. This overview is also used as reference for repairs and updates.
External: Check for scratches and stains.

A) If everything is ok.

Vonk	Miele Germany
1. Separates thin cover. 2. Cleans machine and control content. 3. Machine is ready for new cover.	1. Covers are sent to Miele to be sandblasted and powder coated to be used again.

B) If there is external damage.

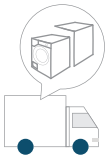
Vonk	Miele Germany
1. Separates all covers. 2. Cleans machine and control content. 3. Replaces stainless steel covers	1. Stainless steel covers are sent to Miele to be brushed to be used again.

C) If there is internal damage.

Vonk	Miele Germany
1. Separates all covers. 2. Cleans machine and control content. 3. Miele NL technician repairs machine.	1. Machine is sent to Miele Germany if components need to be replaced or updated.

Logistics, transport and planning.

RECOVERY



Machines with several use cycles or that can not be repaired or updated are sent to Miele Germany for part and material recovery.

The machine is disassembled.

Material can be recycled and used to manufacture new parts.

Electronic components can be properly disposed.

Recycling processes. Disposal facilities.

Pre-use phase

This phase of the journey requires a high level of involvement from the user during the order, purchase and installation processes. Contrary to the current PSS or product based business models where the user chooses from a fixed selection of products, the new PSS proposes the most suitable combination of product and service to best cover the needs of the user based on information provided by him or her. The user also receives a personalized and intensive advisory session from a Bundles (Vonk) technician at the time of installation where he or she gets information about the use of the Washing Package: programs, frequency and personalized tips about clothes care, reduction of environmental impact and machine maintenance. By involving the user intensively in the Pre-use phase, the PSS can ensure the success of many of the processes of the Use phase. The PSS means to deliver more value to the user (through personalization), a more informed but simplified user experience, reduce the environmental impact of the use phase (by offering the best care for clothes with only the necessary resources) and prevent damages or misuse of the washing machine.

Order.
During the order, the user fills up 'The washing test' through the Bundles platform (mobile or web). The input information, related to the personal washing needs and habits of the user is compared against the best recommended parameters to reduce the environmental impact of the washing process. The result of this comparison creates a personalized washing package which includes a set of programs, a proposed washing frequency and personalized set of tips. The user can adjust the package and, after accepted, the platform generates a User profile and an expected washing behaviour. The washing package determines the monthly price for the service. An example of the potential input and output information of the Washing Test and the Washing Package is presented in Chapter 7.2. During the order the user also selects their preferred color or finishing for the exterior of the washing machine. The selection of color is made from a predefined variety that includes 10 to 12 colors (According to Miele GMN, the production on demand of this particular component could have an impact of up to 125% over the current manufacturing costs of the washing machine, for this reason a fixed selection of a variety of colors is proposed).

After the user places the order, an installation appointment is scheduled. Bundles either orders a new machine or only the 'personalized' panel or other missing components to Miele GMN. Miele then sends all components to Vonk so the final details of the assembly and order preparation can be taken care of, such as: installing the personalized panel and installing the washing package and personalized control panel according to the User profile. Each machine is also linked to their corresponding User profile in the system.

Delivery and installation.
Vonk technicians prepare for the installation process by getting the machines and their corresponding User profiles ready. The User profile becomes a guide for the technician to know what kind of programs, washing tips and processes he or she will be explaining to the user during the installation.

During the installation the user receives personalized information and a demonstration of the washing machine. Additionally, the user gets information related to proper maintenance and care of the machine. The technician also shows the user all components are certified by Miele and confirms the IoT module is working correctly. Once the machine is installed the use of the machine starts to be monitored and data from this monitoring stored.

Use phase

The continuous monitoring of use and possibilities to remotely adapt and modify the washing package through the use of IoT technologies, has the possibility of enhancing the value of the PSS over product based business models by allowing

constant personalization. Additionally, it has the potential to reduce the environmental impact of the use phase by eliminating intuitive and careless use of the machine and resources. It economically motivates the users to limit the frequency of washing to their recommended package and offers them constant tips to make a better use of the washing machine and modify negative washing habits.

Recurrent use and monthly adjustments.
The use of the machine is monitored and the results are compared to the 'expected behaviour' of the user profile. If great differences are identified from the comparison, the system will, every month suggest adjustments to the 'Washing Package'. If a user exceeds the defined frequency this can have considerable differences in price from the cycles originally included in the package to motivate the user to stay within his or her package.

Changes in the user's washing behaviour can include for example, having kids or other situations which can cause overuse or underuse or misuse of the package. The monitoring and adaptation characteristics maintain the personalization features of the PSS throughout the use phase. This can positively influence the extension of subscription times. The monitoring of the components and use through the IoT module also allows for the system to detect any malfunctions and even diagnose remotely to accelerate and optimize repair and service times. The user receives a notification every month only if changes are detected to be necessary. The user can then agree or discard the new changes. The user also pays monthly, if changes are made, adjustments to the monthly subscription will apply.

Updates and adjustments can also be suggested by the user through the Bundles platform (mobile or web). All changes to the number of programs, frequency and control panel can be done remotely. Requested changes of exterior will have an additional cost to avoid the user from requesting constant physical changes in the machine. An example of the changes that could be done to the Washing Package can be seen in Chapter 7.2.

Repair and Maintenance.
Necessary repairs can either be identified by the user or automatically identified or predicted by the system with the use of the information obtained through the monitoring of the machine. Bundles will be informed by the system or by the user (through the platform or call service) of the problems. The system will then attempt to do an initial diagnosis to deliver information about the machine and component status to the technician for him or her to prepare accordingly. Depending on the severity of the problem the repair will take place in the house of the user or a new machine will be installed.

The user is expected to perform maintenance to the machine as prescribed by the recommendations given to him or her in the washing package and during the installation. The personalization of the machine also has the intention of augmenting the sense of ownership and care for the machine.

Cancellation.
The user can cancel their subscription in the Bundles platform. The system will notify Bundles and will schedule a pick up meeting time.

Post-use phase

This phase of the PSS is supported by a product that allows the implementation of several use cycles. The product is designed to optimize and allow processes like repairs, updates and part replacement. It allows the access and replacement of components that deteriorate faster, as well as the use of materials that allow continuous loops of refurbishment. It also allows the possibility of updating the looks of the washing machine through a component the user can personalize, and is easily replaceable by Vonk, augmenting the possibilities of user acceptance over refurbished products and PSS. The product maintains the recyclable characteristics of the machine from the current PSS. A detailed explanation of the design of the

product can be found in Chapter 7.3.

Pick up
After the user cancels the subscription Vonk picks up the washing machine and returns it to their facilities, where it is registered in the inventory.

Refurbish
The first step for the refurbishment of the washing machine is the diagnosis step done by Vonk technicians, where the machine is observed and tested to find internal and external damages or malfunctions. This is done using the Product profile as a guide, which includes the monitoring of use history and the present state of the components. Once this diagnosis is done there are several options to follow according to what Vonk determines.

a) Everything is in good condition (internal and external). If the washing machine works properly and there are no visible scratches on the stainless steel the following steps for refurbishment will all be done at Vonk facilities. The processes include 1. The separation of the personalized panel (which is then sent back to Miele Germany for recycling or refurbishment). 2. Cleaning the washing machine with the 90C program as well as its exterior and eliminating the control panel and washing package software as well as previous users information. A new personalized cover is placed on the machine by Vonk technicians and is ready to be installed in a new home.

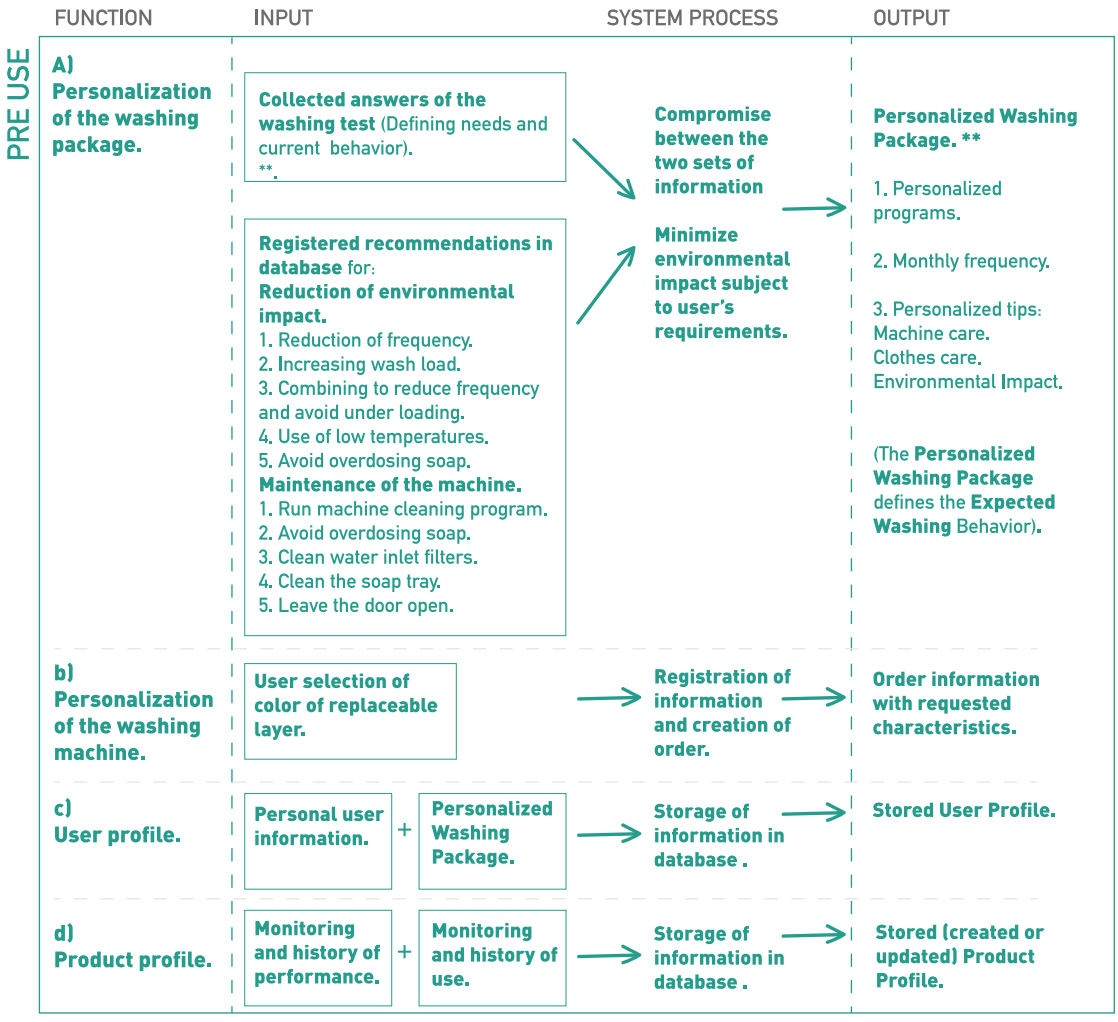
b) External damage (stains or scratches on stainless steel panels or other components). If there are visible damages on the stainless steel surfaces or stains on the rubber ring the refurbishment procedures will be done in Vonk and Miele Germany. The proposed steps are 1. The disassembly of all panels. 2. The stainless steel panels are then replaced for new (or refurbished) ones. The damaged panels are sent to Miele to be brushed or sandblasted to be ready to be used again. 3. Cleaning the washing machine with the 90C program as well as its exterior and eliminating the control panel and washing package software as well as previous users information. A new personalized cover is placed on the machine by Vonk technicians and is ready to be installed in a new home.

c) Internal damage. Depending on the complexity of the malfunction the repair or part replacement will be done by a Miele technician at Vink or the machine will be sent to Miele Germany for the procedure. In any case, steps like cleaning and disassembly of panels is similar to the explained above. A big difference to note on the internal damage procedure is the use of the Product profile as support material to make a diagnosis that can be shared in advance with Miele for the technical team to be prepared and the process can be optimized.

Recovery
If the washing machine (or parts of it) are no longer refurbishable, they are transported to Miele Germany where they can be disassembled and either recycled (upcycled) into new parts or components such as stainless steel components (E.g. outer drum, panels), reused after other processes of refurbishment and repair, or responsibly disposed in the case of displays and Printed Circuit Boards for example.

7.2 The platform

The platform, as mentioned above, supports different processes of the PSS. The proposed functions aim to generate a closer relationship with the user to enhance the perceived value, support the reduction of the environmental impact of the use phase and maintain control over the status of the washing machine and its components. Figure 32 and 33 illustrate the proposed functions of the platform and the processes needed to deliver the expected outputs. The functions are organized and illustrated in the Pre-use, Use, Post-use structure in order to make them easy to identify in the previously shown Service Blueprint. The functions refer to the actions the platform is expected to complete, while the input refers to the information clusters or packages that are then processed by the system's algorithm. These packages of information can be obtained from the user input or data obtained from the monitoring of the machine, a well as information previously defined from research or other sources and stored in the database. Finally, the output refers to the results or information obtained from the processing of the input.



**See example of questions, Washing Package and suggestions in the platform example.

Figure 32. Proposed functions, processes and outputs for the PSS platform.

The variables from the information packages "Registered recommendations for the reduction of environmental impact", "Registered recommendations for the maintenance of the machine" and "Monitoring of use" (from functions a) Personalization of the Washing Package and e) Use monitoring and adaptation of the Washing Packages) were defined by the insights identified from the literature research and user interviews.

An example of what the platform could display to the user is shown below in order to illustrate some of the proposed functions (figure 35-39). The example shows two scenarios, one for the Pre-use phase and one for the Use phase. For the Pre-use phase, it shows the completion of the Washing Test and the resulting Washing Package. For the Use phase, it shows an example of monthly notifications where changes in the Washing Package and new tips are suggested. In order to define this example, one of the previously created Personas (Chapter 3.3.1) is used (figure 34).

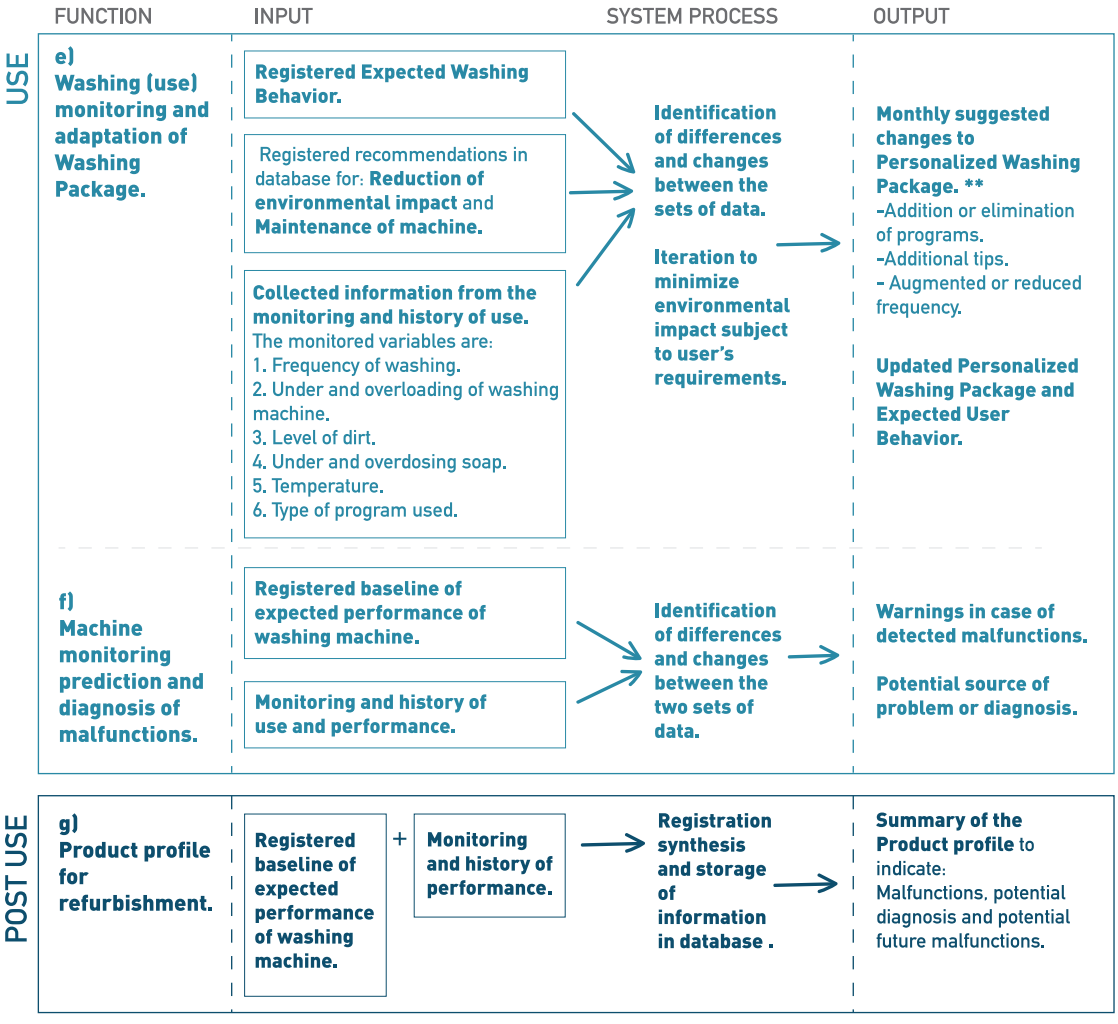


Figure 33. Proposed functions, processes and outputs for the PSS platform.

**See example of questions, Washing Package and suggestions in the platform example.

PERSONA 3

Young couple

Small 1 bedroom studio.

User characteristics

-They do not separate their clothes.
-They do a lot of sports and outdoor activities.
-They have weekly urgencies of washing their sports clothes.
-They are very busy and social. Both of them are PhD's.
-They are disorganized and careless.

Future changes

-She goes on a 6 month research trip.

Figure 34. Persona used for example of platform.

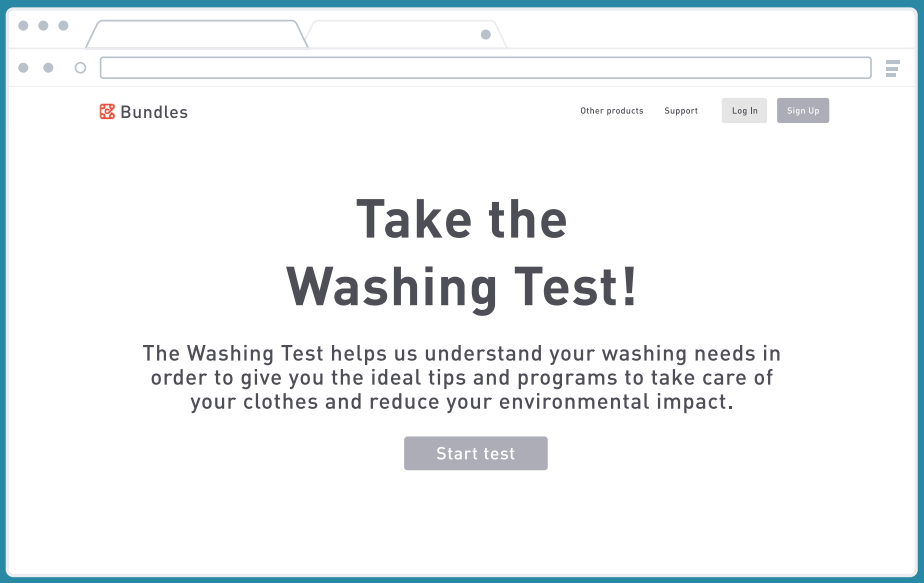
PRE-USE PHASE PLATFORM EXAMPLE

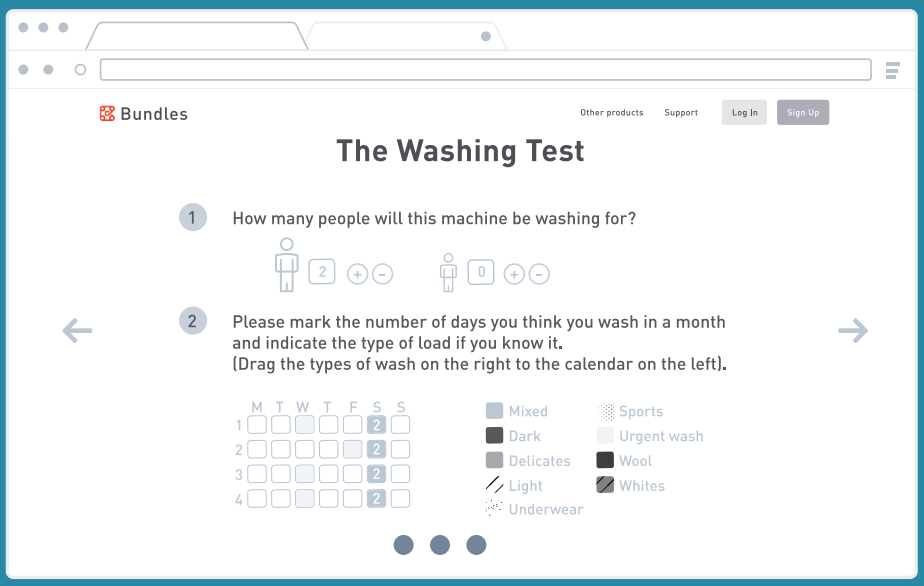
Persona 3
Young Couple

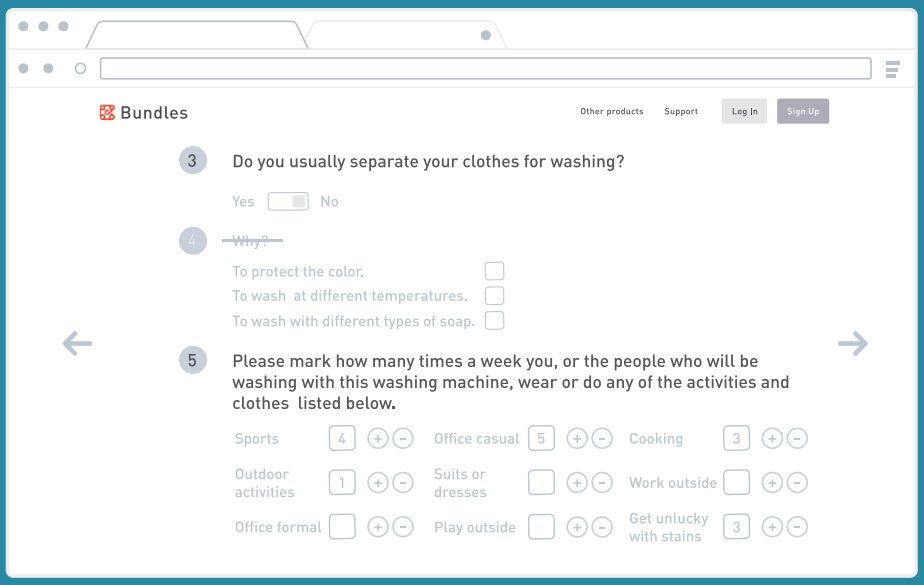
1 Start Screen

2 Washing Test questions

3 Washing Test questions



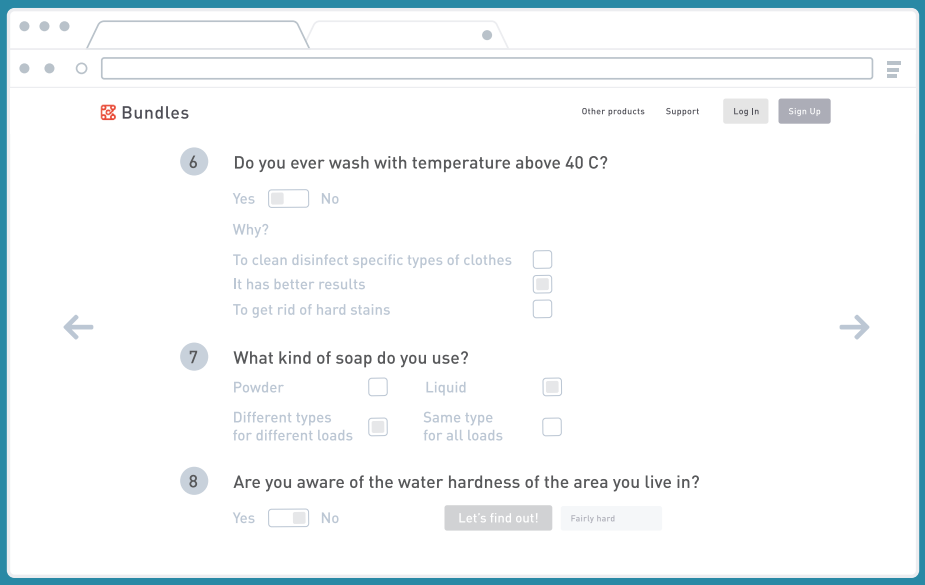


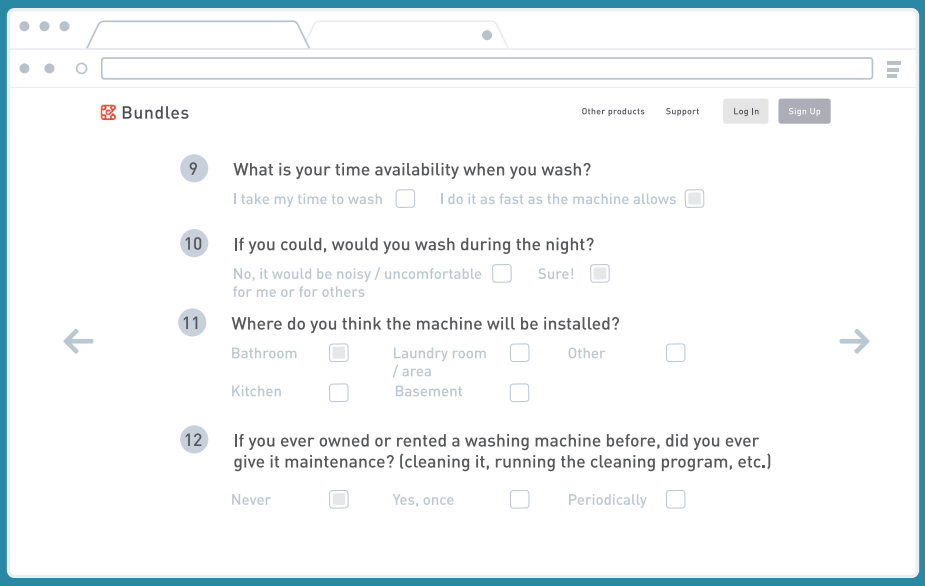


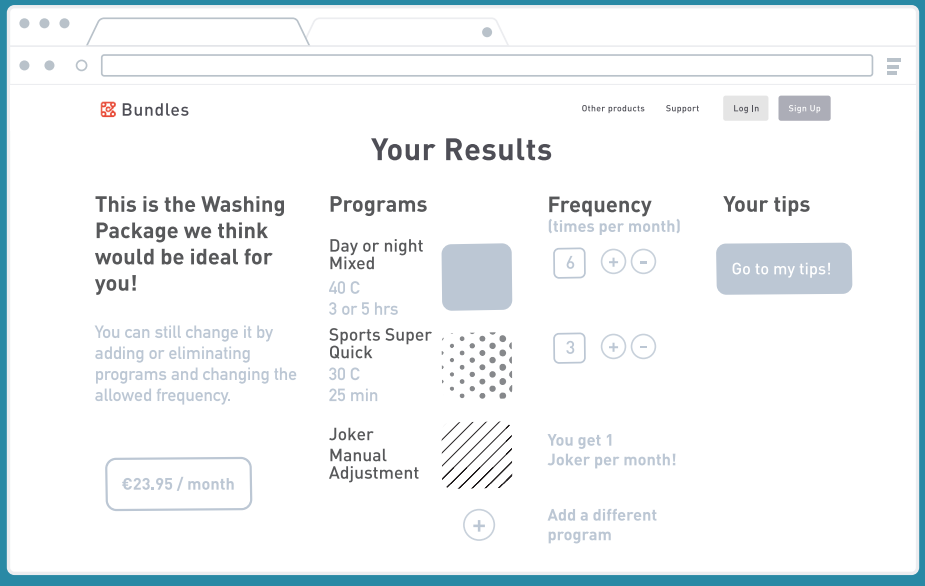
4 Washing Test questions

5 Washing Test questions

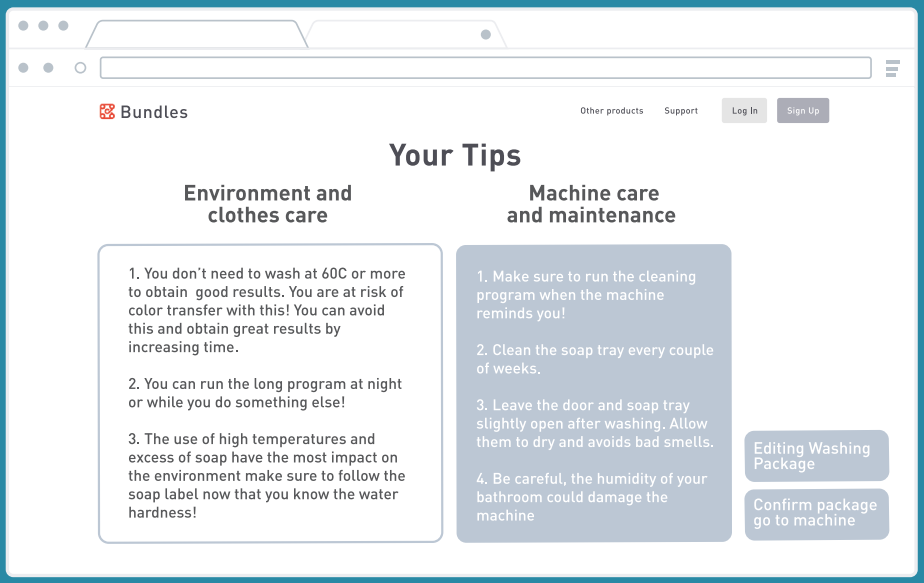
6 Suggested Washing Package



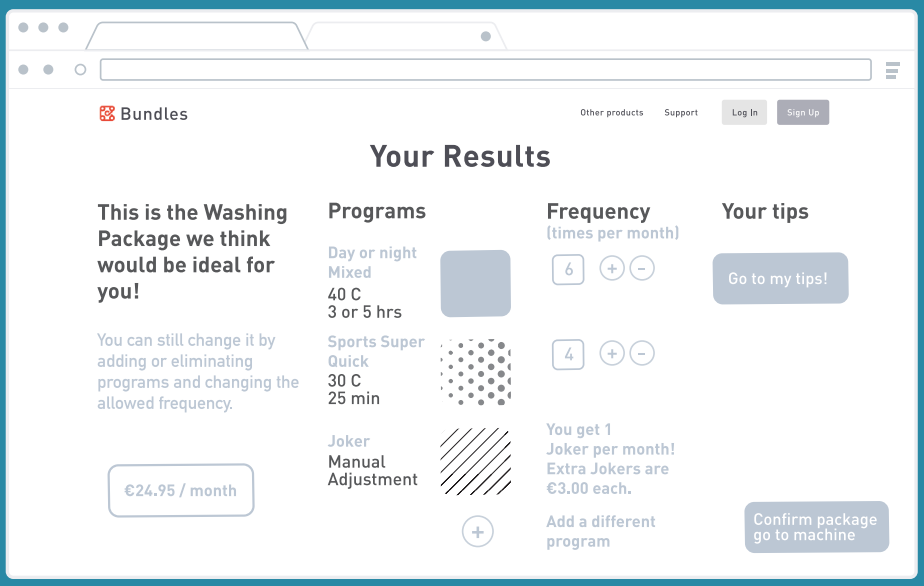




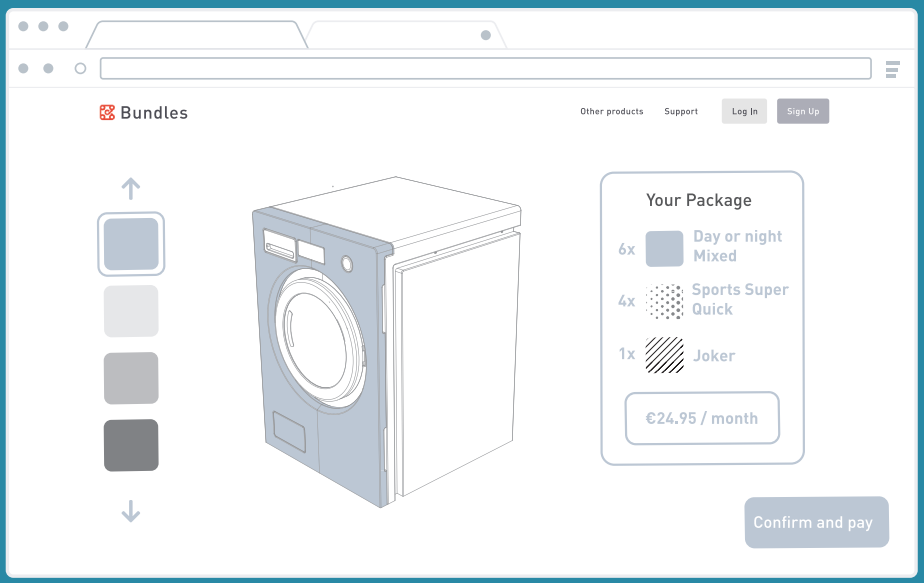
7 Personalized Tips



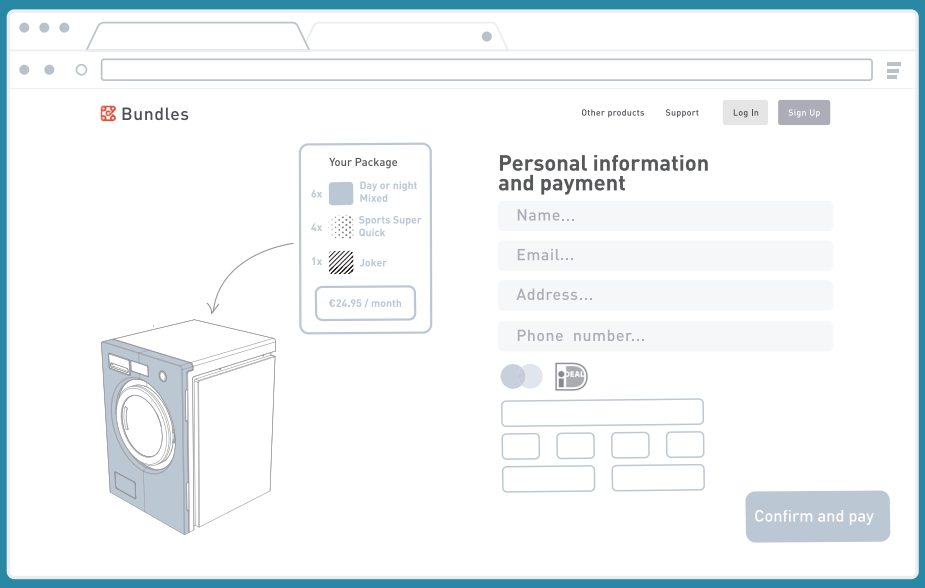
8 User adjusts Washing Package



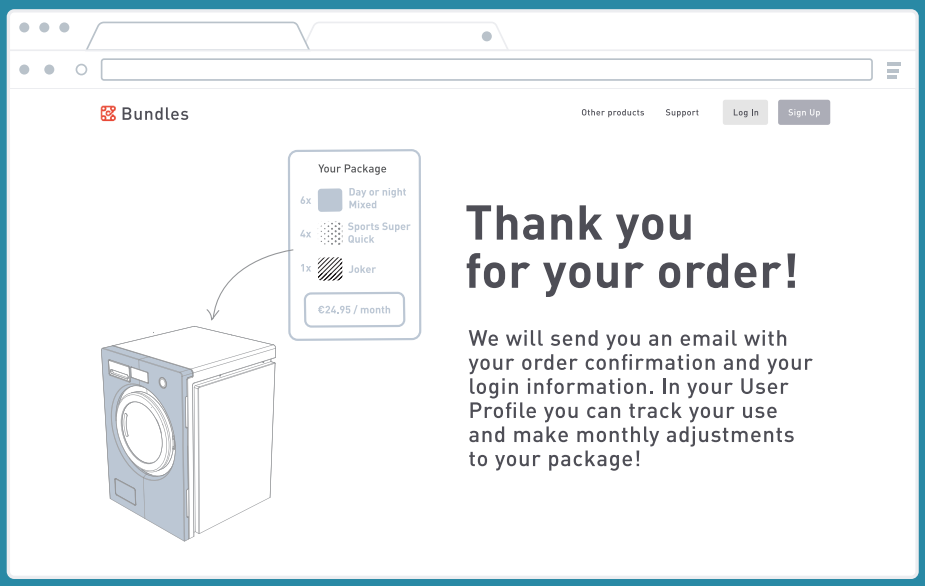
9 User personalizes washing machine



10 Personal and payment information

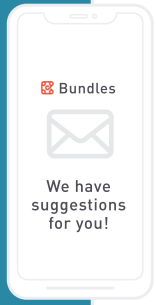


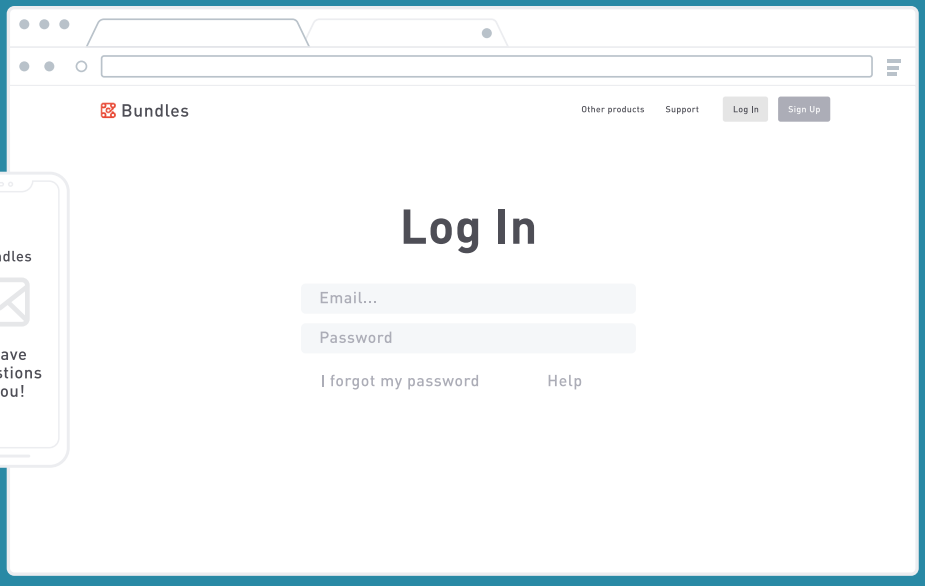
11 Order confirmation



USE- PHASE PLATFORM EXAMPLE

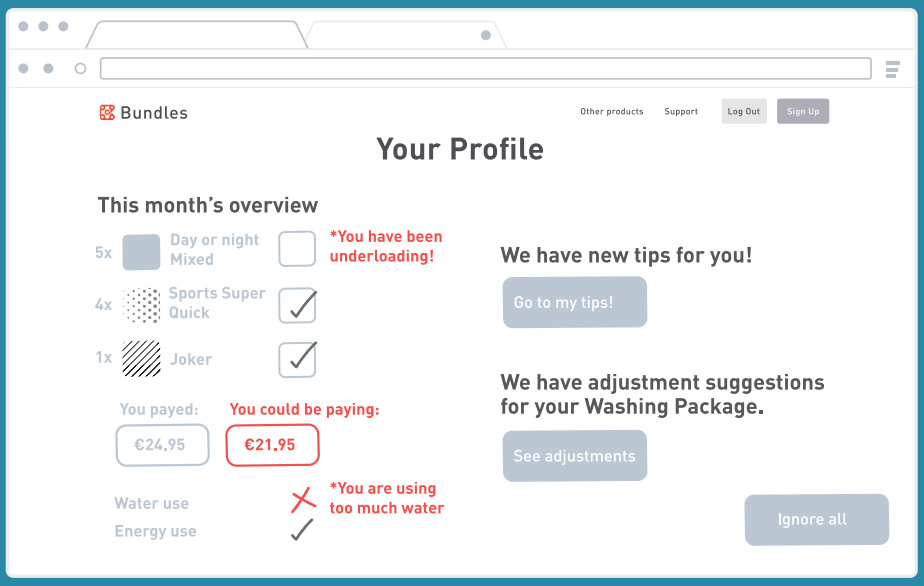
Persona 3 Young Couple



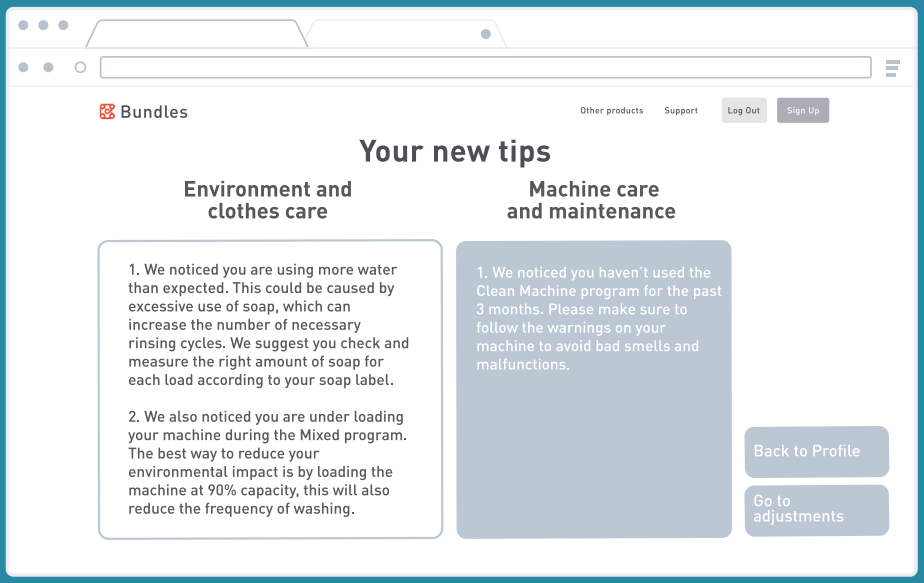


1 Notification and Log In

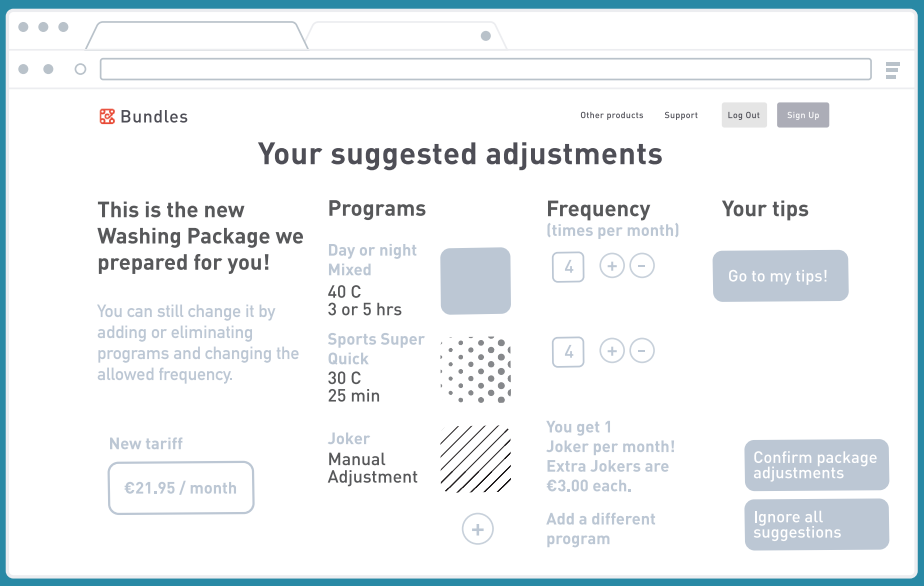
2 User profile and proposed adjustments



3 New generated tips for the user



4 Profile with adjustments



This example includes samples of what the Washing Test questions can be, the questions were formulated considering the influencing factors on the user behaviour and washing needs identified during field research and user interviews (Chapters 3.3.1 and 3.3.2). It then includes an example of what the resulting Washing Package could be including examples of personalized programs, frequency and tips. The tips were created based on the information obtained from the care and maintenance of the washing machine manual and recommendations for the reduction of the environmental impact of washing (Chapter 2.5.1 and 3.3.1). These examples are just an estimation of what the result would look like, the method for the processing of the input information is not considered. The development of an algorithm that can combine and apply all the proposed processes of information (figures 32 and 33) has to be further studied and explored in order to define the number of variables that will be considered when calculating the personalization of the Washing Package. Further research is also necessary to define the amount of possible results from the test, to explore the creation of a number of pre established profiles in order to standardize and simplify decision making in the system.

Figures 35-39. Example of platform functions for the Pre-use phase and Use phase.

7.3 The product - A new washing machine for Bundles' PSS.

The new concept washing machine is designed to meet and complement all proposed processes of the PSS, throughout all of its phases. The proposed product functions are described in detail below. The new concept is designed to allow the machine to have several use cycles without losing its aesthetic value, its quality or its resource efficiency.

The construction of the product maintains the internal components, dimensions and inner distribution of a domestic Miele machine (Figure 40). The model WCE770 TDos Wifi can be taken as a reference, which has already an integrated Wifi module and a capacity of 8kg (model available from Bundles offer). The new machine however, does not include the Twindos system (automatic soap dosing system) because it has proven to cause malfunctions due to cloggings caused by misuse or lack of use (See Appendix B). A manual soap dosing is then proposed for the new machine.

Figure 40. Concept washing machine dimensions.

Personalization

The machine is designed to be personalized by the user. The possibilities for personalization include the color of the front panel and the control panel.
In order to personalize the front panel, the machine counts with a replaceable thin steel layer fit fixed to the top/front panel (figure 41). During the order, the user has a selection of 10 to 12 colors, figure 42 shows examples of the machine with different replaceable layer colors. The selection of colors is fixed to a variety of 10 or 12 in order to avoid the high costs an "on-demand" selection could have over the manufacturing of the washing machine.
The personalization of the panel has the intention of increasing the perceived value for the washing machine and deliver the thrill of newness to the user regardless of the machine being a refurbished product.
The panel counts with a fixed fit generated by the same stamping process from which it is produced. The fixed fit allows Bundles to easily replace the panels during the refurbishment process without needing to access the inner components of the machine and without the need for a Miele professional technician (figure 43).
Additionally, the panel counts with side marks and enough space to be manually pulled out (figure 44). The panels are powder coated, a resistant finishing that once a use cycle is over allows for the panel to be sandblasted and coated once more, making them reusable and refurbishable. Finally, the personalized washing package and the adaptions made to it, are transferred to the machine thanks to the internet module.

Figure 41 and 43. Replaceable layer and fixed fit.

Figure 42. Examples of the machine in different colors

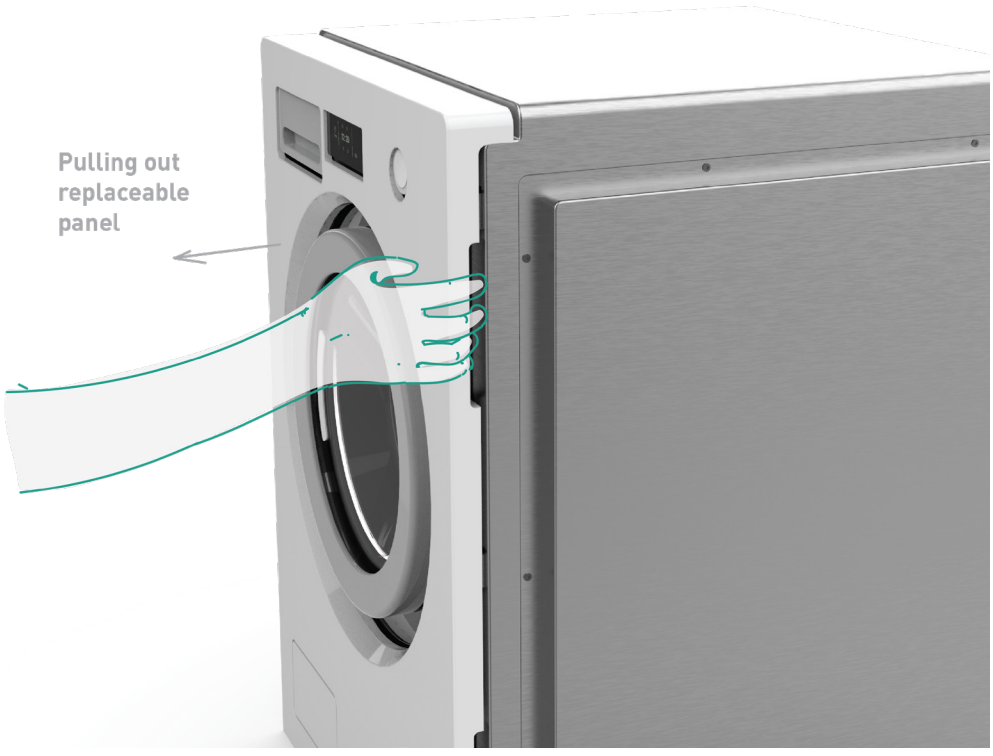


Figure 44. Marks for hands on the side of the replaceable panel.

Access and repairability

The machine is designed to improve access to the previously identified priority components (Chapter 3.4) in order to reduce repair times considering that most of the repairing costs for Bundles are defined by service hours from the professional Miele technicians. The current machine is highly integrated and uses the side panels of the machine as part of the structure and fixed to the base, limiting mobility and visibility when performing repairs to some of the components (See Chapter 8.3). Additionally, components like the door, rubber ring and display, are fixed to the exterior of the machine on the front panel, increasing the number of components that need to be removed in order to access some internal components. The new configuration aims to reduce the number of steps to access components and/or improve the visibility and mobility when doing repairs.

The new machine counts with an inner steel structure that is independent from the panels (figure 45 and 46). The structure also holds the door and display making them completely independent from the disassembly of the panels. The configuration of the door is similar to those of professional machines, where the door moves together with the drum and is no longer fixed to the front panel (figure 47).

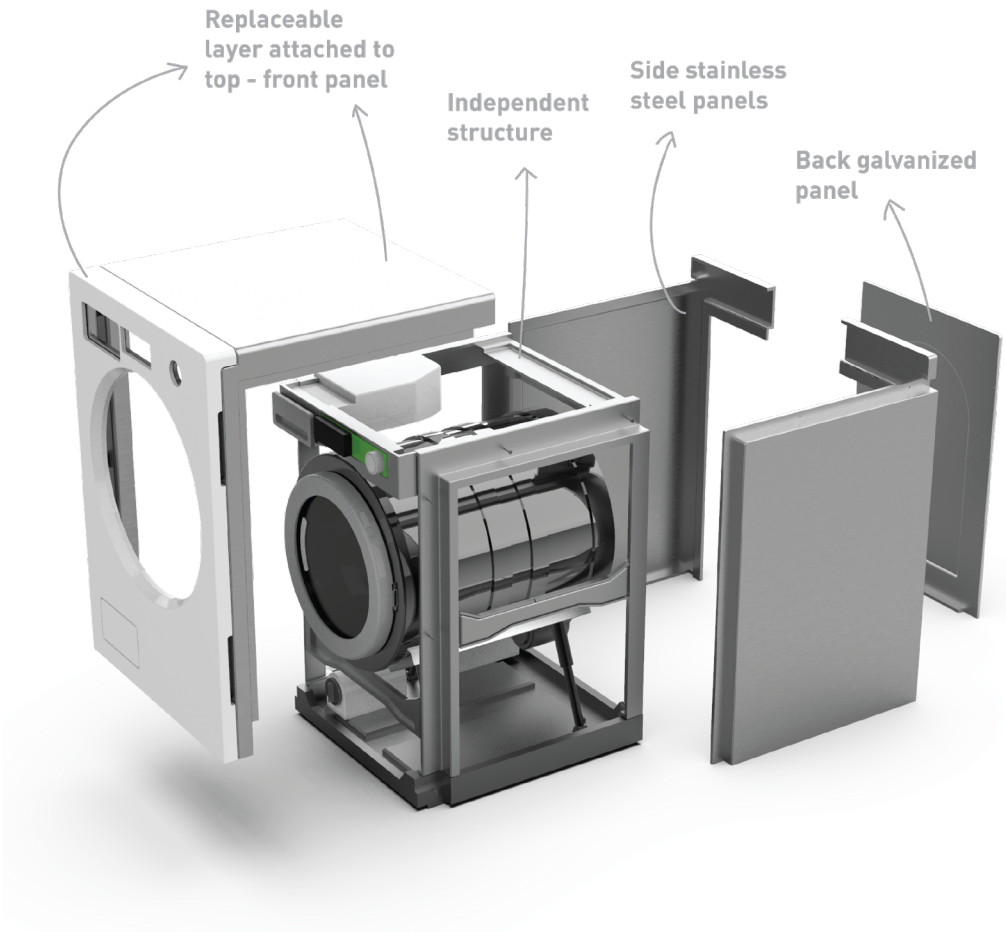


Figure 45. Disassembly of the machine panels.

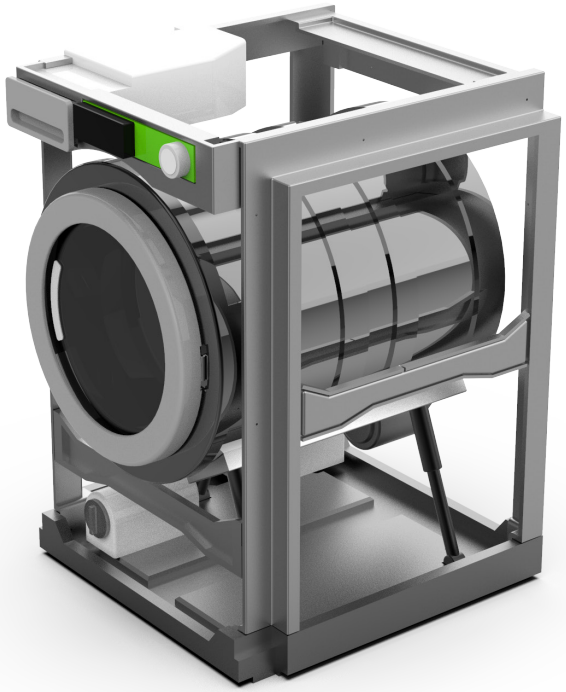


Figure 46. Structure is independent from panels and holds the display and door.

Figure 47. Attachment of the door to the front section of the drum. Independent form the exterior panels.

The machine counts with stamped, brushed stainless steel sides, front and top panels and a stamped, galvanized steel back panel and base (maintaining the current processes for these components). The machine is designed to provide different possibilities to disassemble the exterior panels depending on the available space for repairs and the part that needs to be accessed (figures 48, 49 and 50). The panels have shared and independent fasteners (screws) that allow the different disassembly configurations: 1. The front top panel can be disassembled by releasing the side and front fasteners. 2. The back oanle can be disassembled by releasing the back fasteners. 3. The side panels can be disassembled independently, or together with the back panel by releasing the sides and back fasteners. The personalized panel attachment to the top front panel is independent and does not interfere with the disassembly of the panels from the structure (figure 48).
Figure 51 shows an example of the product in a possible repair context while figure 52 shows cut views of the attachment of the replaceable panel to the front panel (right) and the stainless steel panels to the structure (left).

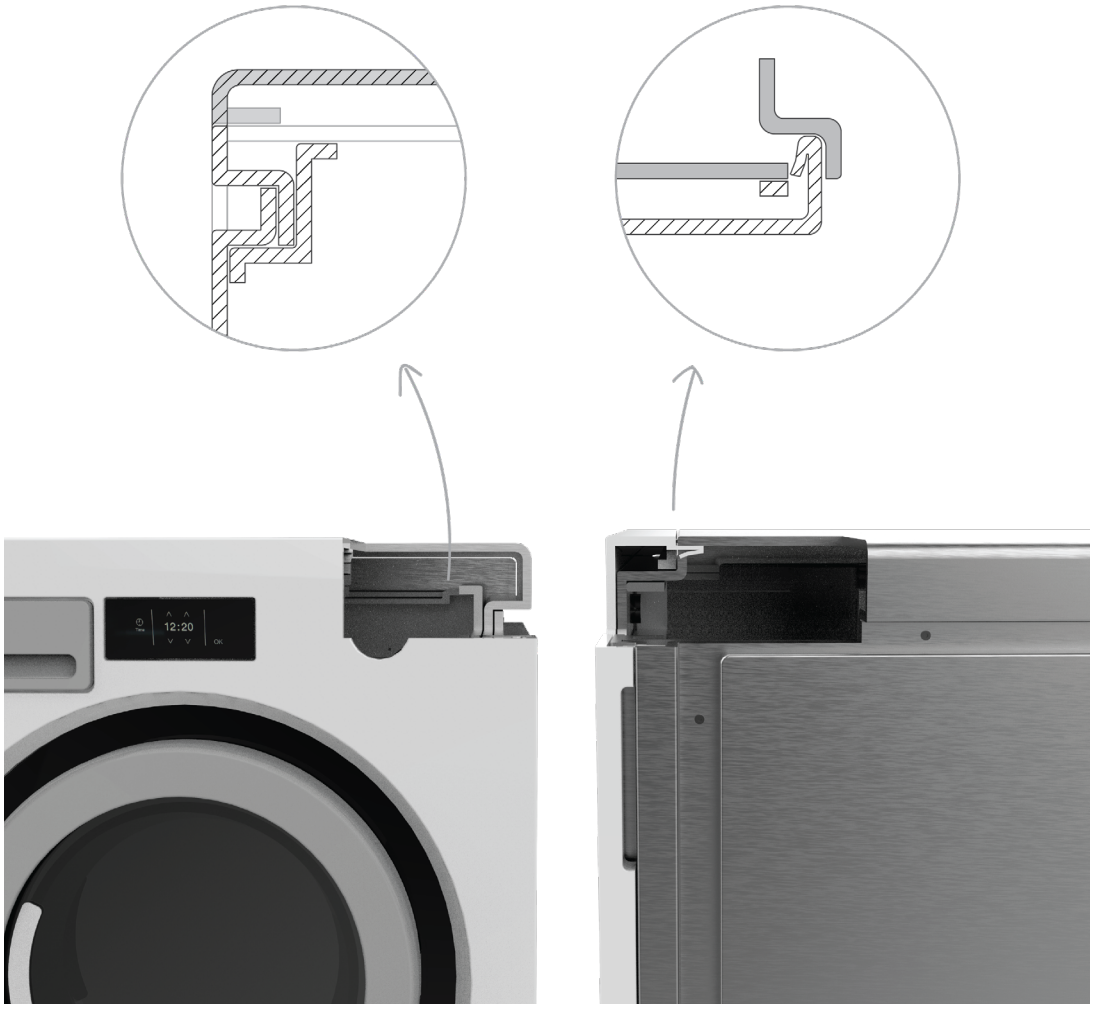
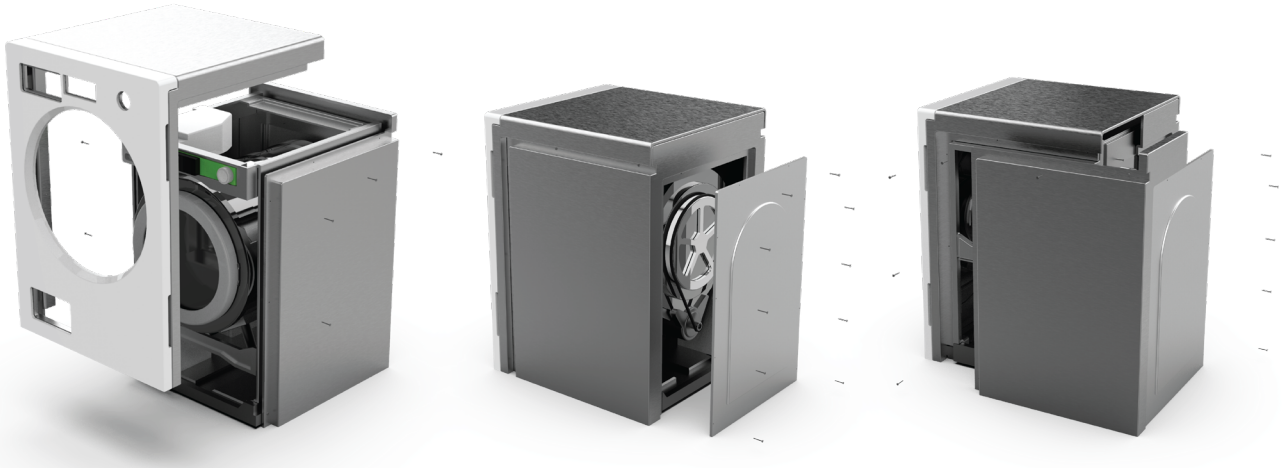


Figure 52. Cut views of the assembly of the panels to the structure (left) and the assembly of the replaceable panel to the front-top panel (right).



Figures 48, 49 and 50. Disassembly options for the different panels.

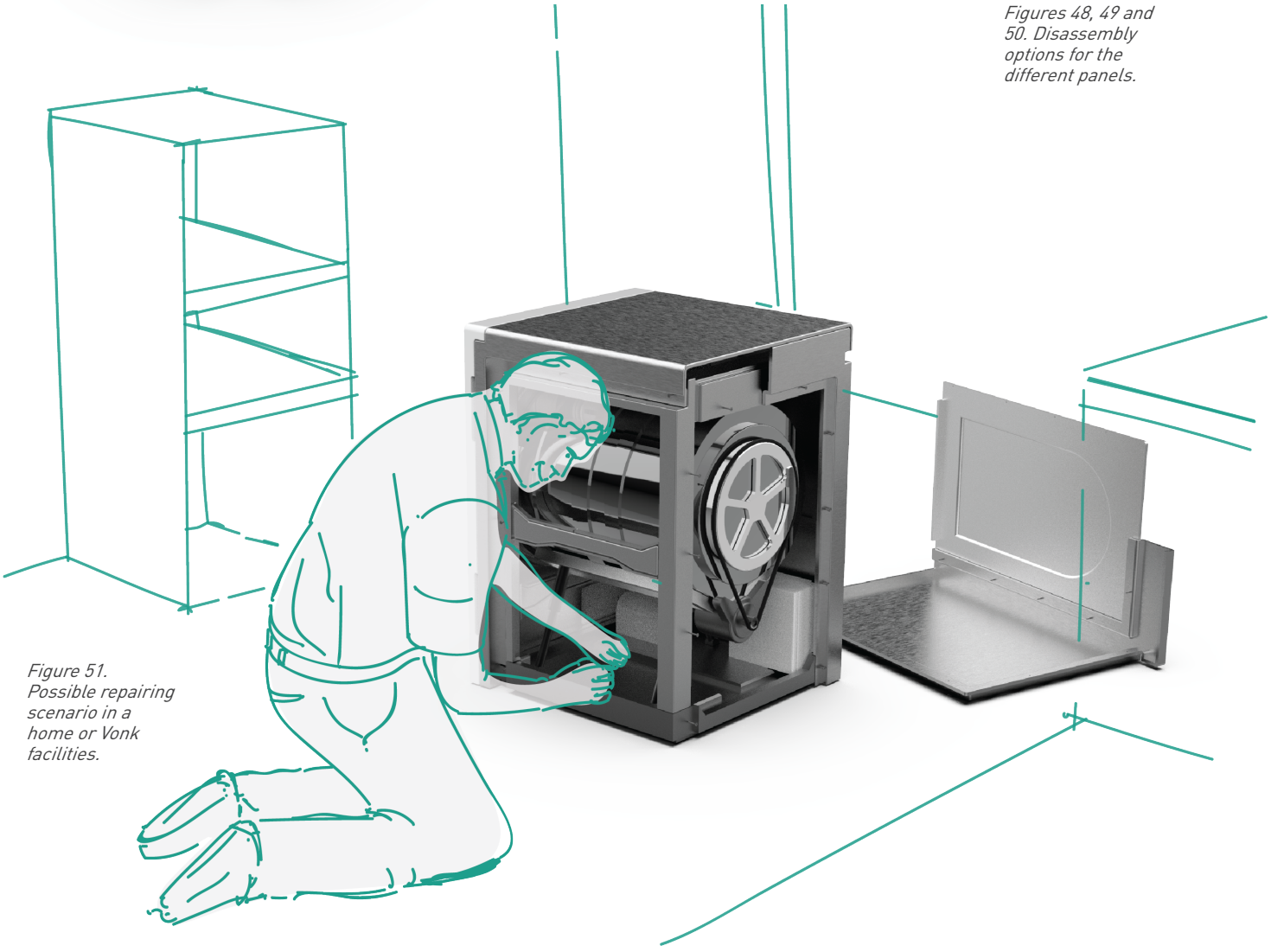


Figure 51. Possible repairing scenario in a home or Vonk facilities.

Refurbishable

Several characteristics of the washing machine were designed to improve refurbishing procedures which today are limited to cleaning the machine and using plaster on the surfaces. As mentioned above, the personalized panel can be sent back to Miele in Germany, for it to be sandblasted and powder coated again. It can also be easily attached and detached from the machine without the need of a professional technician. The stainless steel panels can be fully disassembled from the machine and have a brushed finishing, allowing them to also be sent back to Miele Germany for them to be brushed to eliminate stains or scratches (figure 53). The possibility of detaching the panels from the structure avoids the transportation of the machine as a whole if refurbishment is needed (figure 54). Additionally, the new construction of the door, uses the sealing system of the professional machines. This system does not need the whole door module to be disassembled in case the rubber ring needs to be replaced . Its replacement can be done directly from the door in case of stains or deterioration, saving service time (figure 55). Finally, the possibility of improving access and increasing mobility and visibility when disassembling all panels could facilitate and accelerate part replacement and update processes as described in Chapter 7.1 in order to extend the life of the product as much as possible.

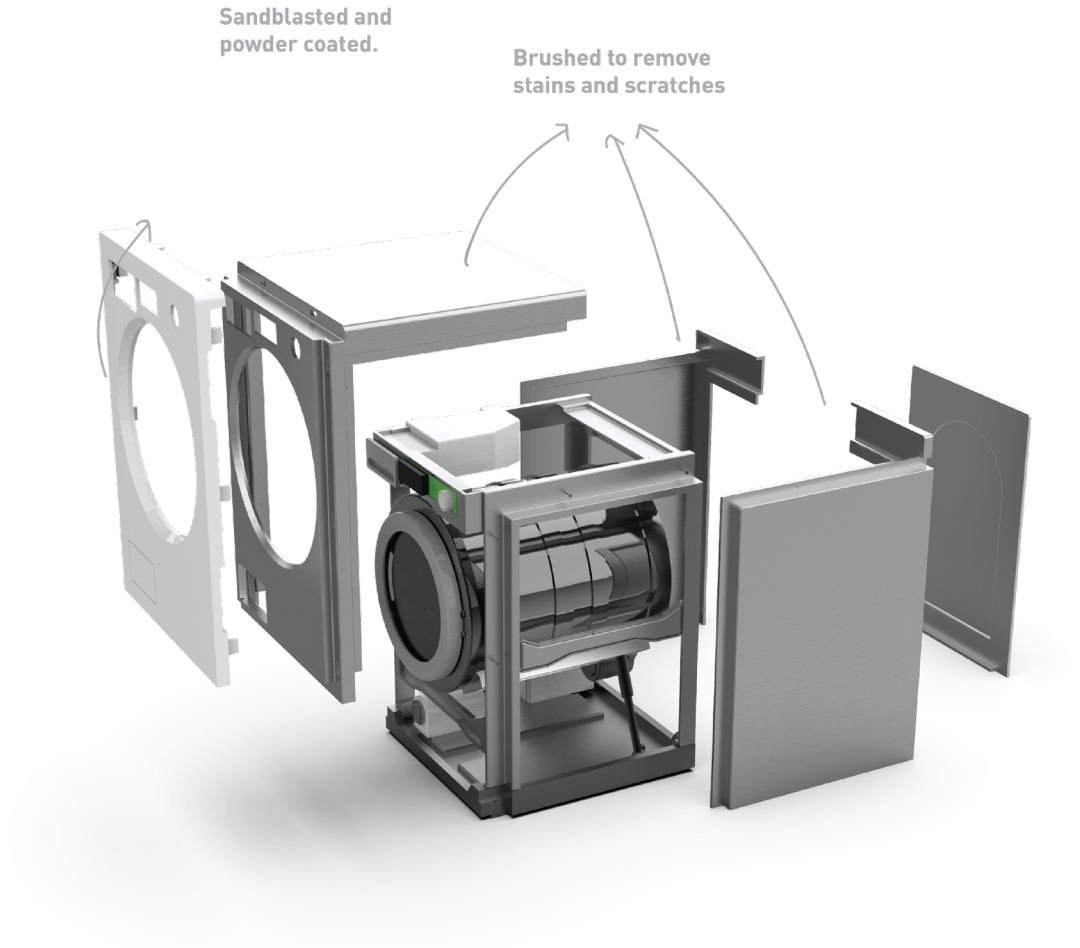
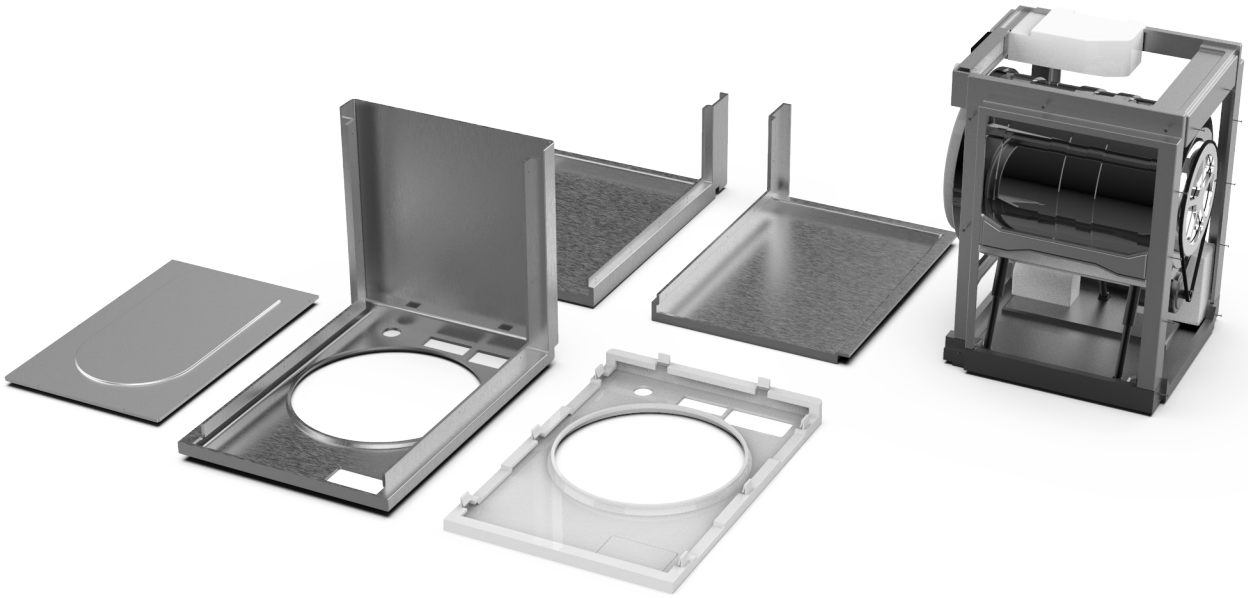


Figure 53. Refurbishment processes for the panels.



Figures 54 and 55. Disassembled panels can be transported separately from machine for refurbishment or replacement.

Improved access to the rubber ring. Application of the construction of the door of a professional machine.

Sensing for monitoring

As mentioned in Chapter 7.1, the machine is connected to the internet through the already integrated IoT module (integrated in the reference model mentioned above), in order to send use monitoring data to the system. The machine monitors and measures the use through a variety of sensors. Table 9 shows an overview of the type of information that needs to be collected and whether that sensor is already available in the reference machine (current machines) or if it needs to be added. Additionally, it shows the type of the necessary additional sensors and its expected position. One additional sensor is necessary in order to measure all the proposed variables.

Necessary information	Availability in reference machine	Type of necessary sensor and approximate position
Frequency of washing (number of cycles)	yes	
Type of program used	yes	
Under and overloading	no	Capacitive-displacement sensor in the dampers (shock absorbents).
Level of dirt.	yes	
Over or underuse of soap	no	No sensor added can be calculated by the number of registered rinsing cycles.

Table 9. Current and additional sensors for the machine and use monitoring

04

VALIDATION AND CONCLUSION

This part of the report shows several activities done in order to evaluate the concept from different perspectives. First, the results from interviews with all main stakeholders regarding the new concept are shown. Second, results from the evaluation of the concept considering its repairability and disassembly, refurbishing characteristics, its viability and the reduction of environmental impact in comparison with the original PSS are shown. It is important to mention that many of these results are based on estimated scenarios since the necessary information to do precise calculations was not available. This part of the report concludes with a list of recommendations, derived from the development of the concept and its evaluation, and a personal reflection.

8. EVALUATION AND VALIDATION OF THE NEW PSS

8.1 Evaluation with stakeholders. Interviews with Miele NL, Miele GMN, User and Bundles.

Several interviews and evaluation forms were delivered to the different stakeholders in order to obtain their feedback and input on the PSS concept. Some of the conversations with the stakeholders focused on the feasibility and viability of the proposal, while others focused more on the desirability and the creation of value for the user. This chapter presents the feedback and comments obtained from these exercises.

Evaluation with Miele GMN

The evaluation of the concept from Miele Germany was done by the head of the design department and a person from the purchasing department. The product is considered to be technically feasible since its characteristics indicate its manufacturing and further development can be done within Miele's expertise and infrastructure. Although the proposal includes several changes to the construction of the machine there is no need of changing the original working principle and internal composition of the current machine. The replaceable layer, together with the possibility of brushing the stainless steel panels was considered a suitable way of always delivering a "new" machine to the customer, increasing the overall perceived value for the product. However, the purchasing department did notice that the manufacturing of this component on demand could highly increase the manufacturing costs. For this reason it was recommended to maintain a fixed color selection. Additionally, Miele Germany expressed interest in the further study of the refurbishment processes. They consider these processes could be automated and optimized, and the design of the product should respond to these characteristics. They also consider there is a lot of value in the data collected from the monitoring of the machine and its components to optimize the refurbishing a repairing processes. Finally, it was highlighted that the possibility of guiding people during the washing process is a next good step to avoid the waste of energy and water.

Interview with Miele NL

Interviews and visits were organized at Miele NL with the head of the service department, the product manager and a professional Miele technician in order to gain feedback related to the feasibility and repairability of the product. The interviewees indicated the concept could have a lot of benefits in the improvement of the repairability of the machine, specifically considering ease of access, since they consider the disassembly times and sequence to be really good already. They raised concerns over the replaceable layer regarding noise during operation due to vibration and suggested to avoid having the panel cover the top of the machine. For this reason, the replaceable panel of the final proposal, only covers the front panel, however, this aspect has to be further studied. While conversing about the most common necessary repairs and the priority components they highlighted that in many cases, the components fail or break due to the user behaviour. The users often forget sharp objects in their pockets or instal the machine is a floor that causes a lot of vibrations, causing cuts and breaks in some components and the unbalancing of the machine. This type of behavior should be further researched and considered as part of the personalized tips and the design of the washing machine.

Evaluation with Bundles

Regarding the product, Bundles showed a lot of interest in the proposed refurbishing processes, although it can be a good strategy to extend the life of the product and maintain it updated and in good conditions, there is a concern regarding the costs and environmental impact of the refurbishment of the replaceable panel and the refurbishment of the stainless steel panels. The estimation of the environmental impact is further explored ahead, however, the estimation of the cost of the refurbishment of the stainless steel panels involves a third party, since today, refurbishment processes are out of the scope of Miele. This information needs to be further explored with polishing services providers. Bundles also raised concerns

regarding the value delivered to the user. Do people value having the possibility of personalizing their washing machine? Bundles does not consider people would be willing to pay extra for this aspect, so the costs of the replaceable layer should be considered within the refurbishment budget of the machine. However Bundles considers the replaceable layer can act as a marketing strategy that makes the product more recognizable.

Concerning the platform, Bundles appreciates the differentiation between generating a Washing Package based on a questionnaire and the adaptation of the package through the monitoring. Several forms of input could allow the PSS to better meet the user needs whilst reducing the environmental impact of the Use Phase. Bundles also highlighted the importance of the tips and their potential to positively influence user. Bundles expressed their interest in understanding how the tips given to the user through the platform differentiate from those given by the technician during the installation. These differences have to be further researched in order to identify which type of information is more valuable throughout the different phases of the PSS.

Interview with Bundles' user

Obtaining interviews with current Bundles' users for the evaluation of the concept was challenging. Although insightful, the evaluation was done with only one user and further input of current and potential users should be obtained. Overall, the interviewee considers the platform could be a very valuable source of information and tool to reduce the environmental impact and keep track of the use of resources. Additionally, the value of having personalized programs and simplifying the interface and interaction with the product was highlighted. However, there is a concern regarding the feeling of restriction, not considering the frequency but the availability of programs. For this reason the idea of the "Joker" was implemented, giving the possibility of a "free" manual program to the user once a month in case of special needs or emergencies. The interviewee also highlighted that the replaceable layer was a nice feature as long as it is included in the price of the subscription. Although the interviewee didn't have problems regarding privacy of data for this specific PSS, it was highlighted that several people could feel uncomfortable regarding the monitoring of their actions. Further research on how to address these concerns and provide a feeling of security to the users is necessary.

8.2 Validation scenarios and limitations

The evaluation of the concept faced many limitations due to the lack of baseline information and the lack of measured information from the concept and the lack of prototypes. However, this chapter shows the results obtained from the assessment of the concept within different criteria, through the use of estimations and scenarios. These evaluations provided further information to identify gaps where further research should be executed in order to continue the development of the concept and understanding better the possibilities and limitations of its implementation.

8.2.1 Refurbishment, repairability and ease of disassembly

In order to assess the repairability and disassembly characteristics of the new concept and compare it to the existing washing machine to understand whether the new design delivers improvements in these areas, a condensed version of the repairability and ease of disassembly assessment tools was used (Cordella et al, 2019; Vanegas et al 2016) (Chapter 3.4.3). The tool was first used on an example of the current machine and then on the concept. Due to the extension and complexity of the original assessment tools, the limited time availability and the limited possibilities of obtaining measurable data from the concept (a prototype has not been developed so all measurements of the new concept can only be estimated) the machine and concept were only assessed considering some of the previously mentioned technical parameters (Chapter 3.4.3). The selection of parameters considered that the obtained information should allow for comparisons between the current machine and the concept. These include: Disassembly and assembly time (not currently possible to measure in the concept), serves as a reference to compare the complexity of disassembly between one component and another in the current machine, Disassembly sequence, and Ease of access, which for this case considers light, position and manipulation, which could be considered to directly contribute to the time of disassembly.

For the assessment of the current washing machine, an experienced Miele technician (18+ years of experience) at Miele NL was asked to disassemble it (available model for the assessment was: PowerWash 2.0 & Twindos XL. Wificonnect) to access several components. The selection of the components was based on the priority components list (Chapter 3.4.4) and includes: one of the 3 shock absorbers (closest one to the front panel), the door seal and lock, the motor and drive belt, and the electronic module for the power control. Table 10 shows a summary of the results and findings of the assessment of the current machine.

General notes:
- The complexity of the machine requires extensive (1.5 yrs) preparation to obtain the necessary knowledge to perform repairs.

-During the observation the machine was on an elevated (approx 15cm) platform with wheels, which facilitates mobility and manipulation of the machine. This is not always the case.

- Miele washing machines, specifically those with an integrated Wifi module, provide the technician with information related to the malfunction and an estimated diagnosis. This information is not publicly available.

-All the tools used for the disassembly of the components are commercial tools. Five different tools plus a support element on the side were used in total.

-The measurements only consider disassembly and reassembly times, leaving out the time that diagnosis and precaution measurements take during a normal service procedure.

Component	**Disassembly and reassembly time (min).**	**Disassembly sequence. No. of steps**	**Notes on conditions. Ease of access, light, position, manipulation.**
Shock absorbent.	Disassembly: 3 min 4 seg Reassembly: 2 min 56 seg	1. Remove back panel. 2. Remove internal screw and external nut (bottom). 3. Manipulate the component to release.	A) Limited mobility and visibility. The component is far from the access point. Needs arm and tool extension to be reached. No space for tool manipulation. B) Lifting is necessary from the side. A supporting element is used. (Images 16 and 17)
Electronic module, Printed Circuit Board (Power control).	Disassembly: 3 min 44 seg Reassembly: 4 min 11 seg	1. Remove back panel. 2. Manipulate and remove the cover of the module housing. 3. Unplug all connections to other components. 4. Remove top element of the control module. 5. Remove the screw and manipulate to release PCB.	A) Limited mobility and visibility. The housing of the electronic module stays in. Limited space to manipulate cover. Even with a lamp visibility is limited for connections. B) Sharp edges and limited space. The technician got a cut in the process. Gloves are recommended but they limit sensitivity and mobility. (Image 18)

Component	Disassembly and reassembly time (min).	Disassembly sequence. No. of steps	Notes on conditions. Ease of access, light, position, manipulation.
Drive belt.	Disassembly: 1 min Reassembly: 1 min 30 seg	1. Remove back panel. 2. Manipulate to release the belt.	A) Good visibility and space for manipulation. (Image 19)
Motor.	Disassembly: 2 min 56 seg Reassembly: 4 min 26 seg	1. Remove back panel. 2. Manipulate and release belt. 3. Remove screws and release motor housing. 4. Unplug all connections to power control. 5. Remove screws to release motor from housing.	A) Good visibility and easy to access. Subassembly makes process easier. B) Space is limited for tool use. (Image 19)
Door Lock.	Disassembly: 4 min 11 seg Reassembly: 5 min 48 seg	1. Remove tip panel. 2. Remove Soap drawer. 3. Remove control panel. 4. Remove lock cover. 5. Remove door seal external fastener. 6. Remove front panel. 7. Manipulate to release the lock module.	A) Good visibility.
Door seal (rubber ring).	Disassembly: 6 min 8 seg Reassembly: 8 min 31 seg *Longest time of disassembly of all assessed components.	1. Remove tip panel. 2. Remove Soap drawer. 3. Remove control panel. 4. Remove lock cover. 5. Remove door seal external fastener. 6. Remove front panel. 7. Unplug control, pipes, and light. Release door seal internal fastener. 8. Manipulatie to liberate door seal	A) Good visibility. B) Connections to the door seal are too short and hard to manipulate. C) Extraction and insertion of the seal is complex. D) Sharp edges require the use of gloves, limiting sensitivity. (Image 20)

Table 10, Assessment of the current machine. Disassembly sequence and ease of access.

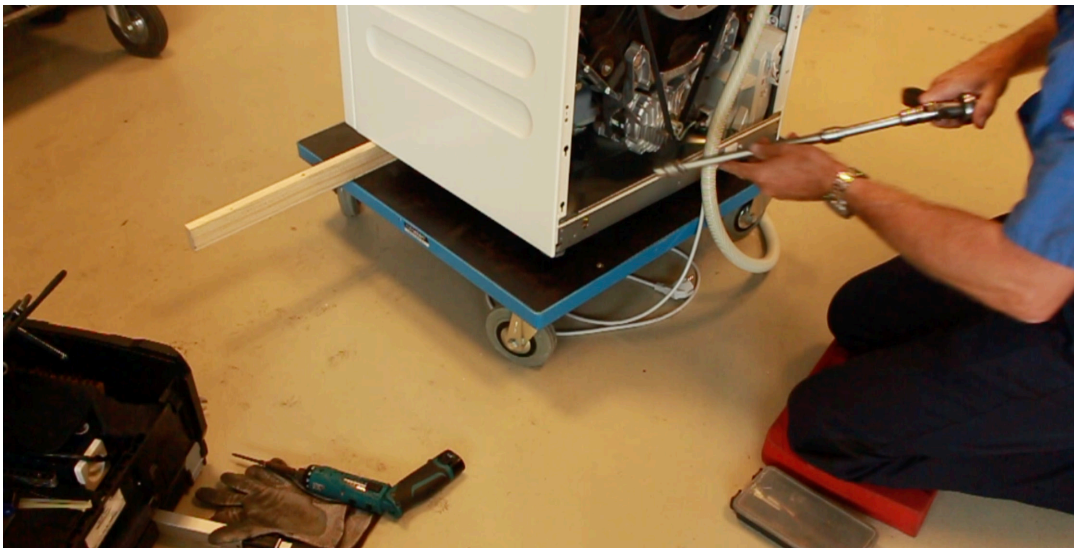


Image 16. Tool extension needed to reach the component.

Image 17. Lack of visibility and extension of both arms needed to reach and release the component.

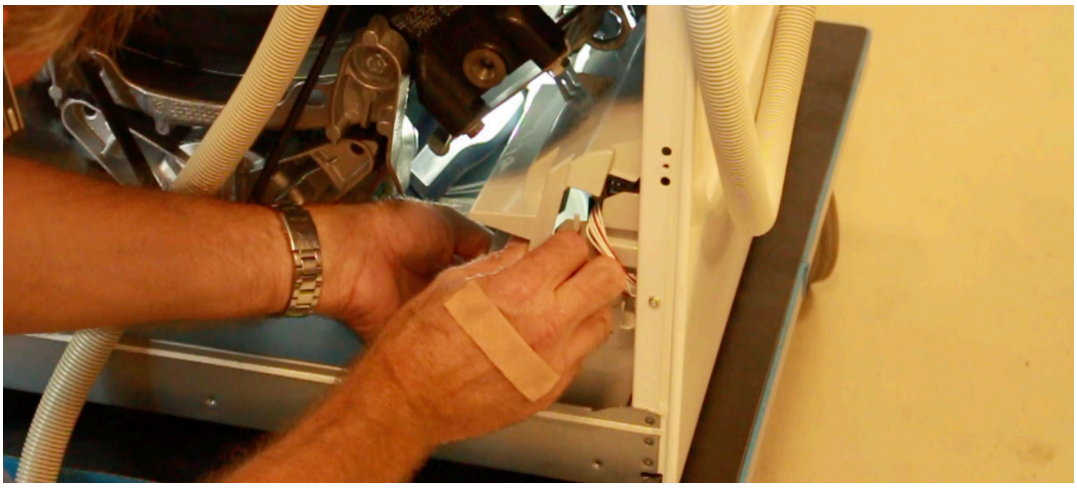


Image 18. The technician puts a lamp inside in order to improve visibility. Lack of space to move and release the housing of the PCB.

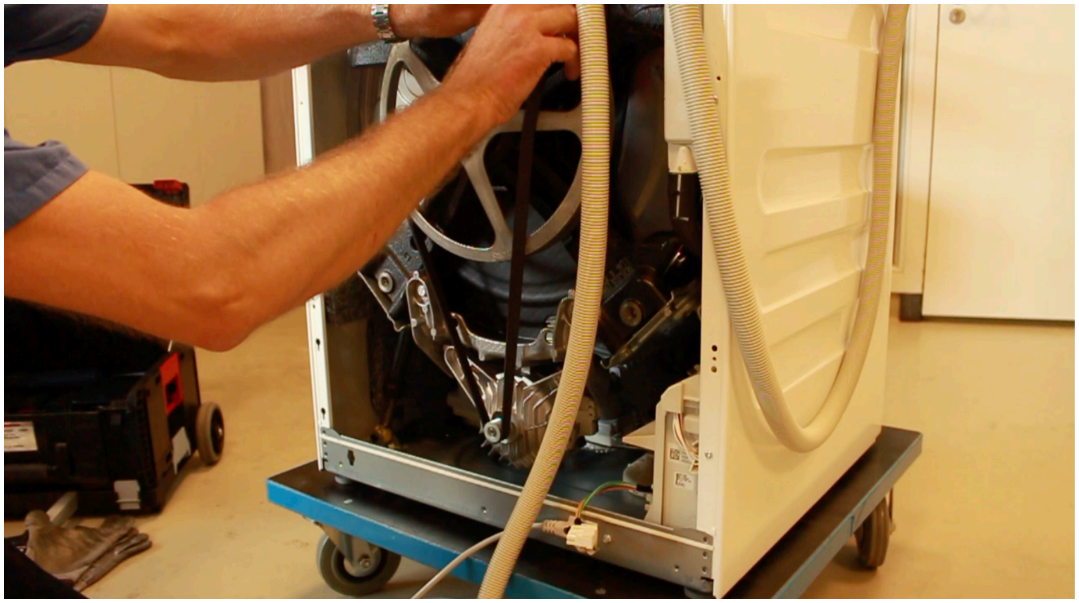


Image 19. Good visibility and good mobility for the assembly and disassembly of the belt.

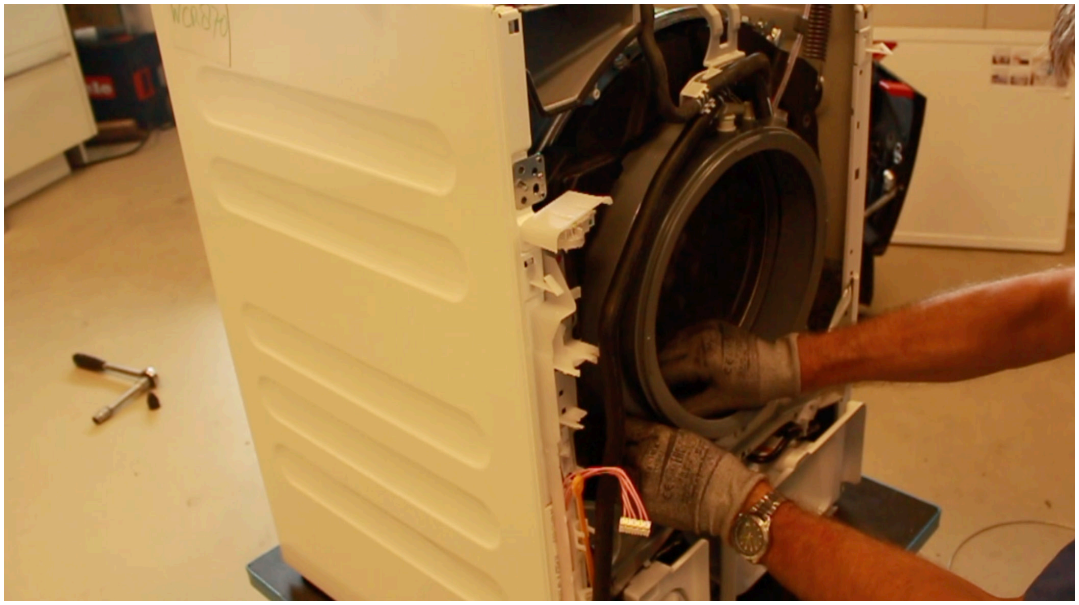


Image 20. Necessary disassembly and gloves in order to reach the door seal (rubber ring).

Table 11 shows the estimated improvements delivered by the new concept in comparison with the current machine. These however, are considerations that should be measured with the use of a prototype. A testing setup is proposed in the recommendation chapter of this document.

Component	**Expected disassembly sequence. No. of steps.**	**Notes on expected improved or worsen conditions. Disassembly sequence, ease of access, light, position, manipulation.**
Shock absorbent.	1. Remove back + side panel. 2. Remove internal screw and external nut (bottom). 3. Manipulate the component to release.	- Although the disassembly sequence has the same amount of steps as the original machine, the new concept improves the visibility of the component as well as providing a more accessible position from the side. This avoids the need for the extension of tools and the need to reach and extend the arms. (Figure 56)
Electronic module, Printed Circuit Board (Power control).	1. Remove back +side panel. 2. Unplug all connections to other components. 3. Release the screw to open the power control housing. 4. Manipulate component to release PCB	- By opening the side of the washing machine, the mobility and visibility to access the component and its connections is improved. The improved mobility could also avoid the contact of the skin with the sharp edges, and possibly reduce disassembly times. -The possibility of being able to extract the PCB together with its housing as a subassembly could improve the mobility even more and avoid damages on the PCB caused by the manipulation of the component. (Figure 57)
Drive belt.	1. Remove back panel. 2. Manipulate to release the belt.	-The disassembly and access characteristics from the original washing machine are maintained. (Figure 58)

Component	Expected disassembly sequence. No. of steps.	Notes on expected improved or worsen conditions. Disassembly sequence, ease of access, light, position, manipulation.
Motor.	1. Remove back panel. 2. Manipulate and release belt. 3. Remove screws and release motor housing. 4. Unplug all connections to power control. 5. Remove screws to release motor from housing.	-The disassembly and access characteristics from the original washing machine are maintained. (Figure 58)
Door Lock.	1. Remove Soap drawer. 2. Remove top-front panel. 3. Remove screws and release the drum front ring cover together with the door. 4. Remove the door lock module.	- The number of steps of the disassembly sequence appears to be reduced with the new assembly and construction of the door. However, the available information is insufficient and further detailing of the assembly of the door lock is necessary in order to assess the ease of access and define the disassembly steps more accurately. (Figure 59)
Door seal (rubber ring).	1. Remove the seal fastener. 2. Remove door seal. .	-The new construction allows the replacement of the ring directly from the door. This eliminates the need for disassembling the panels and avoiding the access to internal components. This could potentially reduce the service times. (Figure 60)

Table 11. Assessment of concept. Disassembly sequence and ease of access.

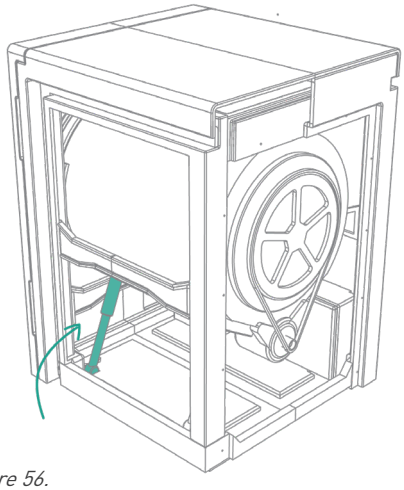


Figure 56.

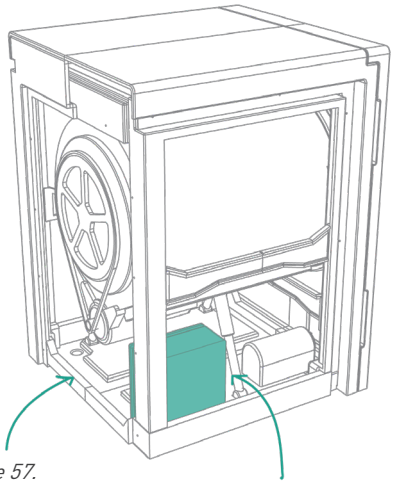


Figure 57.

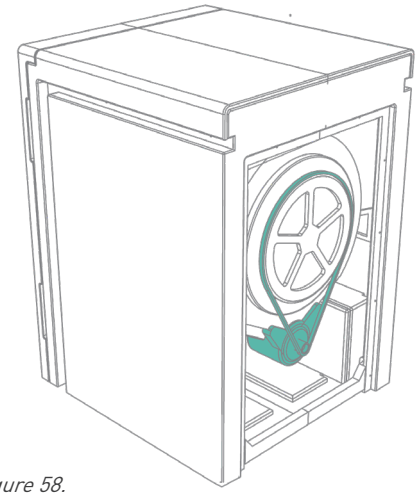


Figure 58.

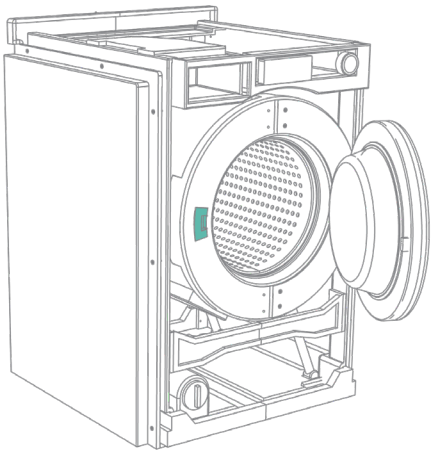


Figure 59.

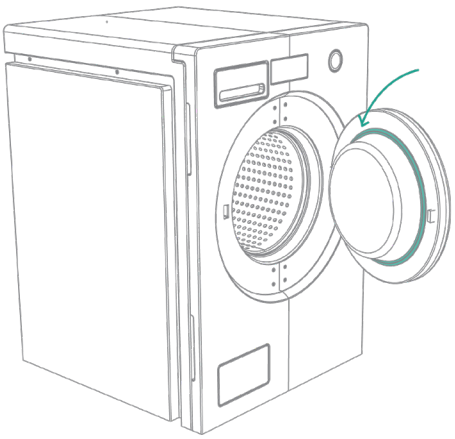


Figure 60.

From the assessment, it can be concluded that although for many of the components the number of steps of the disassembly sequence wasn't reduced (with the exception of the rubber ring), the overall conditions of ease of access are presumed to be improved. Specifically considering visibility, light and increase of space for mobility and manipulation of components for their assembly and disassembly. As a hypothesis, these improvements have the possibility of reducing the service times, however, this has to be further explored and measured in order to derive any conclusions and find potential counter effects that are not evident from the available information.

Refurbishment

Regarding the refurbishment of the washing machine it is important to do a comparison between the current refurbishment processes and new proposed processes in order to define the possible advantages and limitations of both of them (Table 12).

The new concept aims to improve the possibilities of part replacement and increase the possibilities for their refurbishment. These aspects, together with the personalized panel are expected to maintain the visual quality of the machine, while maintaining the original materials and parts throughout the overall expected lifespan of the machine, 20 years (as defined by Miele), in contrast with the 10 year expected lifespan Bundles considers today. However, the proposed processes for refurbishment should be submitted to further study whilst considering the costs of the procedures and transportation of parts from refurbishment facilities and back, as well as understanding the periodicity in which they are necessary, in order to adapt them to the budget for refurbishment established by Bundles after each use cycle (Appendix B).

Component	Refurbishment processes today and limitations.	Proposed refurbishment processes and expected benefits.
Door seal	a) Cleaning with a cloth. b) Replacement in case of stains and deterioration. **The replacement of the rubber ring is expensive considering it has to be done by a professional technician since it is necessary to access the internal components of the machine and its disassembly time can be long due to the number of steps of its disassembly sequence.**	a) Cleaning with a cloth. b) Replacement in case of stains and deterioration. **In case of necessary replacement, the component can be disassembled without accessing the internal components of the washing machine, potentially making the procedure less complex and the disassembly time shorter.**
Front and Top panels + Control panel	a) Cleaning with a cloth. b) Applying plaster to scratches and marks. c) Replacement in case of severe deterioration. **The use of plaster still leaves marks of deterioration. Since the part is not being refurbished, in case of severe damage it must be replaced. Spare parts are expensive e.g. the control panel spare part is 70 Euros, without considering service times.** **Additionally, if the part was refurbished, it would be necessary to undergo several sanding procedures or chemical removal, due to the use of a vitreous material.** **Additionally, the control panel and the top section of the top panel are made of plastic, which cannot be refurbished, only replaced.**	a) Cleaning with a cloth. b) Brushing and Grinding the part in case of stains or scratches. **The stainless steel parts can be refurbished with mechanical procedures to restore the part to its original characteristics. No plastic parts are considered.**
Side panels	a) Cleaning with a cloth. b) Applying plaster to scratches and marks. **The use of plaster still leaves marks of deterioration. In case of severe damage the part can not be replaced since it is part of the structure of the machine.**	a) Cleaning with a cloth. b) Brushing and Grinding the part in case of stains or scratches. **The new construction allows the disassembly of the side panels for their refurbishment, which can be done with mechanical procedures to restore the part to its original characteristics**

Table 12. Comparison of refurbishment processes.

8.2.2 Cost estimations and viability

Because the new concept proposes several changes to the original construction of the machine, and adds material through the replaceable layer and the separation of the panels from the structure, the question if whether these changes affect the viability of the overall PSS arises. A short assessment of the consequences of these changes was done by estimating the increased manufacturing costs and comparing the impact of this increment considering the life expectancy of the product from the current and new concept PSS. Table 13 shows an overview of the assessment scenarios done with the model WCE770 TDos Wifi at its original online price of 1,200 Euros, as a baseline.

With the support of the purchases department from Miele Germany, a 50% over the manufacturing costs of the baseline model was estimated, as a result of the following changes:

- The addition of the replaceable personalized layer. Manufactured in a diversity of 10 colors.
- The addition of the capacitive - displacement sensor.
- The elimination of the automated soap dosing system (Twindos).
- The manufacturing of the top-front and sides-back panels in stainless steel.
- The addition of material in the structure (frame) to make it independent from the panels. Including the connection of the door, display and control panel to the frame.

Since the information of the specific manufacturing costs of the washing machine is confidential, 2 scenarios were formulated to make rough estimations.

In these rough calculations it can be observed that the 50% over the manufacturing costs translates into a 50% over the original price, this is because the remaining percentage (other expenses and profit) is calculated over the new manufacturing costs. If these expenses and profit margin were assumed to remain the same (or similar) for the original model and the new concept, the results for Bundles' investment would be less than what was calculated above (example in table 14).

Scenario 1. **Bundles' initial investment on the machine: 1200 Euros** **Manufacturing costs: 50% Remaining 50% (Retail, delivery, R&D, etc.)**			
Current PSS		**Concept PSS**	
Manufacturing costs	600 Euros	Manufacturing costs (50% over current)	900 Euros
Other (remaining 50% : profit, retail, delivery, R&D, etc.)	600 Euros	Other (remaining 50% : profit, retail, delivery, R&D, etc.)	900 Euros
Total	**1200 Euros**	**Total**	**1800 Euros**
Yearly investment for Bundles with a 10 year expected lifespan.	**120 Euros / year**	**Yearly investment for Bundles with a 20 year expected lifespan.**	**90 Euros / year**

Scenario 2. **Bundles' initial investment on the machine: 1200 Euros** **Manufacturing costs: 40% Remaining 60% (Retail, delivery, R&D, etc.)**			
Current PSS		**Concept PSS**	
Manufacturing costs	480 Euros	Manufacturing costs (50% over current)	720 Euros
Other (remaining 60% : profit, retail, delivery, R&D, etc.)	720 Euros	Other (remaining 60% : profit, retail, delivery, R&D, etc.)	1080 Euros
Total	**1200 Euros**	**Total**	**1800 Euros**
Yearly investment for Bundles with a 10 year expected lifespan.	**120 Euros / year**	**Yearly investment for Bundles with a 20 year expected lifespan.**	**90 Euros / year**

Table 13. Scenarios for cost estimation.

Scenario 1. Manufacturing costs: 50%	
Other (remaining 50% : profit, retail, delivery, R&D, etc.) of the **current machine**	600 Euros
Manufacturing costs of the new concept	900 Euros
Total	**1500 Euros**
Yearly investment for Bundles with a 20 year expected lifespan.	**75 Euros / year**

Table 14. Estimation of final retail price of the new concept considering the remaining profit and other expenses margin from the original product.

In all cases, the characteristics of the new design could potentially allow the product to be considered to have a lifespan of 20 years. As a consequence, the initial investment (even though it has increased considerably) is distributed along 20 years instead of 10 years (as Bundles does today) reducing the annual investment. Bundles should explore the possibilities and implications of implementing this product as part of their business model considering the higher initial investment but the expected long term benefits. Additionally, further analysis and calculation of the costs of refurbishment procedures should be done. Although these processes allow the extension of the life of the product, they also represent an investment. The processes should be further studied in order to understand if their costs fit within Bundles' budget for refurbishment after each use cycle. The product should also be further analyzed in order to make predictions regarding its deterioration after each use cycle. Table 15 shows an overview of the procedures and additional parts needed for the refurbishment of the new concept, indicates which of these are expected to reduce or increase costs compared to the current product and highlights those where information regarding costs is still missing (in green).

Table 15 only shows a general estimation of the consequences of the new proposed refurbishment processes due to the lack of accurate information. The estimation of these costs is scenario specific, since it is subject to different conditions and levels of deterioration of the product, therefore it should be further explored and accounted for in that way. In addition to manufacturing and refurbishment costs, and although Bundles already counts with an App and a website, the further development of the new platform as well as the necessary research for it needs to be accounted for. Other considerations include database licenses and infrastructure costs (servers, etc).

In the case of Miele, as it was mentioned above, the new concept could be manufactured within Miele's current expertise and infrastructure. However, in a future scenario where the PSS grows and the volume of components that need to be refurbished increases, Miele would have to invest in the infrastructure and people necessary to accommodate all procedures.

Refurbishment processes necessary after EACH use cycle		
Current product	**New concept**	**Expected impact on refurbishment costs.**
Cleaning.	Cleaning.	Same as current product.
	Refurbishment and replacement of the personalized layer.	Increased costs over current product.

Refurbishment processes ONLY necessary in case of malfunctions or SEVERE DETERIORATION.		
Current product	**New concept**	**Expected impact on refurbishment costs.**
Repairs and part replacement.	Repairs and part replacement.	Reduced costs over current product due to reduction of service times. Reduced costs considering panels don't need to be replaced in case of surface damage. The replacement of these can range from 150 to 250 Euros.
	Brushing of stainless steel panels.	Increased costs over current product.

Table 15. Overview of refurbishment processes and expected impact on costs.

8.2.3 Assessing the environmental impact

Manufacturing and additional materials
As mentioned in Chapter 2.1.1 and 2.2.1 PSSs have the potential of reducing the material input when delivering a function to a user. Although the concept aims to increase the current life expectancy of the product within the PSS from 10 to 20 years, it does it by adding parts, materials and processes over the current product. Therefore the question regarding the environmental impact of this augmentation rises and extends to the impact generated by the proposed refurbishment processes as well. In order to understand the impact of the proposed changes a rough estimation of the absolute values of carbon footprint generated by the additional materials and processes is shown in table 16. It is important to mention that due to the lack of information (E.g. List of components of the current product and their characteristics, Bill of materials (BOM), manufacturing processes...) a rough estimation of a baseline was first done in order to be able to do a comparison with the new concept. An additional note should be made considering the estimate was done based on the current level of detail of the concept. A more extensive LCA performed with a higher level of detail in the concept would be necessary in order to find more information of where specific improvements can be made to the product and the PSS overall, considering all other indicators of environmental impact and not only carbon footprint, as well as all phases of the life cycle together.

Since the internal construction and internal components of the new concept remain similar to those of the current machine, only the following changes are considered for this estimation:
-Top- front and side panels now produced in stainless steel.
-Addition of the replaceable panel.
-Separation of the structure from the panels.

The estimation was done based on the current available CAD model of the components of the concept washing machine. The results could be lower or higher if a greater level of detail of the dimensions, definition of types of steel and specific processes for manufacturing is considered in future estimations.

The estimation of the material input of the components of the current machine was obtained with the data available from the model WKH 130 WPS in the LCA done for Miele (Öko institute, 2015). All values regarding Carbon Footprint of material supply and manufacturing processes were obtained from the Idemat 2018 database considering their estimated average values for each material and process. Transportation is excluded since sufficient information is missing to make an estimation.

	Components	Material	Total Unit	Material Supply kg (CO2/kg)	Material Supply Total Carbon footprint (kg CO2)	Manufac-turing process (estimated)	Manufac-turing process (kg CO2/kg Or Kg CO2/ m2)	Manufac-turing process Total Carbon footprint (kgCO2)	Estimated Total Carbon footprint of considered parts (kgCO2)
Baseline Machine	-Drum -Suds container (outer drum)	Stainless Steel	11.68kg	1.76	20.55	-Steel rolling -Deep drawing	0.41 0.68	12.72	33.27
	-Front panel -Side panels -Top panel -Base and frame -Back panel -Other (springs, damper supports etc).	Steel	26.98kg	2.04	55.03	-Steel rolling -Deep drawing	0.41 0.68	29.34	84.37
	-Finishing	-	1.53m2	-	-	Enamel	11.71	17.9	17.9
						Total weight of machine	**96kg**	**Total c. footprint from material and manufac-turing**	**135.54 kg CO2**
New concept	-Side panels -Top/front panel -suds and drum	Stainless Steel	31.08kg	1.76	54.70	-Steel rolling -Deep drawing	0.41 0.68	33.87	88.57
	-Back panel -Base and frame -Replaceable panel -Other (springs, damper supports etc).	Steel	31.5kg	2.04	64.26	-Steel rolling -Deep drawing	0.41 0.68	34.33	98.59
	-Finishing	-	0.49m2	-	-	Powder coating	3.57	1.74	1.74
						Total weight of machine	**120kg**	**Total c. footprint from material and manufac-turing**	**188.9 kg CO2**

Table 16. Estimation of the carbon footprint generated by the changes made to the washing machine (absolute values).

The table shows that the changes have an estimated 40% more carbon footprint over the material supply and manufacturing of the current machine steel and stainless steel components. The estimation presents absolute values and does not consider that the new concept is meant to extend the expected life of the machine to 20 years in the PSS, as opposed to the 10 years of the current machine. Although the increase of the footprint could be distributed along the 20 years, the estimation also leaves out the impact derived from the refurbishment processes that could allow this extension. For example, although the Powder Coating has a lower carbon footprint compared to the Enamel, this coating is expected to be done for every use cycle of the machine, as a result, it should be multiplied by the number of expected use cycles (4 use cycles estimating an average subscription duration of 5 years), also representing an excess when calculated as absolute values.

It is important to mention that the carbon footprint of the material supply and manufacturing of the washing machine only account for approximately 24 % of the total footprint of the whole lifecycle, with the use phase being 75.8% (Öko institute, 2015). Although the increased impact of the manufacturing of the machine does not represent much when compared to the impact of the use phase the new concept should be reevaluated and detailed considering the reduction of all extra materials.

Use of resources during the Use-Phase
As mentioned in Chapter 2.5.1, the use phase of a washing machine is resource intensive and therefore accounts for most of the environmental impact of the machine's life cycle. The design brief and the design goal both state that the new PSS should help reduce the environmental impact of the use phase, therefore it is relevant to assess the concept within this aspect. Although a proof of concept is not available to make measurements over the new proposal, a scenario based on the same persona 3 (same one used for the platform example) was estimated in order to understand how the Washing Package can help reduce the environmental impact of the use phase when compared with current behaviour.

Table 17 and 18 show the results for expected consumption of water and energy from the current and the concept scenario. In order to create the scenario, a table of the possible water and energy consumption of a washing machine with an optimized automatic level detection from an LCA done on washing machines by the Öko institute (2015) was used as a reference (Chapter 2.5). This reference considers a 5kg maximum capacity of the washing machine. The scenario compares the "current" monthly washing behaviour of the persona and its impact, to the "expected" behaviour when using the machine with the Washing Package.

The results of the scenario assessment show a potential reduction of 15% in water consumption and 46% in energy consumption. The reduction can be mainly attributed to the reduction of frequency, the loading to maximum capacity, the reduction of the used temperature and the reduction in rinsing cycles due to correct dosing of soap. Although this estimation shows the potential the platform has in the reduction of the environmental impact of the use phase, several notes should be considered: The estimation is specific to a single persona, other scenarios should be measured considering different user profiles to understand the differences of the potential benefits of the Washing Package from one profile to another. The results could also be considered to be biased as the scenario considers the use of the Washing Package as prescribed and does not consider the use of the "Joker" programs for example. The Washing Package is subject to people's behaviour and the relationship between the both should be further analyzed and measured in order to find the critical monitoring points, variables and washing package formulations that have most potential of reducing the environmental impact and overcome the influence of negative user behaviour.

Current scenario					
Type of program	**Water (start of cycle) Litres**	**Water (per rinsing cycle) Litres**	**Number of rinsing cycles 2 average and 1 extra for soap overdose.**	**Total Water consumption Litres**	**Energy consumption kWh**
Urgent wash. 40C and half load (2.5kg)	6	4.5	2	15	0.35
Total consumption for a 4x monthly frequency.				**60**	**1.4**
Mixed wash. 60C full load (5kg)	11	8	3	35	0.83
Total consumption for a 4x monthly frequency.				**140**	**3.32**
Mixed wash. 60C half load. (2.5kg)	6	4.5	2	15	0.57
Total consumption for a 4x monthly frequency.				**60**	**2.28**
Total estimated monthly consumption.				**260 Litres**	**7 kWh**

Table 17. Estimated water and energy consumption for Persona 3 in the current scenario

Concept scenario (Washing Package)					
Type of program	**Water (start of cycle) Litres**	**Water (per rinsing cycle) Litres**	**Number of rinsing cycles 2 average and 1 extra for soap overdose.**	**Total Water consumption Litres**	**Energy consumption kWh**
Urgent wash. 30C and half load (2.5kg)	6	4.5	2	15	0.25
Total consumption for a 4x monthly frequency.				**60**	**1**
Mixed wash. 40C full load (5kg)	11	8	2	27	0.47
Total consumption for a 6x monthly frequency.				**162**	**2.82**
Total estimated monthly consumption.				**222 Litres**	**3.82 kWh**

Table 18. Estimated water and energy consumption for Persona 3 using the Washing Package.

To conclude, a combination of the estimated values from the use phase and manufacturing impact is presented in Table 19. The combination of the results is based only on the carbon footprint indicator, considering the available information. The table presents the estimated monthly carbon footprint of washing laundry (for a household of two) of the current and concept PSS. It considers a 10 year lifespan for the current machine and 20 for the new one.

The estimation shows a reduction of 43% of the carbon footprint of the new concept over the current PSS. Again, this estimation excludes other environmental impact indicators, the impact derived from refurbishment processes and is only based on one use scenario. However, the estimation illustrates the potential of the new concept to reduce the environmental impact of the overall PSS through the extension of the product's life expectancy and the personalization of the Washing Package. Additionally, it would be interesting to estimate scenarios to measure the potential reduction of the impact of the use phase, through the adaptation of the Washing Package throughout time with the monitoring of users' behaviour.

	Current PSS 10 year lifespan			**New concept 20 year lifespan**		
Material Supply and manufacturing (Absolute values considering only the changes made to the product (Table 16 and 17))	135.54 kg CO2			188.9 kg CO2		
Material Supply and manufacturing (monthly)	1.12 kg CO2			0.78 kg CO2		
	Impact of domestic electricity use NL			Impact of domestic electricity use NL		
Monthly use impact	25.6 MJ	0.175 kg CO2/MJ	4.41 kg CO2	13.75 MJ	0.175 kg CO2/MJ	2.40 kg CO2
Total monthly carbon footprint.	**5.53 kg CO2**			**3.18 kg CO2**		

Table 19. Comparison of combined environmental impact results of manufacturing and use phase.

9.RECOMMENDATIONS AND CONCLUSION

This chapter first includes conclusions derived from the comparison between the new concept with the original brief and established design goal/ focus areas to identify its limitations and contributions as well as possible further research directions. It then includes recommendations regarding the information gaps identified during the concept assessment as well as proposed methods and further steps to identify the missing information and continue the development of the concept.

The design goal and the new concept

When considering the established design goal, it can be concluded from the validation, that the new concept PSS appears to have the potential of having a positive effect on the way the product and service respond to each other throughout different aspects of the different phases of the life cycle of the PSS. The established design goal and proposed focus areas read as follows (Chapter 4.2):

Design Goal.
-Designing a PSS where the user experience is improved and the environmental impact of washing reduced through communication and personalization; and the product is future proof, optimized for several use cycles and the recovery of materials.-

Focus Areas.
Personalization, communication and refurbishment.

Different aspects for discussion can be identified from the established goal and focus areas:

1) The new concept proposes to improve the user experience and increase the perceived value over the PSS and refurbished products through the personalization of the physical product (replaceable layer) and the Washing Package and the delivery of transparent and reliable information. The Washing Test makes the Pre-use phase more intensive involving the users more during the order to better identify and meet their needs. From the validation with the user the appreciation for this characteristic in addition to the adaptation features of the Washing Package throughout the subscription was highlighted. The user appreciates the guidance and support delivered from the platform to take better care of his or her clothes and have a more positive environmental behaviour.

The personalization of the physical product is perceived as a nice characteristic but not something worth to pay extra for. Bundles and Miele both believe it could be a good strategy to increase the acceptance over refurbished products as long as it can be considered within the available budget for repairs. The validation however, does not provide enough information in order to identify if personalization is truly perceived as an addition of value to the user or if too much personalization could eventually be perceived as restrictive. Further research regarding the effects different levels of personalization could have in the acceptance of PSSs and refurbished products is needed. Additionally, it should be further assessed if the personalization of the product and Washing Package would increase the perceived value of the PSS enough to expand Bundles' current market target and attract users who have the economical possibilities to purchase a high end machine and today, perceive the PSS as expensive and not worth it in the long term. Perhaps personalization could also be explored to be a strategy to adjust the monthly tariff of the subscription to make it more attractive to customers.

A final note regarding the delivery of value includes the further exploration of the perception of the user regarding privacy, data sharing and monitoring, to identify actions and strategies to increase the feeling of trust and comfort. This project contributes with several examples of how personalization can be implemented in PSSs to increase the perceived value from the user. The benefits

of this implementation should be further analyzed and explored within this and other examples of PSSs.

2) The concept proposes to reduce the environmental impact of the use phase through the personalization and continuous adaptation of the Washing Package and the continuous delivery of information in the form of tips. From the validation, it is clear that personalization is a suitable strategy to support a positive and more informed user behaviour. Both information and personalization are values that allow the PSS to meet the user needs with only the necessary resources and avoid an intuitive use of the machine. Additionally, the increased involvement of the user during the order provides a medium for the system to receive sufficient information to generate the best selection of variables that meet the user needs whilst following the recommendations to reduce environmental impact and take care/ maintain the machine. The application of IoT technologies for the monitoring of use provide an example of how the collection of data could allow this personalization to be adaptive, considering the challenge of people's lives and behaviour being subject to a diversity of changes.

3) The concept aims to increase the circularity of the PSS by reinterpreting the current concept of longevity from a non changing long lasting product to one that allows several use cycles without losing its visual quality and resource efficiency. The last is achieved through the proposed refurbishment processes, the possibility to remotely update the machine's software and the improvement of the product's disassembly ease of access and construction, which could contribute to the reduction of costs of service times as defined by the assessment. Moreover, the proposed refurbishment processes and construction of the machine avoid the replacement of the panels, maintaining this materials throughout several use cycles of the PSS. Additionally, the new concept makes use of the findings regarding the delivery of information to improve user behaviour to avoid misuse and damage of the washing machine, by providing general and personalized tips.

The current level of detail of the concept leaves a lot of uncertainty is left regarding the recovery of the product and the recycling of its materials. Although Bundles has the potential to become a recovery point for Miele washing machines, it is unclear how the materials and components of the machine could be reintroduced in the manufacturing of new machines. Further research on how the recovery and recycling procedures could be implemented in Miele is necessary in order to detail the concept accordingly. The disassembly of all components and the types of materials that can be used according to current and future regulations, as well as the components where the use of recycled materials is feasible should be defined. Although the product is being properly disposed and recycled today, the PSS will only truly augment its circularity by recovering and reintroducing the materials of the product into new life cycles. The viability of this recovery and recycling has to be assessed using simulations of current and future growth scenarios that illustrate the potential benefits or limitations of all necessary processes and infrastructure.

The previous point indicates that there is a need for a change in the collaboration between Bundles and Miele, not only considering the integrated development of the product and the service but also the delivery and further processes of the PSS. The possibilities for growth should be explored in order to consider the role of Miele in the refurbishment of the washing machines, considering the automation of these processes and the implications this could have in the design of the product. It should be noted, that a lot of the knowledge Miele has acquired from their professional line could be applicable to the use oriented PSSs.

The new concept successfully applies many of the insights derived from the literature and field research, translating them into functions and characteristics of a product and platform, however, the further detailing, proof of concept and detailing of these components could deliver more insights and directions for further research and exploration of the design and implementation of PSSs and their contribution to circular economy and sustainable development.

Information gaps, proof of concept and further development

Although the results of the assessments and methods used to perform them, give estimations of how the new concept improves all the aspects mentioned above in comparison with the current PSS, there is still a lot of uncertainty in the results due to the lack of accurate information, both from the baseline and from the concept itself. In order to fill the gaps of missing information and continue with the development of the proposal, a proof of concept, further research and detailing for each one of the components of the PSS is necessary. Recommendations on the directions and methods for further research and how to continue with the development of the product and the platform are presented below.

The product
As an initial step the repairability and disassembly of the new concept needs to be assessed in detail with the use of a prototype that allows the measurement of the disassembly time, sequence, and overall conditions of access as explained in Chapter 8.2.1. The assessment should be done for the same critical components identified in Chapter 3.4.4 and within the same conditions as done with the original product: performed by an experienced Miele technician and in the same or similar context characteristics. The testing prototype should be produced in a 1:1 scale and entail the 6 original critical components. The frame construction can be done in wood as well as the elements that support the original components. The panels are proposed to be produced with sheets of steel that can be laser cut, folded and welded, this in order to have a close representation of the weight, dimensions and geometry the real panels would have and the implications of this in the manipulation for the technician and the context. Figure 61 shows a rough sketch of the proposed prototype for the assessment. Additionally, it would be interesting to assess both, the original product and the new concept prototype in a user's home in order to identify space and mobility limitations.

Further detailing of the concept is also necessary considering the following aspects:

-Although the separation of the structure from the panels and the replaceable layer have a lot of benefits considering disassembly, repairability and refurbishment, it has as a result, added a lot of material to several components. A new iteration of the construction of the product could focus in the delivery of the same functions but with the reduction of material in mind.

-Additionally, the replaceable panel has arised several concerns regarding the noise it can cause when the machine is operating. The panel and its assembly have to be further detailed in order to be able to accurately model them to run simulations of the vibration dynamics and simulations of the acoustics of the machine.

- Considering that the concept is designed to be refurbished to maintain its visual quality as well as facilitating the repair, replacement and update of components and software, it would be interesting to analyze the possibilities for the product to have a lifespan of more than 20 years. However, further analysis and simulations should be done in order to identify the consequences this could have in the resource efficiency and overall deterioration of the machine and the possibilities of overcoming them through the update of components and software.

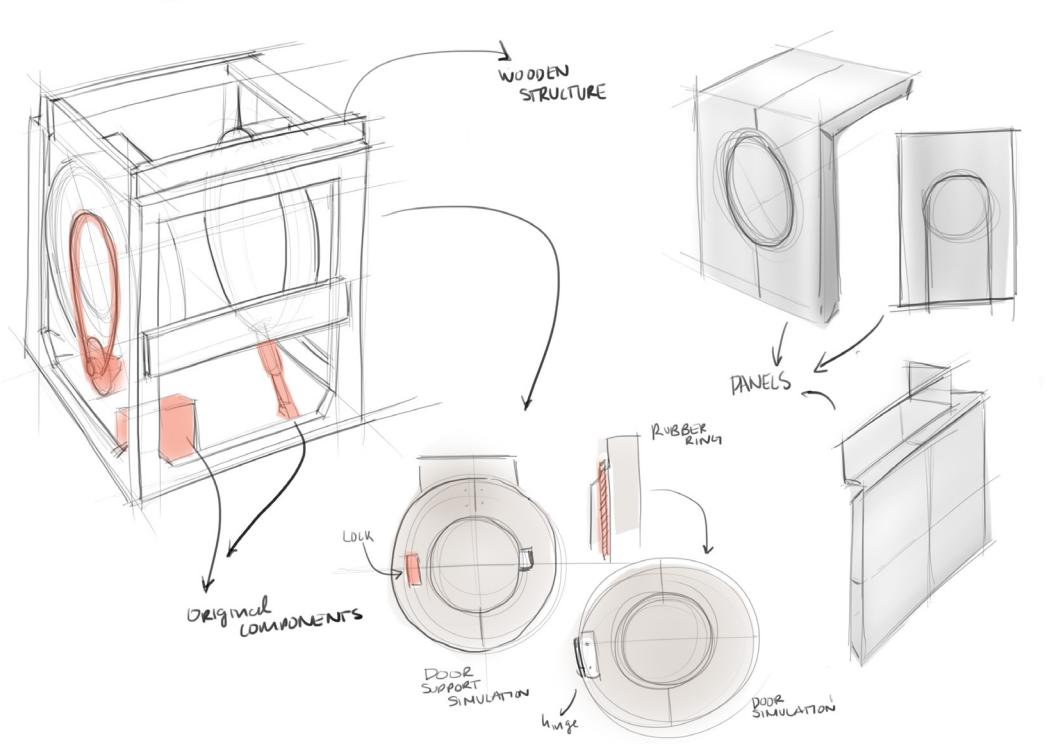


Figure 61. Sketch of the prototype components and structure.

The platform
Similar to the product, the platform and its system should be prototyped and put through a pilot test in order to identify and measure the following aspects:

-Its influence in the reduction of the environmental impact of the use phase. Additionally considering whether the reduction of impact can be improved even more through the delivery of more information to the user and continuous adaptation of the Washing Package.

-Identify whether people perceive the new interaction as more valuable or restrictive. And if the personalization and adaptive characteristics could have an influence in increasing the average length of a subscription. Which could bring economical benefits to Bundles considering the reduction of investment in refurbishment procedures.

The pilot test is suggested to be done with a group of users with different washing needs and demographic characteristics, the formulated personas in this report could be used as a reference. The users will have a current Miele machine with an integrated Wifi module, installed in their house for them to use normally. The use of the machine can be monitored for a month in order to form a user profile, identifying the frequency of washing, the types of programs used, temperature, water and energy used. The users can then be submitted to a prototype of the Washing Test and receive an estimated of the Washing Package. The results of the washing test can be compared to the data obtained from the first month of the monitoring of use to identify information gaps that need to be improved in the Washing Test. A prototype of the interface with the resulting Washing Package included can be installed in the machines. The machines are then installed in the users' homes and a new monitoring period begins. The results of the second round of monitoring can be used to identify the accuracy of the Washing Test and Washing Package results, the possibilities for improvement and the definition of the variables for the development of the algorithm for the information processing as well as the most critical monitoring points. Additional monthly monitoring periods after the adaptation of the Washing Package can be done in order to obtain further input on these functions. Once the pilot test is over the volunteer users can be interviewed in order to obtain information on their perspective towards the new concept and suggestions for its improvement.

Apart from the identification of the relevant data for the development of the platform and monitoring system, the alternatives to capture the information and methods to process it should be further analyzed. Perhaps personalizing for each type of user would deliver a high amount of variables and it would be more effective to formulate profiles or personas for the prescription of the Washing Package.

Life Cycle Assessment of the PSS
This report provides a rough assessment of the potential environmental impact of the concept PSS based on estimations and the available information. Assessing the concept PSS more accurately could help identify specific points of improvement within its different components and processes for its delivery. In order to do this, a complete set of information is necessary in order to construct the baseline for comparison. Including for example, the BOM (bill of materials), manufacturing processes, logistics information, etc. Additionally, a similar set of information should be made available considering the concept, for which further detailing and development is necessary. The LCA should be done considering several environmental impact indicators and not only the carbon footprint in order to have an accurate comparable overview of the generated impact.

10. PERSONAL REFLECTION

About the process

Considering the complexity of this project, and the amount of variables that compose the PSS, the project was at times, hard to manage and hard to make decisions towards a specific direction because everything seemed very much interrelated. Within the scope and limitations of a master thesis project it was interesting for me to have this holistic approach, since it allowed me to understand and learn about the complexity of designing for PSSs, the different methods to perform research on the field and different stakeholders, and specifically, different methods to synthesize all the obtained insights in ways that allowed me to consider them in an integrated way.

In a different scenario or situation, I would ideally work with a more focused approach, within a team, with people with different expertises to run further research and detail the specifics of each component whilst discussing and having a more holistic overview as a group. Although I am most motivated when designing for complex problems, I believe that collaboration and teamwork are the keys to best approach them. Discussion and collaboration in my opinion, have the greatest potential to deliver new, more valuable, applicable knowledge. Although working individually was challenging for me because I missed having these continuous discussions within a team, I did my best to have them with other people and experts. Doing this is what kept me motivated, since it allowed me to see my mistakes and successes, and learn from other people's input.

On many occasions throughout this project, it was difficult to keep track of all the obtained information from the different stakeholders, not only considering Miele and Bundles as a whole but considering the different departments that conform the internal organization of Miele in Germany and the Netherlands. Although this gave me more experience with stakeholder management, I believe I still have a lot to learn and improve in the organization of information and insights from different sources, and communication skills (as a designer) with the different stakeholders considering their different backgrounds and priorities. With this I am not trying to say I would have spent more time planning some of the sessions and interviews with the stakeholders but plan ahead to be more prepared for the unforeseen. I have found a number of books which explain and recommend methods and tools, but most of them do so for ideal conditions and scenarios. This is a big insight for me to learn to plan my research methods to be adaptable and flexible.

Ideally, I would have given the project a more practical, tangible approach, although this was limited by the amount of available resources (such as time and budget), it would have been interesting for me to have developed a prototype of some of the new disassemble or personalization characteristics of the concept, for example, in order to perform tests and be able to measure the results to continue iterating. This is a way of working I always enjoy more because it makes results more tangible, provides quantifiable information and overall maintains me more active and closer to the context and stakeholders. Although I was not very successful at implementing this aspect in this project, I am aware there were limitations for it and understand I have to be more specific in defining these aspects in earlier stages. This Master thesis allowed me to identify many of my weaknesses and dislikes, and it taught me a lot about controlling my frustration when understanding my own limitations. Additionally, it allowed me to identify many of the strengths, preferences and passions I have as a designer which I know I can contribute with, to the research and design for complex problems, specifically those related to circular economy and sustainable development.

About the PSS, environmental impact and circularity

Although this project managed to propose several changes and modifications to the components of the current PSS that could allow it to reduce its environmental impact and increase its actions towards circularity I cannot help but think that a more radical change is necessary in order to have a higher positive impact in these two goals. While doing this project I identified that the environmental impact of washing is the consequence of a complex set of factors that condition and have consequences over one another. Washing machines seem to be designed to fulfill the requirements surrounding the textile industry, in the definition of washing programs for example, and not so much to fulfill the user needs. At the same time, user needs are very diverse and conditioned by a set of intangible and immeasurable, societal rules that define levels of cleaningness. Users are pushed to use the machine intuitively since a full comprehension of how and when to properly take care of the clothes is subject to undefined rules and reading each label on every garment as well as the whole operating manual of the washing machine and soap labels. It is a complex situation since it relies on different industries with different interests and ways of delivering developments and information.

When speaking of a more radical change several things come to mind, as well as several levels of intervention, for example, the implementation of result-oriented PSSs, which could have less environmental impact in comparison to Use-oriented PSSs considering they deliver results collectively making use of resources more efficiently (Tukker, 2004), could be further studied to reduce their costs to the user, increase the perceived value towards them and make them resilient to negative user behaviour. Other interventions could consider different ways of delivering information to the user or influencing their behaviour to reduce the washing frequency, or achieving measurable ways of defining when something needs to be washed, or even eliminating the need to wash at all. All of these require a lot of changes in the infrastructure and way of working of a diversity of industries as well as technology development. Radical changes are not always feasible or not immediately feasible in many ways due to their complexity and dependence in an infinite number of factors and interests, however, I believe further research and study could provide the guidelines to achieve them. I consider that what Bundles is doing is already proposing changes and generating insights and new knowledge regarding the way we consume and use things. These contributions, although not the most radical or with the most potential of reducing impact and material input are important and perhaps a first step into future developments over the current system for its change.

11. REFERENCES

A.I.S.E., International Association for Soaps, Detergents and Maintenance Products, (2013). I Prefer 30, Low Temperature Washing Initiative.

Bocken, N., Ingemarsdotter, E., & Gonzalez, D. (2019). Designing Sustainable Business Models: Exploring IoT-Enabled Strategies to Drive Sustainable Consumption. In Sustainable Business Models (pp. 61-88). Palgrave Macmillan, Cham.

Bundles (2019), How it works. Retrieved on April 10th 2019 from: https://bundles.nl/en/how-it-works/

Care Labelling symbols and standards. Retrieved April 10th, 2019 from: https://www.intertek.com/uploadedFiles/Intertek/Divisions/Consumer_Goods/Media/PDFs/Services/Low%20Res%20CompleteCareLabelling.pdf

Ceschin, F., & Gaziulusoy, I. (2016). Evolution of design for sustainability: From product design to design for system innovations and transitions. Design Studies, 47, 118-163.

Ceschin, F. (2013). Critical factors for implementing and diffusing sustainable product-Service systems: insights from innovation studies and companies' experiences. Journal of Cleaner Production, 45, 74-88.

Dewberry, E., Cook, M., Angus, A., Gottberg, A., & Longhurst, P. (2013). Critical reflections on designing product service systems. The Design Journal, 16(4), 408-430.

Directive (EU) 2017/2102 of the European Parliament and of the Council of 15 November 2017 amending Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (Text with EEA relevance.) https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1512061986553&uri=CELEX:32017L2102

Ellen Macarthur Foundation, (2013). Towards the circular economy. Journal of Industrial Ecology, 2, 23-44.

Ellen MacArthur Foundation, (2016). "Intelligent Assets: Unlocking the Circular Economy Potential." .

Ellen MacArthur Foundation, (2019). "Bundles, A model offering multiple benefits for multiple electronic products." (2019). Retrieved on April 10th from: https://www.ellenmacarthurfoundation.org/case-studies/internet-enabled-pay-per-wash-a-model-offering-multiple-benefits

European Commission, Cordella, M., Alfieri, F. & Sanfelix J. (2019). Analysis and development of a scoring system for repair and upgrade of products. JRC Technical Reports, European Commission, Joint Research Centre, Seville, Spain. Retrieved on June 5th, 2019 from: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC114337/jrc114337_report_repair_scoring_system_final_report_v3.2_pubsy_clean.pdf

European Commission, Vanegas, P., Peeters, J., Cattrysse, D., Duflou, J., Tecchio, P., Mathieux, F. & Ardente, F. (2016). Study for a method to assess the ease of disassembly of electrical and electronic equipment. JRC Technical Reports, European Commission. Retrieved on July 3rd, 2019 from: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC101479/lb-na-27921-en-n.pdf

European Commission, (2016). COMMISSION DECISION (EU) 2016/1371 of 10 August 2016 establishing the ecological criteria for the award of the EU Ecolabel for personal, notebook and tablet computers. Retrieved on July 3rd, 2019 from: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016D1371&from=EN

Gensch C. , & Blepp M., (2015) Betrachtungen zu Produktlebensdauer und Ersatzstrategien von Miele-Haushaltsgeräten, Öko-Institut e.V.

Gensch C. , Rüdenauer, I., Quack D., (2005) Eco-Efficiency Analysis of Washing machine. Life Cycle Assessment and determination of optimal life span , Öko-Institut e.V.
Gram-Hanssen, K. (2008). Consuming technologies–developing routines. Journal of Cleaner Production, 16(11), 1181-1189.

Hekkert, P., & Van Dijk, M. (2011). ViP-Vision in design: A guidebook for innovators. BIS publishers.

Jack, T. (2013). Nobody was dirty: Intervening in inconspicuous consumption of laundry routines. Journal of Consumer Culture, 13(3), 406-421.

Koerner, M., Schulz, M., Powell, S., & Ercolani, M. (2011). The life cycle assessment of clothes washing options for city west water's residential customer. In ALCAS Aust. Life Cycle Assess. Soc. Conf.

Miele, Washing Machines, Operation Instruction Manual M.-Nr. 11 009 900. Miele, WCE660.

Mont, O., & Plepys, A. (2003). Customer satisfaction: review of literature and application to the product-service systems. International Institute for Industrial Environmental Economics at Lund University.

Porter, M. E., & Heppelmann, J. E. (2014). How smart, connected products are transforming competition. Harvard business review, 92(11), 64-88.

Regulation (EU) No 1007/2011 was adopted on 27 September 2011 and became applicable on 8 May 2012. Textile fibre names and related labelling and marking of the fibre composition of textile products. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX-:02011R1007-20130701&from=EN

Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX-%3A02006R1907-20140410

Roy, R. (2000). Sustainable product-service systems. Futures, 32(3-4), 289-299.

Saccani, N., Perona, M., & Bacchetti, A. (2017). The total cost of ownership of durable consumer goods: A conceptual model and an empirical application. International Journal of Production Economics, 183, 1-13.

Shove, E. (2003). Converging conventions of comfort, cleanliness and convenience. Journal of Consumer policy, 26(4), 395-418.

Tecchio, P., Ardente, F., & Mathieux, F. (2019). Understanding lifetimes and failure modes of defective washing machines and dishwashers. Journal of Cleaner Production, 215, 1112-1122.

Tukker, A. (2004). Eight types of product-service systems: eight ways to sustainability. In Innovating for Sustainability. 11th International Conference of Greening of Industry Network, San Francisco e USA (pp. 2-27).

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. (Eds.). (2017). New business for old Europe: product-service development, competitiveness and sustainability. Routledge.

Van Boeijen, A., Daalhuizen, J., van der Schoor, R., & Zijlstra, J. (2014). Delft design guide: Design strategies and methods.

Van den Berg, M. R., & Bakker, C. A. (2015). A product design framework for a circular economy. Product Lifetimes And The Environment.

Van Weelden, E., Mugge, R., & Bakker, C. (2016). Paving the way towards circular consumption: exploring consumer acceptance of refurbished mobile phones in the Dutch market. Journal of Cleaner Production, 113, 743-754

Vezzoli, C., Kohtala, C., Srinivasan, A., Xin, L., Fusakul, M., Sateesh, D., & Diehl, J. C. (2017). Product-service system design for sustainability. Routledge.

Vezzoli, C., Ceschin, F., Diehl, J. C., & Kohtala, C. (2015). New design challenges to widely implement 'Sustainable Product–Service Systems'. Journal of Cleaner Production, 97, 1-12.

Whitmore, A., Agarwal, A., & Da Xu, L. (2015). The Internet of Things—A survey of topics and trends. Information Systems Frontiers, 17(2), 261-274.

Designing a washing machine
for the service economy

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MSc Integrated Product Design
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