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Circular Business Model in an R&D service business

A ROADMAP FROM INITIATION TO IMPLEMENTATION

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Abstract

Purpose

Due to excessive material usage, CO_2 emission production increased, the increased amount of waste that is dumped and the increasing damage to the environment. To reduce the environmental footprint, the aim of this research is to guide Benchmark, an R&D service and manufacturing company for other businesses, in the transition to a more circular economy.

Design

Following the literature, the best practice to transition to a circular economy is to implement a roadmap. In this thesis, a roadmap is constructed from relevant literature. To implement this roadmap in the organisation of Benchmark, semi-structured interviews with twelve employees provided solutions for the transition to a more circular economy. These solutions were validated by the twelve employees on impact, feasibility, profitability, the willingness of the client to implement changes and the time span. Best practices are identified and an explanation on how they can be imbedded in the current business model is made.

Findings

The model of Frishammar & Parida (2019) provides the structure of the roadmap, where four phases are identified. These are external opportunities, internal opportunities, design & development and to conclude validation, implementation and scale-up. The activities to complete the phases are discovered and embedded in this research. After applying the four phases at Benchmark for the client Coloplast, eight ideas are found and assessed by experts. These eight ideas are: (1) conduct a research to find the weakest link in the product, (2) reduce or remove the glue from the production process, (3) offer a green alternative of the product to Coloplast, (4) use bio material instead of plastic for the packaging, (5) investigate if the instalment of solar panels is possible, (6) offer circular workshops at Coloplast, (7) incorporate circularity in the Hoshi Kanri (a tool to specify the company's strategy) and in the newsletter, and (8) the introduction of a circularity research group.

Value

The contribution of this research are the discovered and embedded activities, which are (1) the inclusion of the internal enablers and barriers, (2) incorporating the activities from the ReSOLVE framework from the Ellen MacArthur Foundation (2015) with the four strategies of Geissdoerfer et al. (2020), and (3) the introduction of a continuous improvement cycle. These activities, together with the model of Frishammar & Parida (2019), contribute to a more comprehensive roadmap. With the research on one particular product, this research provides the roadmap with the corresponding activities, as well as an example on how to execute the activities.

Limitations

This research lacks data on CO_2 emissions, amount of waste, but also on the costs and benefits of the proposed solutions, as well as a risk assessment on these solutions. Furthermore, none of the solutions are implemented at this moment. To conclude, the outcomes are limited as only twelve employees were interviewed.

Key words

Circular Business Model, Roadmap, Circular Business Model Innovation, Continuous improvement, Circular economy.

Acknowledgements

This thesis marks the end of my student life. In the past couple of years, I have had some great adventures and was able to learn a lot, for my study but maybe even more about myself. After working on it for the past 6 months, this thesis is the last assignment for my master's degree, which I could not have finished without the support of several people.

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Vincent Janssen

2022

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List of abbreviations

BM	Business Model
CBM	Circular Business Model
CBMI	Circular Business Model Innovation
CE	Circular Economy
CO_2	Carbon dioxide
EMF	Ellen MacArthur Foundation
IP	Intellectual Property
Mfg	Manufacturing
PCB	Printed Circuit Board
PSS	Product-Service-System
R&D	Research & Development
SG&A	Selling, General & Administrative Expenses

1. Introduction

This research is divided into six chapters, where the first chapter provides an introduction. In this chapter the situation is described, from which the research question is derived. To answer the main research question, sub research questions are formulated. The product that is used to test the roadmap that is proposed in this research will be described in Section 1.3. The product itself is used to transmit a signal when a stoma is leaking. To conclude, Section 1.4 provides an outline of the rest of this research.

1.1. Situation

Benchmark Netherlands is a company that offers customers Research & Development (R&D) services such as industrial design, electronics, mechanical and embedded software engineering, and fast prototyping. Next to these services, Benchmark also manufactures these products. Key market sectors serviced include complex industrial, defense, commercial aerospace, semiconductor capital equipment, and medical. The focus of Benchmark Netherlands is to serve the European clients, with Dutch clients in particular. One of these clients expressed the concern that the strategic focus on circularity is missing within Benchmark Netherlands. This focus on circularity concerns the areas of material scarcity, the increase of carbon dioxide (CO_2) emissions and waste dumped in the environment (Kirchherr et al., 2017). The effects affect all entities of the triple bottom line, which are the environmental, social and economic areas (Du et al., 2016). Benchmark Netherlands is therefore planning on integrating a circular economy, but the knowledge how this should be realised is missing, as well as a strategy to implement it. Since the organisation is starting without any form of prior research, a demand has arisen to integrate a CBM into the company, which serves as a starting point for the transition to a circular economy. Circular business models are used to drive the transition from a linear economy to a circular economy (Bocken et al., 2019).

Therefore the context of this research is to discover the barriers and enablers of implementing a circular business model at Benchmark, and to search for the internal capabilities that should be present in mature R&D service businesses (Lawson et al., 2015). This will be researched in the area of medical devices, as the customer of Benchmark which is used for this research produces these type of products. Further elaboration on the product will be provided in Section 1.3. When these aspects are determined, a strategy to overcome the barriers and utilise the enablers and capabilities should be written. A leading concept within this research will be Circular Business Model Innovation (CBMI), which can be defined as the conceptualisation and implementation of circular business models (Schaltegger et al., 2012).

1.2. Research question

Since this research will start without prior research within the company, and with no specific plans or actions to have a more circular production system, the transition from a linear business model to a circular business model contains the roadmap of the entire process. Therefore the research question that will be answered is:

'How to implement a roadmap for the transition from a linear business model to a circular business model in businesses that provide R&D services?'

1.2.1. Sub research questions

The first aspect that should be considered when designing a roadmap, is the scope of what will be integrated in the CBM, and what kind of CBM will be chosen (Comin et al., 2019). Ideally every aspect of the production, from designing the product to the reuse of compartments and materials, should be included in the CBM. However, due to limited resources, the scope of this research is narrowed down to a qualitative research. These limited resources are a time constraint and no data on the CO_2 emissions of Benchmark. The first sub question that should be answered is:

(1) What should be included in the scope when designing a roadmap for the transition to a CBM?

When the scope is clarified, the second step in this research is to identify the barriers and enablers to adopt a CBM. Step 3 in the process will be to identify the internal capabilities required to, ultimately, achieve a circular economy within the company. Step 4 will be to write a plan for a CBM with a strategy to implement it, taking into account the barriers, enablers and internal capabilities. As an additional step the use of maturity models will be examined. Therefore the following sub questions should be answered:

(2) What are the internal barriers and enablers within R&D service businesses for adopting a Circular Business Model concerning an electronic medical device?

(3) What are internal capabilities that employees in R&D service businesses should possess to successfully implement a Circular Business Model concerning an electronic medical device?

(4) What are strategies to select a CBM concerning an electronic medical device in R&D service business?

(5) Are maturity models an addition for a strategy to implement a CBM concerning an electronic medical device in R&D service businesses?

1.3. Product

The product covered by this study is used to transmit a signal when a stoma of a patient is leaking[1]. The main part is a transmitter which is attached to the digital leakage sensor layer. When the stoma leaks, this is detected by the sensors, which have been developed by another manufacturer. This is reported using the transmitter, which sends a signal that the user can find in the corresponding app on their smartphone. The transmitter consists of a printed circuit board (PCB) and a plastic housing for protection. The transmitter works on batteries, which can be charged via a customised charger, which is the second part of the product. The charger also works by means of a PCB. The charger is plugged into the socket through a USB-C cable, which is the standard and therefore purchased as a whole by Benchmark. Finally, the product is shipped to Coloplast, which is a company that provides service and products for patients with bladder and intestinal problems[2]. The product is shipped in a polystyrene packaging as depicted in Figure 1.

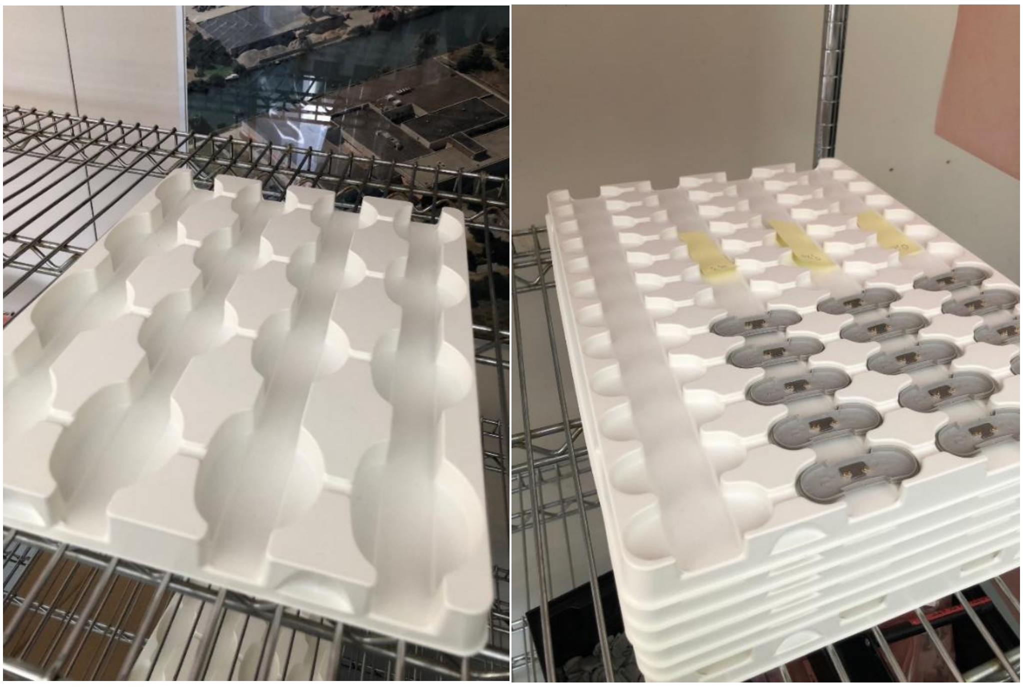

Figure 1. Polystyrene packaging towards Coloplast.

1.4. Outline of this research

The theoretical framework is described in Chapter 2, where definitions regarding this research are elaborated on. Furthermore, in chapter 2 a theoretical perspective is provided on a roadmap to design and implementation a Circular Business Model (CBM). In the last phase of the roadmap, maturity models are introduced. An explanation on how to proceed from the theory is the focus point in Chapter 3. An explanation on the interviews is provided, as well as the technique to analyse these interviews. Chapter 4 discusses the outcomes of these interviews, and the outcomes of the questionnaire. In this questionnaire, the solutions provided in the interviews are reviewed on impact, feasibility, profitability, willingness of the client and the time span. The solutions that are rated as the most promising and feasible solutions are stated in Chapter 5, with a comparison to innovative business models. Furthermore the current business model is reviewed and a continuous improvement plan is drawn. To conclude this research, Chapter 6 provides a discussion and a conclusion.

[1] Heylo product: https://ifdesign.com/en/winner-ranking/project/heylo/348443
[2] About Coloplast: https://www.coloplast.com/about-coloplast/

2. Theoretical framework

Definitions regarding subjects within this research will be elaborated on in the first section. The second section of the theoretical framework is an explanation on the outline of the roadmap for a CBM. Section 2.3 describes the first phase of the roadmap, which is the …. In Section 2.4, the second phase of the roadmap is described, which are the internal opportunities and shortcomings. The third phase of the roadmap is described in Section 2.5, where the design of the CBM and the alignment within the organisation are elaborated on. Lastly, in Section 2.6, the fourth phase of the roadmap will be described, with the subjects of the validation, implementation and scale-up of the CBM .

2.1. Definitions

In this chapter, the definitions of the circular economy, business models, CBMs and CBMI are elaborated on.

2.1.1. Circular economy

The concept of circular economy (CE) has gained popularity and support as the solution for resource scarcity, waste increase and an increasing amount of CO_2 emissions (Hansen et al., 2020; Kirchherr et al., 2017). The proposed alternative of a CE means that a company makes the transition from a traditional linear supply chain to a closed loop supply chain (Kirchherr et al., 2017). Within the linear supply chain, the 'take-make-disposal' principle is central (Antikainen & Valkokari, 2016), where resources are extracted, the product is produced and after use it is discarded. This is harmful to the environment as an increasing amount of waste is dumped, and emissions from the extraction of materials are increasing (Hansen et al., 2020). Within the circular economy, the aim is to reduce waste dump and CO_2 emissions to zero (Kirchherr et al., 2017). This is attempted by reusing products that are at the end of their life, in the production of a new product, extending the use-phase of a product or designing for an extended life cycle (Geissdoerfer et al., 2020). An overview of the circular supply chain is depicted in Figure 2.

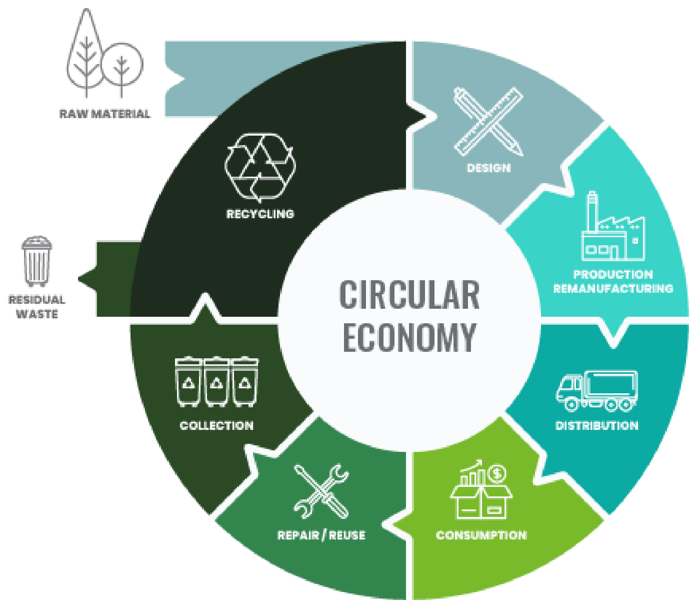

Figure 2. Interpretation of the circular economy.

2.1.2. Business Model

The concept of business models is hard to define, but can be interpreted as a unit that can be used for the analysis of a business (Zott et al., 2011). Following this assumption, the concept could be further elaborated on by stating that "*a business model describes the rationale of how an organization creates, delivers, and captures value*" (Osterwalder & Pigneur, 2010). The business model canvas of Osterwalder & Pigneur (2010) provides a comprehensive overview of what a company does, how the company is executing and which people are involved in the organisation (Joyce & Paquin, 2016). This canvas is depicted in Figure 3 and consists of nine components. An explanation of the key partners, key activities, the resources and the value proposition together explain how a company creates value (Joyce & Paquin, 2016). The type of connection with the customers, the type of customers and the communication channels provide an overview of how the value is delivered to the customer (Joyce & Paquin, 2016). To conclude, how a company makes profit describes how value is captured (Joyce & Paquin, 2016).

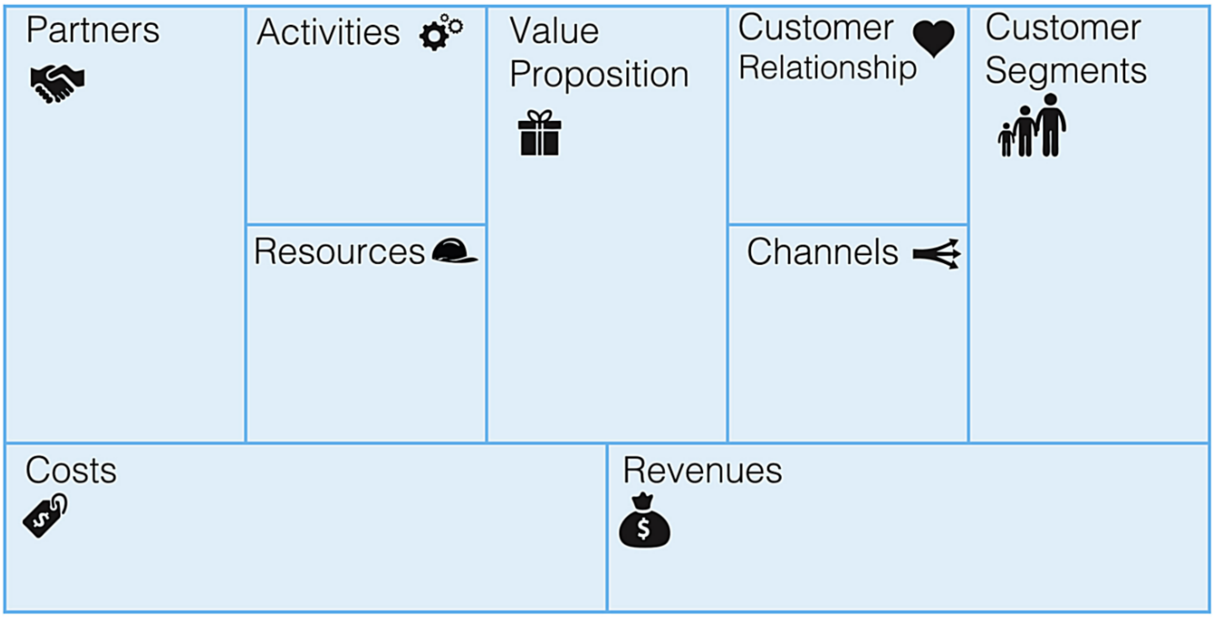

Figure 3. Business Model Canvas. (Osterwalder & Pigneur, 2010)

2.1.3. Circular Business Model

The essence of a CBM is to reduce the environmental footprint by tracing materials and creating value out of 'waste' (Bocken et al., 2019). Following Geissdoerfer et al. (2020), CBMs can be defined as "*business models that are cycling, extending, intensifying, and/or dematerialising material and energy loops to reduce the resource inputs into and the waste and emission leakage out of an organisational system."*. Another definition is provided by Bocken et al. (2019), who say that "*CBMs focus on slowing, closing and narrowing loops to maintain the embedded economic value for as long as possible, reduce environmental impacts and deliver superior customer value"*.

2.1.4. Circular Business Model Innovation

Circular Business Model Innovation (CBMI) can be defined as "*the conceptualisation and implementation of circular business models, which comprises the creation of circular start-ups, the diversification into circular business models, the acquisition of circular business models, or the transformation of a business model into a circular one*" (Geissdoerfer et al., 2020).

Another definition related to the subject of business model innovation is given by Bocken et al. (2019), who state that "*Business model innovation can be thought of as an iterative process that consists of several phases (e.g., ideation, implementation and evaluation) and involves different levels of detail (e.g., changes at a conceptual level to changes in operational practices)*". It serves either as the reconfiguration of a BM, or the design of a new BM (Antikainen & Valkokari, 2016).

The concept of CBMI not only compromises the design of a CBM, but also the implementation, whether or not as an improvement or an extension of an already existing CBM, or the transition from a LBM to a CBM (Bocken et al., 2019). The design of a CBM differs per situation, and accordingly so does its implementation and the strategy for adopting the CBM within the company (Bocken et al., 2019). Especially within incumbent companies, that have made no changes in the production process ever, the transition to a circular economy is challenging. To support and facilitate this transition, enablers, barriers and capabilities should be identified to ensure the successful design and implementation (Urbinati et al., 2021).

2.2. Outline of the roadmap

A lot of research is conducted on the concept of a CBM and the urgency to implement it (Antikainen & Valkokari, 2016). In addition, many studies can be found on the implementation of a CBM. However, at this moment there is no complete roadmap with clear steps for an incumbent firm that provides R&D services in the medical field. Besides, there is also a limited amount of literature on PCBs and the thrive for circularity in this field.

An explanation of how an incumbent company can go from a linear to a circular economy is explained by Frishammar & Parida (2019), however, the provided roadmap is too general as the exact course of actions is missing. Key activities are mentioned, but a strategy on how to carry them out is not included. The roadmap designed by Frishammar & Parida (2019) is, however, a clear, general structure to start with, which is why this roadmap is further used as the structure in this theoretical framework. The roadmap consists of four phases. The first phase elaborates on the external transformation opportunities for incumbent companies, whereas the second phase is related to the internal transformation opportunities. After the external and internal opportunities are examined, the CBM is designed and developed in the third phase. The fourth and last phase is dedicated to the implementation and validation of the CBM, as well as the scale-up of the CBM (Frishammar & Parida, 2019).

A study by Planing (2015) is strongly focussed on the adaptation of CBMs and the reasons for consumer non-adoption. Several CBMs are presented, but the mechanism on how to select the best suited CBM is missing. Antikainen & Valkokari (2016) mentioned that "*there is a lack of frameworks for supporting business model innovation in companies in the context of a circular economy*". According to Antikainen & Valkokari (2016), newcomers can design their business model for circularity, but redesigning an existing business model is perceived as a major challenge. To fill the gaps of a CBM selection procedure and a framework for CBMI support, Reim et al. (2021) composed a decision tree, including tactical choices, but this decision tree is restricted to Product-Service- System (PSS) solutions. This type of CBM will be elaborated further on in the second phase of the roadmap.

Nussholz (2018) developed a visualisation tool to guide practitioners in circular business model innovation. An introduction is made into the elements of a CBM in relation with some of the Rs that are depicted in Figure 4 (Yildizbasi & Arioz, 2021), but this is standardised and key activities are not mentioned. Besides, not all R-strategies are included. Therefore, Geissdoerfer et al. (2020) propose four strategies that extend existing business models to reduce resource and energy inputs, and the waste and emission leakage in the material and energy loops.

The CBM strategies that can be derived from this process consist of cycling, extending, intensifying or dematerialising (Geissdoerfer et al., 2020), and encompass the complete field of the R-strategies. The intensifying strategy directly relates to R1 of Figure 4, dematerialisation is mentioned in the R2 strategy. For the extending strategy mentioned by Geissdoerfer et al. (2020), the R4 strategy applies as the product is designed for renovation, maintenance and the use phase is extended (Yildizbasi & Arioz, 2021). The strategies listed under R5, R6, R7 and R8 are all part of the cycling strategy. To further guide the strategies with actions, the Ellen MacArthur Foundation (EMF) (2015) composed the ReSOLVE framework, which consists of six actions with the purpose to guide the transition from a linear to a circular economy.

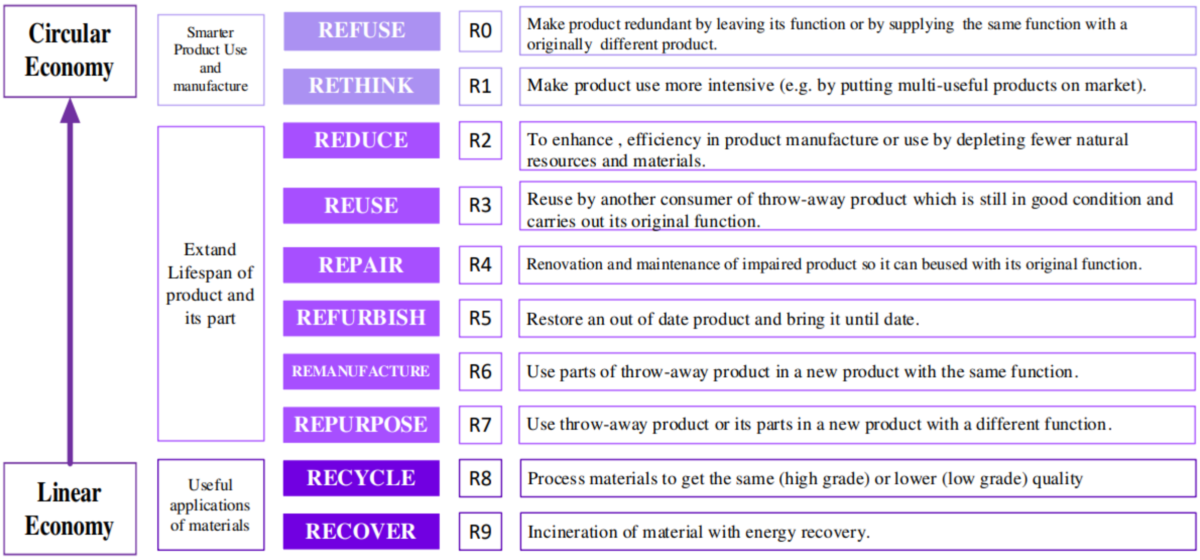

Figure 4. R-strategies. (Yildizbasi & Arioz, 2021)

2.3. Roadmap phase one: Transformation requirements of the CBM

Phase one of the proposed roadmap by Frishammar & Parida (2019) is the phase where trends and guidelines are scanned and read through for opportunities. Next to this, the ecosystem in which the company operates is investigated, and to conclude a customer analysis could be performed to get a better understanding of the ecosystem the circular business model is meant for. This is performed in this study by providing an overview of the enablers and barriers of a CBM. The outcomes of this phase should be a comprehensive understanding of the transformation requirements.

The changing requirements of customers are causing businesses to review how they offer their products (Marzec, 2016). The trends that cause the requirements to change are mainly focused on a financial profit for the customer, while reducing emissions and waste (Cadez et al., 2019). The general trends are highlighted in the study of Marzec (2016), which focusses on globalisation development, a shift in culture values and the use of modern techniques.

The globalisation development resulted in a legislation trend, which obliges companies to behave in an environmentally responsible manner. This is facilitated, among other things, by cheaper production in other countries, with the logistics causing rising CO_2 emissions (Berger-Walliser & Scott, 2018). Cultural values are ever changing, resulting in different requirements from the customers. Climate change mitigation is a topic which is highly valued nowadays, and customers aim to contribute to the mitigation (Cadez, Czerny & Letmathe, 2019).

Therefore, to comply with this change in cultural value, business should aim to provide the opportunity to do so (Cadez et al., 2019). Finally, the integration of modern technologies could mitigate the CO_2 emissions too (Marzec, 2016). Following the study of Derendiaeva (2022), trends in the United States of America concern energy conservation, whereas the United Kingdom focusses on low carbon emission vehicles. China is planning on a carbon tax, and meanwhile is focussing on using renewable energy sources (Derendiaeva, 2022). In all of the three nations, the usage of green energy is stimulated by various projects which are referred to as the 'Green investment' (Derendiaeva, 2022).

2.3.1. Medical products trends

Observations from the medical field relate to a service-oriented design solution (Cengjuan, 2022), and pharmaceutical packaging (Salmenperä et al., 2022). The goal is to reduce the amount of pharmaceutical packaging waste, as well as preventing packaging waste to enter the environment (Salmenperä et al., 2022).

2.3.2. PCB trends

Due to the complexness of the design of a PCB, the trends related to circularity comprise the area of recycling. Literature suggests this can be achieved by dismantling and crushing at high temperatures (Qiu et al., 2021), chemical-free green ultrasonication technology (Jadhao et al., 2020) or using a shredder and multiple scraping techniques (Li, & Xu, 2010). Besides, regarding EU legislation on PCBs, selective treatment of PCBs greater than ten square centimetres is required from electronic waste (European Union, 2012). A PCB should meet the RoHS (Restrictrion of Hazardous Substances) requirements which will result in a C E quality mark. Without the C E quality mark a company cannot sell its products in countries that are part of the European Economic Area.

2.3.3. USB-C cable and charger trends

The USB cable used is the Type-C, which must comply with the regulations as stated in the USB-IF specifications. This is currently the most used USB type (Starr & Gazali, 2019), which prevents the necessary acquisition of a new one when it no longer functions. Additionally, the RoHS requirements should be met for both the charger and the USB-C cable.

2.3.4. Enablers and barriers

The aim of the first phase of the roadmap is to gain an overview of the opportunities for a shift to a circular business model. However, whereas Frishammar & Parida's (2019) model primarily focuses on the external opportunities for the transition from a linear to a circular BM, the internal organisation will not yet be investigated thoroughly. The essence to conduct an internal investigation stems from the fact that there are both enablers and barriers within an organisation that need to be identified before a CBM can be designed and implemented. If essential enablers are missing, or insurmountable barriers are detected, the transition to a circular economy will be impossible to be completely successful (van Keulen & Kirchherr, 2021).

Urbinati et al. (2021) identified multiple internal enablers and barriers, which could be categorised as technical, informational, technological, supply chain, customer management or organisational related. Important enablers identified are the availability of partners in the supply chain, technical solutions for Rs practices as can be seen in Figure 4 and technical solutions for a reverse supply chain (Urbinati et al., 2021). These enablers are related to the technical, informational and technological categories, whereas important enablers as a high price of input resources and a high volatility of input resources' price can be financially categorised (Urbinati et al., 2021). However, the most important enabler identified in Urbinati et al. (2021) is the environmental awareness and dedication of the management.

The categories identified as internal barriers relate to management, finances, information and organisation (Urbinati et al., 2021). A lack of knowledge and information on how to design and implement a CBM is also identified by Vermunt et al. (2019), where in addition the lack of the required technology presence or technical know-how contributes to the barriers. The risks associated with this lack of knowledge are often perceived as too challenging, and the investment costs could therefore not be justified. The financial barrier accompanied with a high perceived risk is another area of interest for the internal investigation (Vermunt et al., 2019). The third area of attention to address are the organisational barriers, where intrinsic motivation of both employees and management could become a barrier, as well as the company culture (Urbinati et al., 2021). A lack of interest or perseverance by the management team, missing intrinsic motivation to adjust the production process by the employee or an aversion of change in the company culture all contribute to a possible failure of the design or implementation of a CBM (Vermunt et al., 2019; van Keulen & Kirchherr, 2021).

The main barriers related to the medical field are the quality and safety requirements, which are relatively high (Alshemari et al., 2020). Decontamination or disinfection by sterilisation is a solution, but a study to determine whether the advantages outweigh the costs is missing (Damha et al., 2019).

2.4. Roadmap phase two: Opportunities and shortcomings in the current BM

Roadmap phase two aims to provide an overview of the current business model, and to identify the opportunities for a CBM and the shortcomings of the current business model. In this phase the triple bottom line is a central subject, however, the social aspect is receiving less attention. Where the model presented by Frishammar and Parida (2019) includes the social aspect, the scope of this study is to design a circular business model, which following the literature (Hansen et al., 2020; van Keulen & Kirchherr, 2021; Kirchherr et al., 2017) aims at reducing the environmental impact whilst increasing the profit. The social aspect will be highlighted in phase four.

The ecosystem that will be included in the transition to a CBM will be analysed according to the value capture, value delivery and value creation dimensions of the business model canvas of Osterwalder and Pigneur (2010). Besides the mapping of the value creation, value delivery and the value capture, the customers and customer segments should be mapped simultaneously (Frishammar & Parida, 2019). The understanding of the customer segments that are served, as well as the individual customers themselves, is an important aspect of understanding the current business model (Osterwalder & Pigneur, 2010). The results of a changed business model also affects the customer, so an analysis on this subject is necessary for the successful implementation of an improved business model (Marzec, 2016).

The final key activity in this phase is the determination of the scope for the transformation. The nine dimensions of the business model canvas from the first phase will be connected with the opportunities and shortcomings, and the magnitude of change for each dimension will be determined (Frishammar & Parida, 2019). Together, the key activities in phase two will ensure that the opportunities, the shortcomings and the scope for the transformation to a circular business model within the current business model are made explicit (Frishammar & Parida, 2019).

2.4.1. Circular business model strategies, measures and actions

The key opportunities and shortcomings will be reviewed by explicating the concepts of value creation, value delivery and value capture (Hansen et al., 2020), and construct the relationship with the four CBM strategies identified by Geissdoerfer et al. (2020). These strategies are cycling, extending, intensifying and dematerialisation (Geissdoerfer et al., 2020).

Cycling measures comprise the recycling of materials or energy streams. This can be achieved by reusing, remanufacturing, refurbishing or recycling (Geissdoerfer et al., 20202). The timing of utilising the correct process for materials is displayed in Figure 5. These processes can be carried out when a product no longer can serve its function and no longer has the desired quality (Kirchherr et al., 2017). The product can be repaired and reused without the need to disassemble it, e.g. a bottle reuse system, or can serve another purpose, e.g. a car tyre can be used as a flower container. In the situation of a disassembly of the product, the processes of refurbishing or remanufacturing can ensure the reuse of parts and products (Thierry et al., 1995). By extracting a part from a discarded product, a product can be remanufactured by placing the working part in the product (Kirchherr et al., 2017). Refurbishing a product relates to the process of improving an old product to a certain level of quality, being the quality level of a completely new product or slightly below (Thierry et al., 1995).

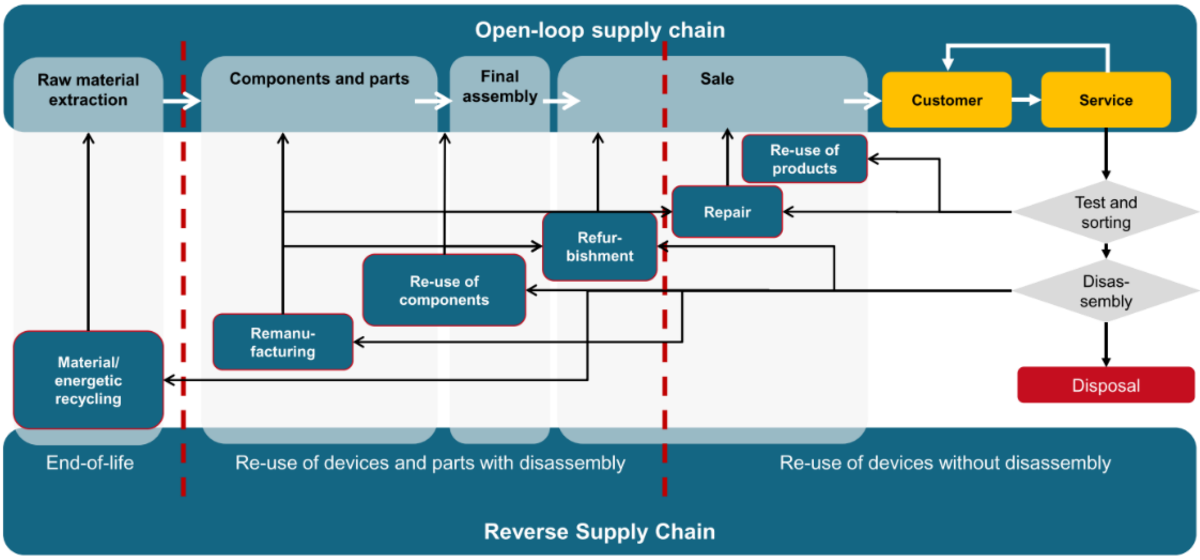

Figure 5. Reverse Supply Chain. (Derived from Thierry et al., 1995)

The cycling measures relate to the loop action, as proposed in the ReSOLVE framework of the EMF (2015). The loop action is described as "*keeping products and materials in cycles, prioritising inner loops*", where processes as refurbishment, remanufacturing, recycling and reusing are central (EMF, 2015). To determine whether a measure is proportionate with the expected savings, the description of the measures in the guideline of the VDI 3800 (2001) will also be taken into account. The measures of the guideline are process-integrated, product-integrated, in-plant or end-of-pipe (VDI 3800, 2001). The combination of the CBM strategies by Geissdoerfer et al. (2020), the action framework of the EMF (2015) and the financial measures of the VDI 3800 guideline (2001) provides an overview for a comprehensive framework to identify the shortcomings and the opportunities in the current business model. Figure 6 provides an overview of how these concepts are related.

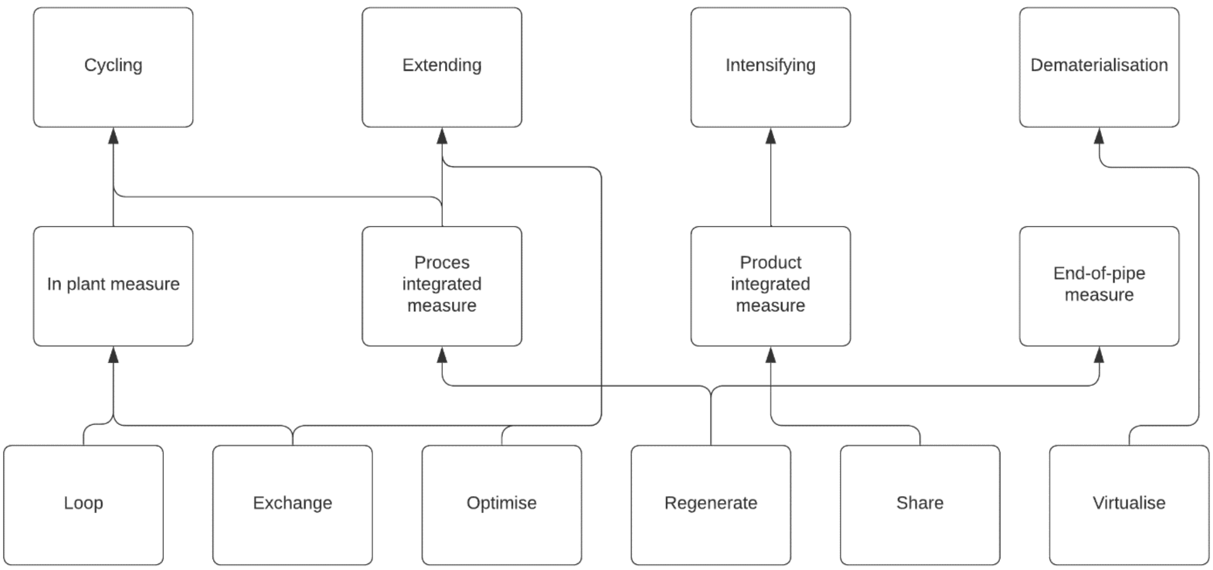

Figure 6. Circular Business Model framework. (Derived from Geissdoerfer et al., 2020; EMF, 2015; VDI 3800 guideline, 2001)

The process-integrated measures are related to the cycling measures, as these measures contribute to a lower environmental impact, e.g. by making use of recycled materials (VDI 3800, 2001). Next to the process-integrated measures, the plant-integrated measures also focus on the circulation of materials and products. An example of a plant-integrated measure is the reuse of internal heat waste (VDI 3800, 2001). The costs associated with the in-plant measures are easily computed, as these investments are registered as environmental protection measures in the plant.

The benefits from these measurers can be easily computed, as they can be derived from other companies. In-plant measures are usually not unique, so similar computations from other companies can be used as an initial calculation. Actions related to the in-plant measures can also be derived from the correct selection of resources and technology, or exchanging as stated by EMF (2015). By replacing traditional resources or technology with modern solutions, an optimal usage should be identified to minimise the environmental impact. A study by Schulte et al. (2021) provides evidence that medical recycling is a viable solution. End-of-life recycling of PCBs is possible (Rocchetti et al., 2018), however, the chemical technique that is mostly used is environmentally-unfriendly (Hadi et al., 2015). Due to the usage of the USB-C standard, cables from other electronic devices could be reused. Packaging made from polystyrene could be reused for the same purpose, or could be recycled (Samper et al., 2010).

2.4.2. Extending

The process-integrated measures also relate to the extending CBM strategy of Geissdoerfer et al. (2020). Extending a product is mainly focussed on improving the design for a longer lasting product, which can be easily repaired and is timeless designed for maintenance. By implementing a long-lasting design, the use phase of a product can be extended. Related to Figure 5, the long lasting design results in the repair without disassembly, decreasing repair costs and increasing efficiency (Geissdoerfer et al, 2020). The relation with the process-integrated measures is the focus on changing the design to minimise the creation of pollutants and the amount of emissions (VDI 3800, 2001).

Following the ReSOLVE framework, the proposed actions associated with the extending strategy are optimising and exchanging (EMF, 2015). Optimising the system performance is achieved by decreasing the resource usage and prolonging an asset’s life, so extending the use phase. Exchanging the resources and technologies used in the design phase of the production process, the use phase of the product can be extended (EMF, 2015). Next to these actions, also regenerating materials and products could be applied when implementing the extending strategy. Regenerating focusses on the resilience of ecosystems, which should be increased, restored and safeguarded, alongside the biological nutrients which should be returned to the ecosystems (EMF, 2015).

The action complies with the measures of the process-integrated measures of the VDI 3800 guidelines (2001). The change in design is applicable for medical products, however, the functional reliability must be ensured (O’Leary, 2009). This can be achieved by designing modular products to ensure multiple life cycles (O’Leary, 2009). A similar technique is applicable for PCBs (Tóth et al., 2007) The USB-C standard design ensures cyclability, preventing additional design changes. Packaging could be improved by designing reusable options (EMF, 2017).

2.4.3. Intensifying

The third strategy mentioned by Geissdoerfer et al. (2020) focuses on intensifying the products’ use phase. An important aspect to increase the efficiency of the use phase is to introduce a product-service system (PSS) (Amaya et al., 2013). These systems are designed to provide service after the product is sold, or providing service as the selling strategy, resulting in an extended relationship between the customer and the producer which increases the loyalty (Green et al., 2017).

There are three categories that could be identified as a PSS (Tukker, 2015). The first category, the product-oriented PSS, is oriented at selling products as the foremost activity, however, additional services as consultancy, insurance or maintenance contracts, or general advice is included in the business model (Tukker, 2015). The second category is the use-oriented PSS, where a company shifts from the traditional product selling approach to the provision of a service, which could be product leasing, renting, pooling etc. (Annarelli et al., 2016). The final category is result-oriented, where the ownership of the product shifts from the manufacturer to the customer (Tukker, 2015). This can be achieved with a pay-per-service unit business model, outsourcing or a functional result (Tukker, 2015).

The intensification of a products use phase could therefore be achieved by sharing, as is best described by the use-oriented PSS. According to the EMF (2015), the sharing element that can be applied has the purpose of the asset being optimally utilised by pooling and reusing, where the examples given for the use of a PSS correspond with the options of a sharing business model (Tukker, 2015; EMF, 2015). In relation to the measures of the VDI 3800 (2001), the product-integrated measures reflect the intensification of a product, as it focusses on the complete product life cycle. To determine whether the measures are proportionate with the costs, the investment costs should be taken into account. Operating costs are not considered in the equation, as the operating costs for the complete life cycle should then be calculated and will not reflect the effect of these measures. Therefore the investment costs will be the determining factor in the calculation. The implementation of a PSS in the medical field depends on the situation, however, the study of Pourabdollahian & Copani (2015) provides evidence of a successful implementation. Operating a PSS for PCBs and USB-C cables is relatively easy, as it not necessary that the customer owns the hardware (Lee et al., 2017).

2.4.4. Dematerialisation

The last strategy mentioned by Geissdoerfer et al. (2020) is the concept of dematerialisation. To achieve the dematerialisation, a PSS can be installed. Where the intensifying of a product focusses on the service provided after a physical product is sold, the PSS with a focus on dematerialisation aims to provide the service as the product. The PSS will therefore be designed as a result-oriented system, aiming to decouple resources, and shifting the ownership of the product to the customer (Tukker, 2015; Geissdoerfer et al., 2020). The product- and use oriented systems are not appropriate for the dematerialisation strategy, as it can result in a rebound effect. The rebound effect is a phenomenon that could occur when an increased efficiency leads to a bigger consumption, due to the product being relatively cheaper (Zink & Geyer, 2017). Therefore, the environmental impact of the increased production could offset the benefits of the efficiency gain (Zink & Geyer, 2017).

To successfully dematerialise, a company should aim to virtualise their services and locations (EMF, 2015). With the rise of the internet in the 21st century, the shift to selling and providing a service online is becoming ever attractive, resulting in a decreased environmental impact at the same time. The logistics will also be influenced by the shift to a virtual workspace, reducing the emissions of cars, aeroplanes etc. (EMF, 2015). Reusable medical products could be used in a result-oriented PSS, however, due to the high quality standards and the safety measures, this type of CBM is unsuitable for non-reusable medical products (MacNeill et al., 2020). Printed circuit boards and chargers have become smaller and required less materials, and with improving technology this trend will continue (Kasulaitis et al., 2019). Plastic packaging reduction can be achieved with various techniques, depending on the situation (Nwachokor, 2020).

2.4.5. End-of-pipe measures

There is one type of measure following the VDI 3800 guidelines (2001), which is not mentioned by Geissdoerfer et al. (2020). This type of measure is referred to as end-of-pipe, where these measures apply to the waste generated in the production process, preventing the waste to end up in the environment (VDI 3800, 2001). Measures to prevent the waste dump are incineration plants, waste water control plants and exhaust gas cleaning equipment (VDI 3800, 2001). Following the actions from the ReSOLVE framework of the EMF (2015), regenerating materials and products also stimulates the end-of-pipe measures. By safeguarding and improving the resilience of the ecosystems, the waste emissions generated in the production process will be minimised or completely captured.

2.4.6. Connection of the Business Model Canvas with the Circular Business Model strategies

To connect the Circular Business Model framework with the business model canvas of Osterwalder & Pigneur (2010), the benefits for the core concepts of value creation, value proposition and value capture should be analysed. To identify the benefits, the motivation for circulation, which is also referred to as the resource strategy (Bocken & Ritala, 2021), must be analysed. According to this model, there are three strategies towards a circular economy, where loops can be closed, slowed down or narrowed (Bocken & Ritala, 2021). Within this research, these strategies are tested within the domain of an open innovation, a closed innovation domain is beyond the scope of this research. A closed innovation domain is applicable if a company chooses to keep the innovation process internally and prefers to keep the knowledge and technology in-house (Bocken & Ritala, 2021). Given the fact that this research focuses on companies that operate as an R&D service provider for other companies, it is a logical consequence to analyse only open innovation strategies.

The closed loops create the biggest positive effect on the environment, since the materials and products are reused within the production process. Ultimately, this is the purpose of circularity, which also avoids the mining of new resources. In addition to a value proposition for the environment, this also has a clear economic value, given the increasing scarcity of natural resources (Schmidt, 2018). This value is created by integrating resources from both internal and external resource flows into the production process and then offering this to the customer. The value capturing consists of lower costs for resources and greater independence, which results in a constant price for resources without excessive outliers. In addition, the company's image is improved, resulting in more customers and increased loyalty. The area of focus in the cycling strategy of Geissdoerfer et al. (2020) is at the end-of-use phase, which corresponds with the concept of the closed loops (Bocken et al., 2021).

Slowing a resource loop refers to "*prolonging the useful life of products and parts*" (Nussholz, 2018), directly relating to the strategy of extending as proposed by Geissdoerfer et al. (2020). However, where the extending strategy focusses on altering the design for a longer use life, the resource slowing loop aims to extend the use phase by selling the products and parts at a lower quality than its original. Therefore, the strategy of intensifying is more suitable to serve as a solution to slow resource loops (Geissdoerfer et al., 2020). By reducing the total idle time of a product, the total waste is reduced (Nussholz, 2018). The value proposition serves new customers who accept the lower quality for a lower price, whereas the value is captured by selling enhanced used products and parts, and value is created by lowering the standard for the product and prevent waste.

The goal of the narrowed resource loops is to reduce the number of resources used, by working together with other companies. The efficiency of the processes is central, with efficiency in the supply chain seen as the area where most impact can be made (Bocken & Ritala, 2021). The value proposition is the reduction in waste and resources, the value creation is achieved through a reduced negative impact on the environment and an improved relationship with the supplier and/or the customer (Bocken & Ritala, 2021). The value capture relates to the reduced costs for buying raw materials and waste disposal. Reducing the number of resources needed corresponds with the dematerialisation strategy of Geissdoerfer et al. (2020), however, the focus of the narrowed loops is not solely on providing services and software. Dematerialisation can be identified as a solution for narrowing resource loops, and is the most permanent solution to require less resources (Geissdoerfer et al., 2020; Bocken & Ritala, 2021). Due to the scarcity of materials, medical products, PCBs and USB cables are already efficiently designed. Manufacturing and packaging waste could be reduced by implementing resource loop narrowing strategies (Singh et al., 2017).

2.5. Roadmap phase three: Design and adaptation alignment of the CBM

Roadmap phase 3 is the design and development of the circular business model. To achieve the revised business model with circular properties, four key activities should be performed (Frishammar & Parida, 2019). Following Frishammar & Parida (2019), the first activity is aimed at the design of the model, where innovative business models are studied and analysed. This analysis is conducted in order for the company to create a benchmark and to investigate whether it could imitate and adjust one of the innovative circular business models, compensating a lack of information on the subject (Huppler, 2009; Burkert & Schwaiger, 2021). The benefit of imitating a business model is the assurance that the model is operative and successful, according to Burkert & Schwaiger (2021), whilst minimising the risk of making the wrong decisions (Cano-Rodríguez et al., 2017).

The remaining three activities mentioned in the third phase of the roadmap of Frishammar and Parida (2019) are to obtain internal and external alignment, and to ensure that the nine dimensions of the business model canvas are coherent with each other. Changing the business model may also require an adjustment in culture, and different departments within the same company may need to collaborate and communicate with each other in a renewed way (Santos et al., 2009). In addition, implementing a circular business model is also likely to cause new stakeholders to enter the ecosystem, with whom there is a need to collaborate as a whole supply chain, rather than communicating in a linear, on a supplier to customer, basis (Cristoni & Tonelli, 2018).

2.5.1. Innovating business models

In order to maximise the outcome of the benchmarking, innovative business models in the areas of medical products, PCBs, USB-C cables and packaging are being investigated. A research into circular business models for medical products was carried out by Guzzo et al. (2020), from which nine models emerged. An overview of these models can be found in Figure 7.

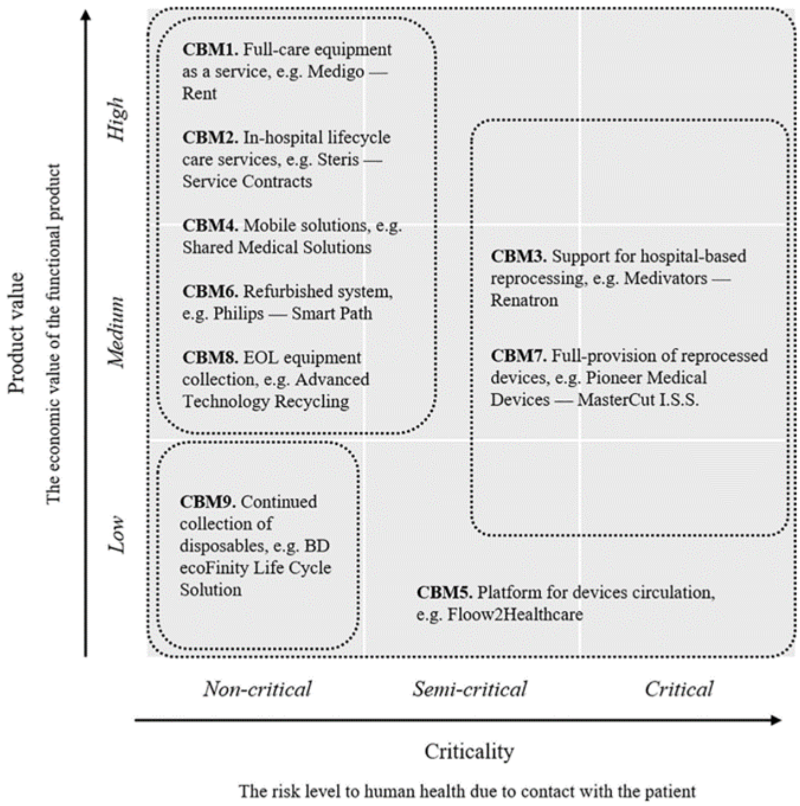

Figure 7. Circular Business Models in the medical device industry. (Guzzo et al., 2020)

Here, a distinction is made between the value of a product and its criticality so that the right business models can be investigated (Guzzo et al., 2020). PCBs can be classified as high value products, as it depends on high technology, USB-C cables are estimated to have medium product value and packaging are low value products (Guzzo et al., 2020). PCBs, USB-C cables and packaging are estimated as non-critical products, given that these products only come into contact with intact skin, and require decontamination with low-level disinfectants (Guzzo et al., 2020).

Therefore, CBMs 1,2,4, 6 and 8 will be investigated for the PCBs and the USB-C cables. CBM 9 will be investigated for the packaging. CBM1 can be described as a combination of use-oriented and product-oriented PSS (Tukker, 2015). This combination follows both the intensifying strategy and the extending strategy (Geissdoerfer et al., 2020). Products can be accessed on a contract base through renting or leasing, and maintenance and repair is provided due to parts being designed to be repaired without assembly (Tukker, 2015; Guzzo et al., 2020). In a study by van Boerdonk et al. (2021), ten hospitals were analysed and six hospitals used this type of CBM, be it only for large investment products. This type of CBM can be suited for a modular PCB plant, which can be leased for the recycling of PCBs (Rosa et al., 2019). Due to the low costs of USB-C cables, this type of PSS is not suitable for this product.

CBM2 is a contract-based maintenance service, which could be specified as a result-oriented PSS (Tukker, 2015). This could be linked to the dematerialisation strategy, as the ownership of the product shifts to the customer (Geissdoerfer et al., 2020). Due to the complexness of PCBs, this type of CBM is not suited for this product. USB-C cables could be used in this type of CBM, however, due to the low costs this CBM will not be economically viable.

CBM4 is classified as a use-oriented PSS, thus related to the intensifying strategy (Geissdoerfer et al., 2020). Mobile solutions for high-value equipment in short-term renting schemes will be used by multiple hospitals, which could be a viable CBM for products with PCBs (Guzzo et al., 2020). The USB-C cable already is designed and produced for mobile solutions, leading to a decrease in e-waste. One cable can be used for multiple devices.

CBM6 as proposed by Guzzo et al. (2020) is the introduction of a refurbishment system, which is already implemented by seven of the ten hospitals in the study of Boerdonk et al. (2021). PCBs are normally not refurbished, due to the large financial risk in case of failure and the inability to implement new technologies (Pamminger et al., 2018). Similar to the previous CBMs, USB-C cables are not suitable due to the low costs.

CBM8 is the last CBM for medium and high value non-critical products and is designed for end-of-life equipment collection, with the purpose to remanufacture or recycle (Guzzo et al., 2020). Take-back centres could aid this process, by lowering the threshold for customers to return electronic devices (Tukker, 2015), which is also suggested by multiple hospitals (Boerdonk et al., 2021). Another supporting concept is modular design of medical products, in order for functional parts to be reused, and broken parts to be repaired, refurbished, remanufactured or replaced (O'Leary, 2009). This is especially viable for USB-C cables, however, products with PCBs can benefit from modular design, by reusing the PCB itself if it is easily disassembled (Nissen et al., 2017).

The recycling of PCBs is traditionally divided in five steps, which are pre-treatment, disassembly, shredding, separation and refining, as can be seen in Figure 8 (Rosa & Terzi, 2016). According to Rocchetti et al. (2018), pre-treatment and micro disassembly and solder in melting can result in recyclable components for new PCBs. The non-metal materials resulting from the micro separation can be treated or crushed to be reused as resin, glass fibre or plastics (Rocchetti et al., 2018). From the metallic materials, after refining, Copper, Gold, Silver, Tin, Nickel, Palladium, Lead, Iron, Cobalt and Antimony could be recovered (Rocchetti et al., 2018). As for the profitability of recycling PCBs, the net present value of recycled PCBs is positive for IT, telecommunication and consumer equipment (Cucchiella et al., 2016).

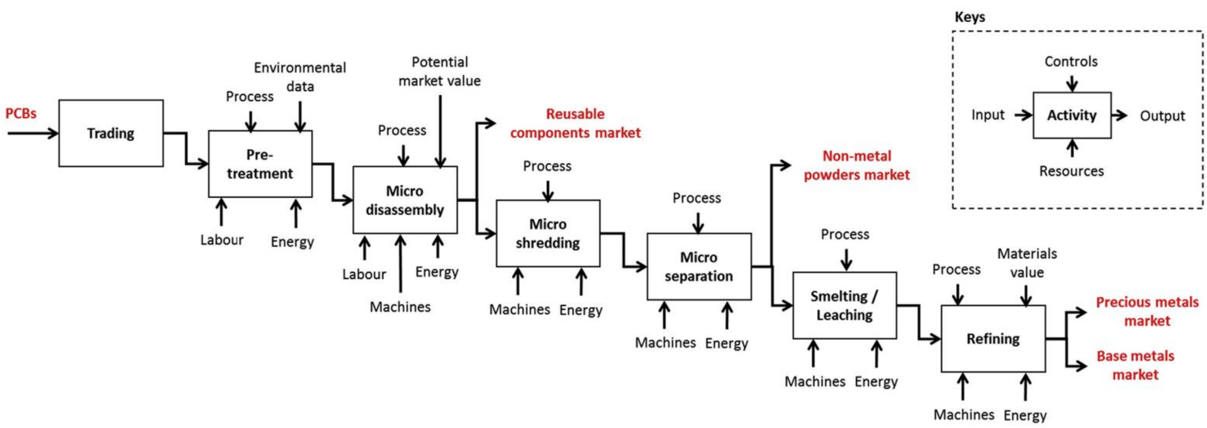

Figure 8. Process of recycling PCBs. (Rosa & Terzi, 2016)

Concerning CBM9, the recycling of plastic packaging has potential to decrease the amount of toxic gases from the incineration of medical waste (Guzzo et al., 2020). Packaging could be improved by designing reusable options (EMF, 2017), whereas various techniques could aid plastic packaging reduction (Nwachokor, 2020). Regarding tray packaging waste, polystyrene based trays show the lowest environmental impact (Maga et al., 2019), whereas polypropylene has the greatest potential for recycling (Faraca & Astrup, 2019). The trend in alternatives in plastic packaging for Europe can be related to extended producer responsibility (Watkins et al., 2017). This improved responsibility will result in an increase in recycling and a cost efficiency in this process. However, due to a lack of a common approach, and data to support an approach, the policy of extended producer responsibility is not adopted yet (Watkins et al., 2017).

2.5.2. Internal alignment

According to Frishammar & Parida (2019), the internal alignment is necessary for firms who are shifting their business from selling a product to selling a solution. The solution that is going to be offered is equal to the unique selling point of the company, which makes it important to gain a sustained competitive advantage (Reim et al., 2021). To achieve a sustained competitive advantage, it is necessary that the required resources and internal capabilities are present, and that a culture is present in which these can be fully utilised (Kraaijenbrink et al., 2010). As stated by Reim et al. (2021), capabilities can be described as "*combinations of routines that provide a structured approach for mitigating new challenges and promoting organizational change*".

The internal capacities that should be present within a company are further highlighted in Burger et al. (2019). This study first discusses the basic capabilities, which are related to acquiring and facilitating knowledge. This assumes a certain degree of basic knowledge, and the ability to apply procedures to acquire knowledge quickly (Burger et al., 2019). Soft skills and hard skills are both part of the basic knowledge. The acquisition of knowledge is required for the identification of complex problems, and the evaluation and implementation of solutions (Burger et al., 2019). The evaluation of the solutions should be based on a competent resource management, whereas the implementation of the solutions should be performed by an employee with social skills as coordinating, persuading, instructing and negotiating (Burger et al., 2019). The sociotechnical systems situated within a firm should be monitored, understood and improved with the proper system evaluation. Furthermore, analysis skills and knowledge on how to make the right judgement and decisions is relevant to improve the systems (Burger et al., 2019). To conclude, technical skills are required to make the implementation of the CBM a success, by operating, designing and correcting malfunctions of machines or technologies (Burger et al., 2019).

2.5.3. External alignment

The external alignment is equally important as the internal alignment for the successful design and implementation of a CBM (Frishammar & Parida, 2019). The changing dynamics with one or multiple stakeholders in the ecosystem requires a revision in the alignment (Velter et al., 2020). This could be caused by a shift in the authority of the product, a stakeholder that entered the ecosystem, the requirement of different materials, etcetera (Ooi & Husted, 2021; Westerman et al., 2020; Hidden & Tresman, 2020). There will also be a shift in finances, given possible changes in product design, authority over the product and contracts with new stakeholders (Ooi & Husted, 2021). To keep track of the shifts in the ecosystem, and to verify if everything is properly externally aligned, a process tool to facilitate the multi-stakeholder alignment is composed in the study of Velter et al. (2021).

First, there is a need for a collective ambition, to align the interests and the opportunities within the multi-stakeholder network (Smets et al., 2020). To achieve the highest level of alignment of the ambition, the interests and opportunities must be considered in the areas of the triple bottom line, i.e. the environmental, social and economic areas (Brenner, 2018). Simultaneously, the organisational boundaries should be reviewed and aligned (Brenner, 2018). To achieve the alignment, the stakeholders map their preferred organisational boundaries and negotiate within the multi-stakeholder network (Velter et al., 2021). Negotiating the organisational boundaries clarifies the tensions and the opportunities, and in the case of a surplus of tensions and opportunities, a ranking should make clear how to proceed (Velter et al., 2021). After the clarification of tensions and opportunities to proceed with, an intervention to help utilising the opportunities and overcome the tensions should result in the multi-stakeholder alignment (Chen et al., 2021).

2.5.4 Coherency

To conclude this phase, the design should be aligned both internally and externally and the dimensions in the CBM should be coherent altogether. By changing one or multiple dimensions of the business model canvas, the alignment between the dimensions that was established could become imbalanced (de Oliveira & Cortimiglia, 2017). An altered business model could offset the profit, customer segments may not be suited with a transformation of the value proposition, or a certain supplier may not be qualified anymore following a revision in the key activities (Sjödin et al., 2020; Girotra & Netessine, 2013; Santos et al., 2009). These situations could emerge from a transformation in the business model and should be addressed adequately before operationalising the new BM (de Oliveira & Cortimiglia, 2017).

2.6. Roadmap phase four: Implementing of the CBM and continuous improvement

Roadmap phase four of the model of Frishammar and Parida (2019) is incorporated to validate and implement the designed CBM. Scoping the entire company can be experienced as too large, and targeting a department first could be helpful to gain insights. Business Model Innovation is an important concept in this conjecture, where the scope of the change in business models is specified (Albats et al., 2021; Foss & Saebi, 2017).

The difference of working with the resources provided by the client instead of deciding as a company how many resources to select for a project could serve as a distinction when designing and implementing a CBM. Berglund & Sandström (2013) already stated the issue of perceiving business model innovation challenges related to resource configuration. An addition to the research of Berglund & Sandström (2013) is the issue of resource configuration in the context of R&D service companies. This selection of resources can change over time, which is another aspect that should be incorporated when introducing a CBM (Horvath et al., 2019). Flexibility is a key factor in the design when the amount of resources can shift, as well as the order size without the company itself initiating the change (Kleinsmann et al., 2010). By separating the departments, the barriers and challenges that relate to an individual department can be handled without antagonizing the process of implementing the CBM in the complete company. Per department there are other resources available to handle the barriers and challenges, and to make use of the capabilities of the employees.

In order to validate the CBM, the model of Frishammar & Parida (2019) proposes a small scale pilot testing and a large scale roll out, where the CBM is continuously adjusted and improved. The small scale pilot should provide an overview whether the CBM could successfully be implemented and if there are positive and negative effects related to the triple bottom line, as well as an analysis on the revenue and costs of the CBM in the BM dimensions. The large scale roll out refers to the situation where the CBM is completely implemented and is adjusted to fit as optimally as possible. The social aspect, which is an area in the triple bottom line, will not be explicitly included in this research as the scope would be too broad with respect to the resources. Therefore the social aspect will be regarded as a section of the scale up, where the CBM could be extended to become a Sustainable Business Model, with the inclusion of the social aspect (Foss & Saebi, 2017).

2.6.1. Maturity level

The final key activity in the implementation of a roadmap is the continuous improvement cycle by using a maturity model. The purpose of a maturity model is to provide a comprehensive overview of the current status of the company's processes, and in particular the quality of these processes (Wendler, 2012). The original five maturity levels of a maturity model are the initial level, the managed level, the defined level, the quantitatively managed level and the optimised level (Facchini et al., 2019). Sehnem et al. (2019) adjusted the levels for the operationalisation of the circular economy, resulting in six maturity levels. The authors added a level zero, which is the non-existent level (Sehnem et al., 2019). The five levels were renamed as the executed level, the managed level, established level, the predictable level and the optimised level (Sehnem et al, 2019). Companies that begin to operationalise the circular economy should focus on level zero and level one, as visualised in Table 1. The complete matrix with all six levels can be found in Appendix B.

Levels	**Technical cycle**	**Biological cycle**
0: Non-existent	No practices were identified.	No practices were identified.
1: Executed	Collect, maintain/cascading, share, reuse/ redistribute and remanufacture/renew from technical materials.	Collection, cascading, extraction of biochemical raw materials, anaerobic digestion, biogas, biosphere regeneration, biochemical raw materials and agriculture/collection of biological materials.
2: Managed	Displays indicators related to the dimensions: collect, hold/prolong, share, reuse/redistribute and remanufacture/renew.	It presents indicators related to the dimensions collection, cascading, extraction of biochemical raw materials, anaerobic digestion, biogas, biosphere regeneration, biochemical raw materials and agriculture/collection of biological materials.

Table 1. Levels of CE operationalisation. (Sehnem et al., 2019)

Summary

In this chapter, the definitions of the CE, a BM and a CBM are discussed and the four phases of the roadmap of Frishammar & Parida (2019) are elaborated on. These four phases are the analyses of the current BM, the shortcomings of the current BM and the opportunities for the CBM, the design of the CBM and the fourth phase is a description on the implementation of the CBM.

3. Methodology

In this chapter the research design is proposed, followed by an elaboration on the procedure for the interviews.

3.1. Research design

This research is designed as an empirical study, where an optimal roadmap for the implementation of a CBM will be defined. In order to determine this, research is first needed to find out what the recent theories and frameworks are to achieve a transition from a linear to a circular business model. Therefore, the first step within this research will be to start a literature review on the topics themselves, in order to further explore from this point how and in which way a CBM will have to be adapted for a company. The topics that will be researched are circular economy, business models, circular business models, circular business model innovation and maturity models. As an addition to this process, it is also important to research how this company specific developed CBM will have to be implemented within the company. The second step that naturally follows from this research is developing interview guidelines, and conducting the interviews. The data collected in these interviews will be analysed as a third step in the process. The last step is the interpretation of the analysis, resulting in composing a CBM and a strategy to implement the CBM.

3.2 Interviews

The method for the interview is to conduct the interviews semi-structured, as the aim of the data collection is twofold. Firstly, questions will arise from the literature review which should be answered by the interviewees. Secondly, and considerably more important, is the desire for unknown information to emerge from the interviewees on the subject of circularity (Tien et al., 2020). By leaving room for the interviewer to ask questions outside the scope of the questions that are composed beforehand, the interviewee can speak more freely and provide new information (Kallio et al., 2016). In order to make the interview semi-structured, topics will be added to the interviews. Adding topics prevents the interviewer from straying away from a certain topic, asking all relevant questions and providing a structure to the interviewees (Kallio et al., 2016).

These interviews will be held in real life, in order to get the essence of the message as clearly as possible. By including this in the interpretation of the words, a report is made that is as complete as possible, which will influence the quality of the CBM. Several employees will be interviewed for 2 reasons. Firstly, this is done to create an as complete as possible overview of what is being experienced and what needs to be done in order to make the organisation more circular (Kallio et al., 2016). Secondly, it is important that as many employees as possible can give their opinion and also see this reflected in the proposal, in order to get the degree of acceptance as high as possible (Kallio et al., 2016).

3.2.1. Interviewed persons

To gain the best knowledge and the best variety of ideas and solutions, employees from different departments that are connected to the problem are interviewed. Departments that are included in this study are, purchasing, testing, planning, manufacturing engineering and supply developer engineering. Furthermore, managers form the fields of mechanical engineering, industrial designing, program volume, test development engineering and the team leader of director engineering are included in this study. These managers are included to gain an understanding of the strategic view of the company (Tien et al., 2020) of their specific stage of the production. Including employees who are specialists in a specific part of a production stage ensures the completeness of the diverseness of the ideas and solutions, and ensures the complete validation of all ideas. The employees who will be interviewed for this research do not have a certain level of knowledge on the subject of CBM.

For the interviews it is important that the employees who will be directly involved in this change have knowledge of the change, and have an acceptance of being able to adapt themselves to operate in a new system (Kallio et al., 2016). In order to achieve this, it is important that the newly designed CBM stems from the ideas of the employees, to make this adaptation as gradual and as easy as possible (Tien et al., 2020). This will increase the acceptance level among the employees. When determining the barriers, enablers and capabilities within Benchmark, it is important to know this from the employees. By analysing which issues are mentioned by multiple employees, the most important and probably the most impactful subjects can be identified.

3.2.2. Analysis of interviews

The analysis of the data will be done by following the next step. The method chosen for the analysis is thematic analysis. This is a method in which qualitative data can be analysed to discover patterns, concepts and themes (Siegel et al., 2004). This method is seen as a convenient method for researches who are new to analysing qualitative data (Olokundun et al., 2018). A disadvantage of choosing this method is the level of freedom when interpreting the outcomes. There are many different ways to interpret the data, but this will be overcome in this study by verifying the results with the interviewees. Another disadvantage could be generalization of the data, where phenome mentioned by a single interviewee could be overseen (Tien et al., 2020). This disadvantage could be overcome as well by verifying the results with the interviewees, and determining whether all important subjects are registered in the patterns, concepts and themes (Siegel et al., 2004).

The program to conduct the thematic analysis is Atlas.ti, which is received as a reliable and intuitive program (Smit & Scherman, 2021). It is a programme that can be used to analyse qualitative research data. Within this program, parts of the interview can be connected to codes. This means that these codes stand for certain statements that fall under a category. By coding all interviews in the same way, it can be examined whether codes occur more often in the interviews, which makes them more important and should be included in the patterns, concepts and themes. The interviews will be recorded, if permission is granted from the interviewee. These recordings are transcribed and put in Atlas.ti. By choosing this method the hazard of losing information is minimized (Smit & Scherman, 2021). When the codes are written on all the transcribed interviews, the outcomes generate topics that should be included in the CBM. These outcomes will not only refer to the topics that should be included, but as well to the strategy to implement the CBM in the organisation. By verifying the results with the interviewees, all useful information will be interpret and used in the designing and implementation of the CBM (Siegel et al., 2004). This verification will be conducted by using a questionnaire, in which employees can rate the ideas on impact, feasibility, profitability, the expected timespan to implement the idea and, if applicable, the expected willingness of Coloplast to implement an idea.

Summary

In this chapter the methodology of this research is discussed. This study will be an empiric study, where interviews will be held with employees from different departments, and with varying positions within Benchmark. The analysis of the interviews will be done by using thematic analysis, in which patterns, concepts and themes can be discovered (Siegel et al., 2004). The outcomes of the thematic analysis will be ideas for the CBM, which will be evaluated by the interviewees.

4. Findings

The findings of this research follow from 12 interviews conducted with Benchmark employees, after which a questionnaire was sent out to evaluate the ideas and solutions from the interviews. A general understanding of which employees were interviewed is presented in Section 4.1. This is followed by two sections in which the ideas and solutions inventoried in the interviews are presented. In Section 4.2, the ideas concerning the opportunities and shortcomings are described, followed by the enablers in the next subsection. In Section 4.4. the barriers and employee capacities are described. To conclude, the evaluation following the questionnaire is described in Section 4.5. The questions for the interviews can be found in Appendix C, and are inspired by the work of Von Kolpinski et al. (2022).

4.1. General information

The employees who were interviewed had different levels of experience, ranging from 6 months until 17 years, with a mean of roughly 7 years. Half of the interviewees are working for the medical customers of Benchmark, whereas a quarter works solely for Coloplast. The remaining quarter of the interviewees completes work for all customers of Benchmark. The knowledge about circularity and the solutions regarding this topic were limited, as the employees ranked their level of knowledge all between 1 to 3 on a scale of 5.

The employees all stated that they were indifferent towards a change in the company or their working responsibilities, as it is normal for employees working in a service providing company. This ensures the internal alignment when altering the business model. Employees in all departments are prepared to conduct a research for solutions when the customer has new ideas or requirements. The knowledge for devising and implementing circular solutions will be acquired in a similar way (Burger et al., 2019).

4.2. Opportunities and shortcomings

The first outcomes of the interviews that will be presented are the opportunities and shortcomings, which relate to the techniques from the theory as presented in Section 2.4. The different opportunities and shortcomings are categorised under either cycling, extending, intensifying, dematerialising or end-of-pipe, as can be seen in Figure 6. The transmitter with the PCB, the charger, the USB-C cable and the packaging are reviewed and potential ideas are inventoried. These ideas are represented in Table 2, with a short comment or description to elaborate more on the opportunity or shortcoming.

Technique	Opportunity (O) or shortcoming (S)	Explanation/Comment
Cycling	There can be an investigation into which part is the weakest link, and whether it is possible to repair, remanufacture etc. (O)	To map out the life stage and identify which materials can be reused from it, a tool can be used (which already exists).
	A take back system can be used, where products are returned at the end of their lifecycle so that they can be reused/recycled etc. (O)	
	The test system can reject products without a clear reason. If this is clarified through a research assignment, the rejected products can be repaired and the waste stream can be reduced. (S)	
	The transmitter is not traceable, so if it is lost, it is difficult to find such a small device. A notification of this in the app on the smartphone of where the transmitter is located could resolve this problem. (O)	
	The packaging should no longer be made of plastic, but of a biomaterial. (S)	A workshop has already been held at another customer and the results can be used as a starting point/input.
	The packaging that Coloplast uses for the customer is very fancy, but not at all sustainable. This could be adjusted in the design. (S)	
	Investigate the possibility of reducing or removing glue from the production process. (S)	
Extending	Ensure that the product becomes watertight. (S)	
	Investigate the possibility for adapting the design around the battery. (O)	Possibilities are altering the design for a modular battery, which will increase the likelihood of recycling the PCB, designing for an interchangeable battery, increasing the battery for longer endurance, a guide for the customer to use the battery more efficient, altering the design so the battery only works when there is contact with the sensors or wireless charging.

Intensifying	If possible, multiple customers can use the same charger. (O)	When two patients live in the same building, the charger can be used by both.
	Investigate the option of wireless charging. (O)	By making use of wireless charging, other electronic devices can utilise the charger.
Dematerialisation	The plastic packaging in which materials arrive at Benchmark can be reduced as the current quantity is excessive. (S)	This material could be sent back for reuse.
	There is 110% to 120% materials purchased per product, which results in a lot of scrap. (S)	To reduce this, the current soldering processes can be replaced by a laser soldering process. It will be a more robust process, resulting in less scrap and less failure. In addition, less heat and less solder are needed.
	When the current line is replaced by a smaller component size line, the product can be reduced in size, so less material is needed. (O)	The best thing to do is to set up a new, smaller component size line.
	Standardisation of, for example, screws. (O)	These materials can be bought in large quantities for several customers. A factory in the neighbourhood could start selling these materials to Benchmark, which saves on transport.
	Reduce transport distance, look for alternatives closer to Benchmark. (O)	The countries around Benchmark have the same safety rules, testing rules etc. If a tool can be made to decide which is the best choice, all the Benchmark branches can use it, so global impact is made.
	The USB-C cable can be left out as customers probably already own one. (O)	Maybe offer a USB-C cable as multi-use, because it is of good quality. Additionally, provide the customer with the choice to include the cable.
	The charger can be made smaller. (O)	There is excessive space in the current design.
	Plastic packaging is widely purchased and sometimes not even used. Besides, there are many types of plastic used. (S)	Here a study is useful to find out how this can be reduced.
	The box in which the trays are shipped can be made smaller, as well as the packaging. In addition, the plastic trays can be made smaller or more PCBs can be put in the current tray. (S)	By reducing the size of the box, no extra security bubble plastic is needed. The large packaging is designed to make the product more appealing.

End-of-pipe	Investigate the possibility of installing solar panels on the roof. (O)	
	Insulate and collect residual heat to heat offices. (O)	There are heat storage units, where the residual heat is not used.
	Some electronic devices are switched on unnecessarily. (S)	This issue can be solved by automatization.
	Instruct all employees to aim for a paperless office. (O)	
	Use a pair of disposable gloves more than once if, or use standard gloves. (S)	Disposable gloves can be used more than once if it is in line with medical safety measures.

Table 2. Possible opportunities or shortcomings.

4.3. Enablers

In addition to the opportunities and shortcomings, possible enablers have been identified that may be beneficial for the transition to a CBM. The enablers are presented in Table 3 below, together with a more in depth description of the enabler if required.

The enablers can be divided in three groups, which include the enablers concerning the customer, which is Coloplast in this research. Furthermore the role of the management in the transition to a CBM is vital for the successful implementation. The third section that would improve the process of including circular options is the culture present in Benchmark. The capacities and competencies of the employees are discussed in Section 4.4., however, aligning the culture with the shift towards a CBM is perceived as an important enabler by the interviewees.

Section	Enabler	Explanation
Customer	The urgency to reduce the environmental impact is also acknowledged by Coloplast.	
	Offer workshops at Coloplast, where new ideas concerning circularity are introduced.	Ideas that concern altering the design need to be approved by Coloplast first. However, before the workshops can take place the engineers must do more research.
	Offer the 'green' alternative besides the traditional solution.	Leaving Coloplast a choice to either go for the cheaper, traditional solution or the more environmental friendly, which will most likely cost more in the earlier stages.
Management	If management provides a clear end goal, the employees will ensure that this goal is reached.	
	To put emphasise on circularity, the management team should appoint a member to be responsible for this subject.	

Culture	By informing employees that being sustainable is also beneficial for themselves, that they are helping to create a better world, it makes people more likely to stay or would like to work for the company.	Potential customers are also more likely to choose the company.
	Incorporate circularity into the Hoshi Kanri and in the newsletter.	The subject must get attention, and people must start thinking more about it. The Hoshi Kanri is a tool to specify the strategy of a company from vision to the production. The newsletter is used to keep the employees up-to-date with all news concerning Benchmark.
	There could be a group that thinks about circularity, which is reflected in the specifications, so that the customer can choose whether to continue with a circular alternative.	The requirement management tool that is currently being developed can also include a sustainability component. A checklist could also be an option.
	Create a global "*Be green*" competition.	Making it a Benchmark global competition, a bigger impact is made.

Table 3. Enablers identified in the interviews.

To conclude, the timing of including circular aspects in the BM is mentioned by one of the more experienced interviewees, who said:

"If you want to adjust something, now is the time with the current long delivery times."

In comparison to the situation before the long delivery times, the time that was required to implement a change was considered too long, for instance when introducing another, more environmental friendly, material. To be able to implement a change this was first needed to be designed, a prototype had to be made and tested, adjustments must be made. This results in longer lead times and additional expenses. However, at this moment more environmental friendly materials could have shorter lead times, making them viable as the extra lead time costs of the original material could outweigh the research costs.

4.4. Barriers and employee capabilities

Besides the opportunities, shortcomings and enablers, the interviews provided additional findings for the successful implementation of a CBM. The barriers that could impact the implementation are presented in table 4.

Section	Barrier	Explanation
Customer management	If the customer is not willing to make change, or if there is no market demand, it will not happen.	

Market	There is no incentive from the electronics market to become more circular.	If several or all companies were working on this, it would be a lot cheaper and therefore more attractive. Nothing will change until the regulations around it are changed: Hazardous substances may no longer be used, for example. Even then, it can take a long time, and parties such as the Ministry of Defence could be excluded.
	It takes a long time to be able to implement a design idea at all, with pilots, tests etc. With a medical product, everything is fixed, and a long process is required to be able to implement changes.	
Financial	The circular alternative cannot be too costly relative to the traditional option.	
	Research and testing may be too expensive for the benefit.	
	Government subsidies are difficult to obtain in an international market. Maybe a subsidy from the municipality could be an option.	
Culture	Employees could be hesitant to implement changes as they are conservative.	
	An employee who is responsible for circularity is missing.	
	There is not enough capacity at the moment to carry out extra projects.	
	About 80% of the time there is not an option to become more circular.	
	It is not in the Hoshi Kanri, so management does not put enough effort into it.	The Hoshi Kanri is a tool to specify the strategy of a company from vision to the production.

Table 4. Barriers mentioned in the interviews.

Besides the barriers that were identified by the interviewees, the capacities that should be present in the company were also addressed. Following the capacities from the study by Burger et al. (2019), the acquisition of knowledge is of importance, as the information required to research and design circular options needs to be obtained. Furthermore, the sociotechnical system within the company is of vital essence for the success of a CBM. The cultural aspect requires attention and de corresponding actions must be carried out. The interviewees mentioned that they are indifferent towards a change for circularity, however, the culture that is present is not suited for a continuous improvement in the field of circularity. Therefore trainings are required, both for the management and the employees themselves. The employee capacities are presented in table 5.

Employee capabilities	Comment from interview
The employee who will be responsible for circularity must think on a system level, oversee the whole envisioning use of the whole product life cycle and also has to know all disciplines.	This could take years.
The management team should follow a training to understand the different methods to include circularity.	
Offer a training for employees to provide an insight in the different methods to include circularity, and what they can contribute themselves.	The theme could also be introduced in general.
Instead of providing a training for the employees, management could establish a guide in which the subject of circularity is embedded.	
Introduce the topic to all employees.	The issue needs to be addressed, and people need to start thinking more about it. Something has to change in the culture. A sort of checklist could be a possibility, or it could be incorporated in the newsletter. When the topic is introduced, employees themselves can work on an impact concerning circularity.

Table 5. Employee capacities mentioned in the interviews.

4.5. Evaluation of outcomes

The relevant ideas that could potentially be implemented in the CBM were recorded, after which they were all presented again to the interview panel in a survey. Here the ideas were assessed for impact, feasibility, profitability and the timeframe for implementation. For the ideas where the final choice lies with Coloplast, an additional factor is added, which is the interpretation of whether Coloplast would be willing to cooperate or not. As implementing a change could cause a shift in the stakeholder relation, a shift in finances or an organisational shift, the external alignment as elaborated on in Section 2.5. should be revised. In Section 4.5.1., the ideas that have potential to be immediately implemented are listed. In Section 4.5.2., ideas that have potential to be implemented in the future are listed.

4.5.1. Potential ideas interesting to pursue at this moment

Firstly, the ideas assessed by the experts as ideas that could be researched or devised in the near future are discussed. These ideas have been labelled as potential ideas if they score average to good in terms of impact and feasibility. The ideas will not be profitable in the short term, however, ideas that do not offer any potential to make a profit are grouped as having no potential. Coloplast's willingness is another factor that is taken into account when evaluating ideas, but this is only a deciding factor if all experts indicate that they see little or no chance for Coloplast. The time frame is not a deciding factor in the assessment, but becomes important when an action plan is drawn up. There are no ideas that are interesting to pursue at this moment for the extending, intensifying and dematerialisation techniques. Therefore, these techniques are not listed in this chapter.

The interviewees were asked to fill in the questionnaire, and give a score of one to five on the factors described above. The blue bars in the assessment of the ideas and solutions, which are visualised in the Figures 9 till 29 and in Appendix D, represent a score of one on a specific factor, the red bars a two, yellow means a three, green a four and purple a score of five. This score is displayed on the X-axis. The amount of votes a particular score received is displayed on the Y-axis.

Cycling

Within the technology of cycling, we can distinguish three potential ideas. The first idea is the possibility of finding out which part of the product is the weakest link in terms of breaking down, and whether it is possible to repair it, overhaul it, etc. By improving the weakest link in the product, the likelihood of failure of the complete product is reduced, and thus is the life time extended. The impact is considered as slightly better than average, as the added impact of conducting this researched is not highly valued by most of the experts, however, most of them also do not value the impact negatively, as can be seen in Figure 9. One of the experts is certain of the long term impact, as he stated:

"Just a great idea, your carbon footprint gets smaller, you offer customers a better product."

The research to find the weakest link is perceived as feasible to conduct, as the research can be conducted at Benchmark and does not require approval of Coloplast. The research can be conducted within a relatively short time range, but will only be profitable after a longer period of time. How long this period will be exactly is impossible to predict.

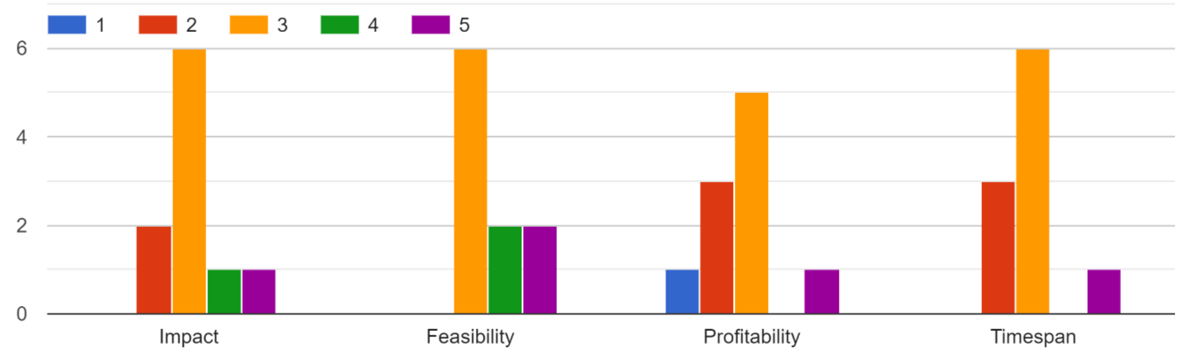

Figure 9. Possibility to research the weakest link.

The second potential idea by using the cycling technique concerns the packaging of the product. One of the ideas brought up in the interviews is the possibility to use bio material instead of plastic for the packaging of the product. In relation to the R-strategies framework of Yildizbasi & Arioz (2021) in Figure 4, the plastic packaging could only be recovered (R9) or recycled (R8). By using bio material, fewer fossil fuel resources are required, which is reducing (R2). Similar to the other idea using the cycling technique, the impact is moderate to great. However, the experts assess the feasibility of implementing this idea positively with an average of 3.8 out of 5 as can be seen in Figure 10. A topic of concern is the contact with human fluids and cleanability, which are compromised as is mentioned in the questionnaire. Despite this concern, the experts value the willingness to cooperate by Coloplast positively in general. The timespan to implement the idea is perceived as relatively short, and will not be profitable for Coloplast and Benchmark. However, by removing the plastics from the waste stream, Benchmark is gaining an indirect profit, with for example new clients who appeal to the circular involvement by Benchmark.

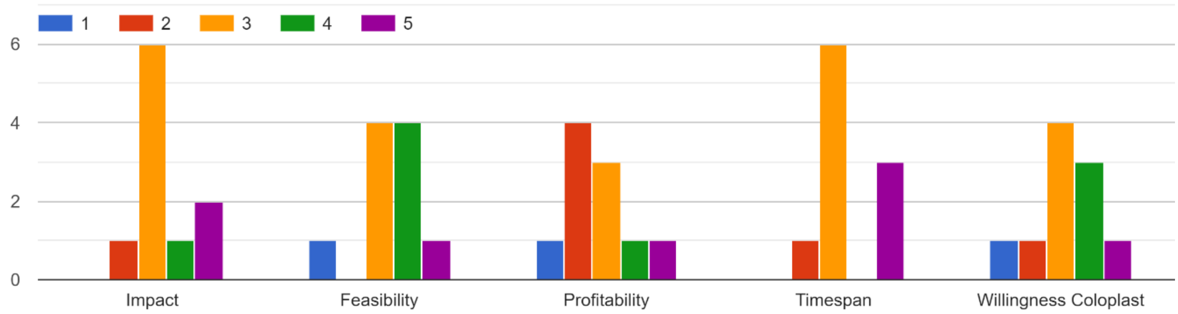

Figure 10. Using bio material instead of plastic.

The third idea is to investigate the possibility of reducing or removing glue from the production process. The glue that is currently used in the production process to glue the shell around the PCB together results in the inability to repair the product. At this moment, the product needs to be milled open to recover parts, destroying the shell in the process. Furthermore, the costs of milling does not outweigh the profit gained. To solve this problem, the glue process should be replaced to enhance the ability to repair the product. Due to the product being close to the skin of the customer and the stoma itself, the product is required to be watertight. This requirement complicates the process of removing the glue from the production process. If this is possible, it will have a major impact as shown in Figure 11. However, feasibility is a point of concern, with experts also doubting whether the investment will eventually be recouped. The last factor that plays a role is the willingness of Coloplast, where the experts also disagree on whether this should be assessed as positive or negative. Given that the impact will be large, and the other factors are not immediately considered negative, it is worth exploring whether the glue can be reduced or removed.

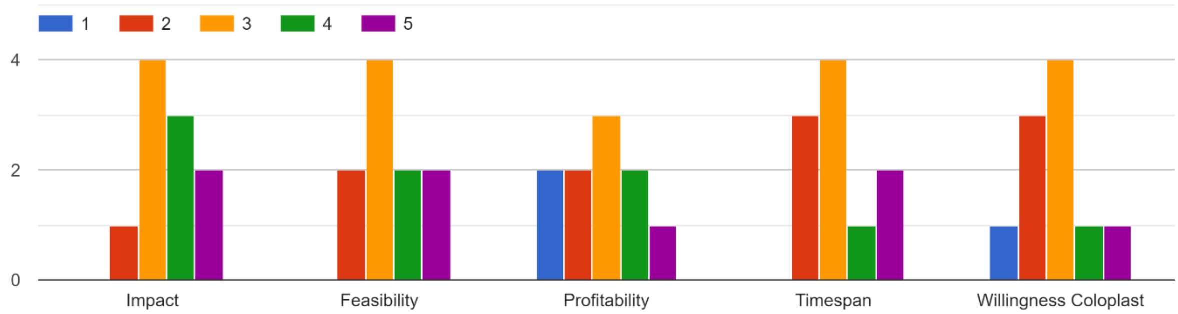

Figure 11. Reduce or remove glue from the production process.

End-Of-Pipe

The only positively assessed idea in the area of the end-of-pipe techniques is the possibility to install solar panels on the roof. The initial investment will be compensated by the earnings on a longer period of time, which explains the outcomes of the profitability in Figure 12. The feasibility of this project is targeted as the main concern, as an expert put it:

> *"To my knowledge, the current roof structure is not suitable for the weight of this installation."*

An alternative is provided by another expert, who suggested building a parking lot with a roof to place the solar panels on. The average score on the impact of this idea is a 3.3 out of 5, which is considered as average by the experts. Figure 12 shows a division, where the experts who value the impact as low consider the project as infeasible. However, the experts who believe that the idea is implementable, with a suggestion as mentioned above, assess the impact as high or even as maximum impact. A research is required to determine if the idea is implementable, although most of the experts believe that the timespan to implement solar panels is long, as can be seen in Figure 12.

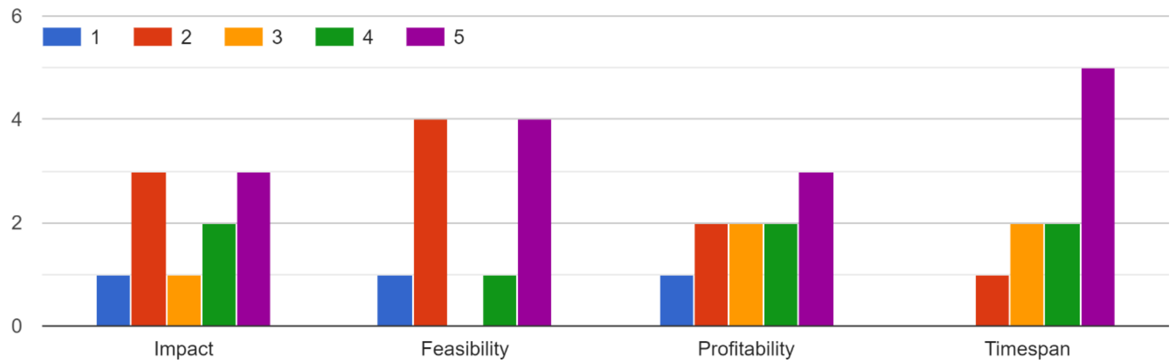

Figure 12. Possibility to install solar panels.

Enablers

The enablers are seen as the area with the most potential, as these ideas are focussed on the processes that do not involve the production directly. These changes are easier made, although the profitability of these ideas is assessed on average as low or neutral.

One of the enablers could be to offer workshops at Coloplast, where new ideas concerning circularity are introduced. Ideas concerning circularity can be conceived by employees at Benchmark, but the circular ideas that affect the product or the production process must first be approved by Coloplast. The impact of introducing these workshops is rated with a 3.0 average, considering this idea has no direct impact on the current way of production. The impact will only come about later, although the experts are of the opinion that the time span for setting up these workshops is fairly short, with 70 percent believing that these workshops can be held within 6 months. Willingness from Coloplast is also seen as better than average (on average 3.4), which is further underlined by an expert:

"And vice versa, no doubt at Coloplast they are also working on this sort of thing."

The profitability surrounding this idea is fairly low because the workshops cost money and there is no direct profit to be made. This will then have to become indirect revenue. Finally, the experts do rate the idea as feasible, with an average rating of 3.5 as can be seen in Figure 13.

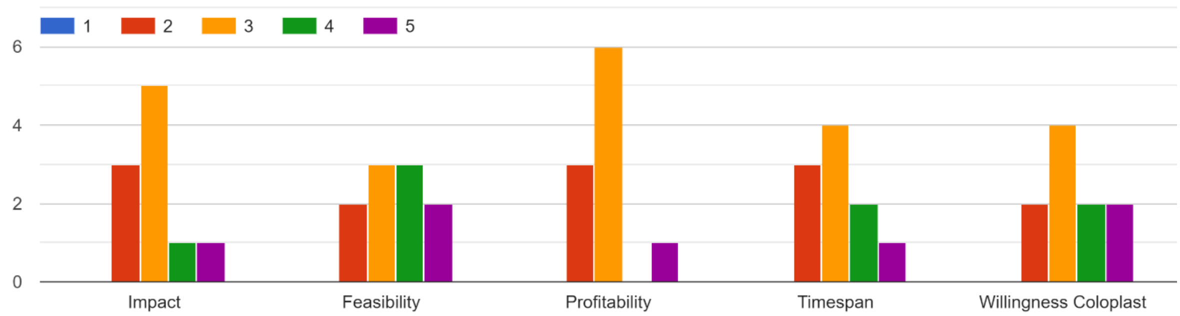

Figure 13. Offer workshops at Coloplast.

Besides offering the workshops at Coloplast, a green alternative could also be provided to Coloplast. The experts value this idea more impactful than the workshops (average of 3.4 over 3.0), with only one experts valuing this idea negatively (Figure 14). The timespan to introduce a green alternative is estimated between 6 to 12 months on average, and the profitability is seen as an investment which will be earned back. This idea is perceived as feasible by the majority of the experts, however, experts mentioned:

Because of the extra time and effort, testing, etc., this is probably going to cause just more environmental burden overall. Two logistic flows, completely new product development, testing, building machines etc. (Expert 1). With the tightness of projects in mind, I don't think the financial/time space is there to offer two alternatives within the current way of working (Expert 2).

These are valid concerns and should be adressed before implementing this solution. The second expert already mentions the current way of working, which is not a suitable environment for this idea. A pilot for a product with a small production volume could provide information on whether the roll out is implementable for other products offered by Benchmark. Therefore the added burden and costs are minimised by not altering large production volume product lines.

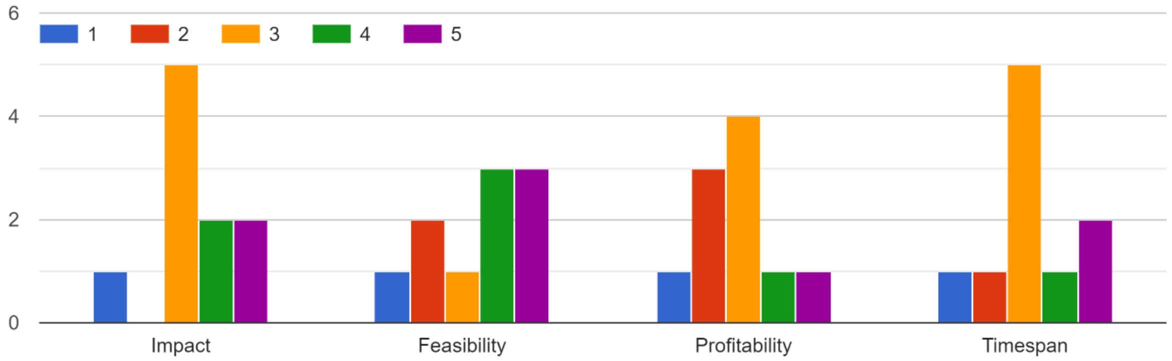

Figure 14. Offer a green alternative to Coloplast.

Incorporating the subject of circularity into the Hoshi Kanri and in the newsletter is another enabler for the implementation of circular solutions. The Hoshi Kanri is a tool to specify the strategy of a company. Multiple experts mentioned that altering the culture within Benchmark is an important first step to introduce circularity in the company. The best and quickest manner to achieve this is to use the Hoshi Kanri.

The impact and feasibility of this ideas are significant following the experts opinions, whilst also being easily implemented with a timespan between one month and a year (Figure 15). The profitability is not an important factor to assess this idea, as the implementation requires man hours, which will be the only costs. However, the implementation will not result in a direct profit.

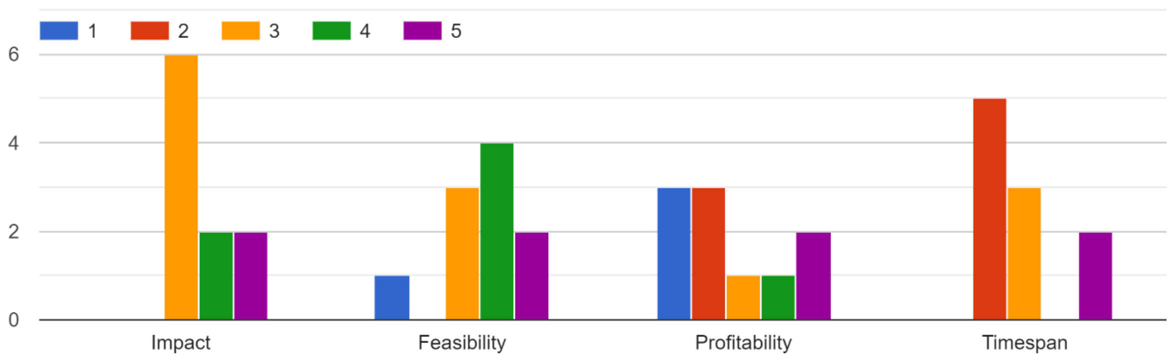

Figure 15. Incorporate circularity in the Hoshi Kanri and the newsletter.

In addition to adding the topic of circularity to the Hoshi Kanri and the newsletter, there could also be a group that thinks about circularity. At the moment there are groups formed to investigate on other topics which are reflected in the specifications, however, no group for the topic of circularity is formed. Including circularity in the specifications allows the customer to choose whether to continue with a circular alternative. The impact and feasibility of this idea are slightly positively assessed by the experts, whereas the costs will eventually be earned back as believed by the experts (Figure 16). A pilot group for one customer at Benchmark could provide proof whether the group is successful or not.

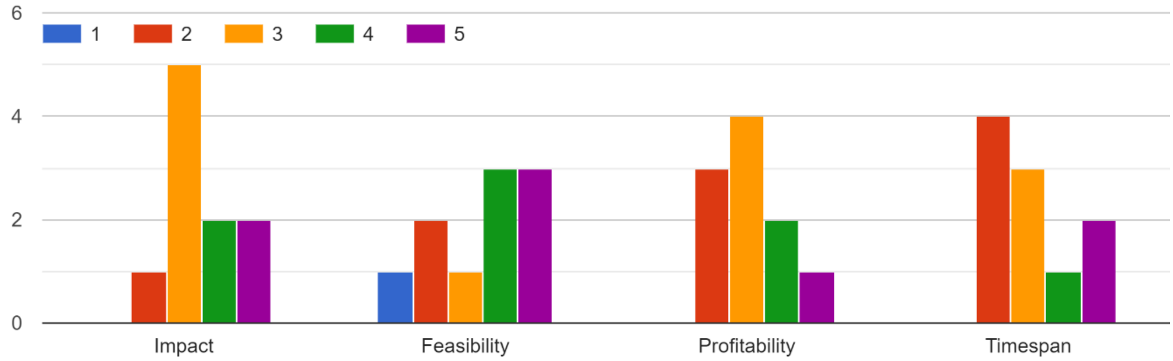

Figure 16. Introducing a circularity research group.

4.5.2. Ideas with potential in the future

The ideas that have potential in the future could need further research, or a better understanding with Coloplast on the opinion of the experts, or a thorough interview with the experts etc. The differ from the ideas mentioned in Section 4.5.1. as the experts do not entirely agree on the potential of the idea on certain or all factors. Furthermore, the technique of intensifying is not listed as no ideas are identified with potential in the future.

Cycling

There are two cycling technique ideas that are assessed as ideas with potential in the future. The first idea is related to the amount of rejected products. The test system can reject products without a clear reason, resulting in an increased waste stream. A research on the unknown reason of rejection can clarify how the products can be repaired. The impact of this idea is estimated exactly neutrally by the experts, with a particular comment on whether such a study will actually add anything. One of the experts named:

"A test system cannot reject without reason. It is programmed with a right and a wrong."

The experts are positive that the idea is feasible to be carried out, however, the profitability is a point of concern, as can be seen in Figure 17. As one expert puts it:

"Profitability: depends on product, whether repairing is more expensive than the product itself."

The division between the experts on the impact and profitability results in an idea with potential to be carried out, however, due to the significant amount of ideas concerning circularity this idea could be re-evaluated after a certain period of time (Figure 17). After this period of time, experts should assess whether the impact and profitability are significant to pursue the research on this subject.

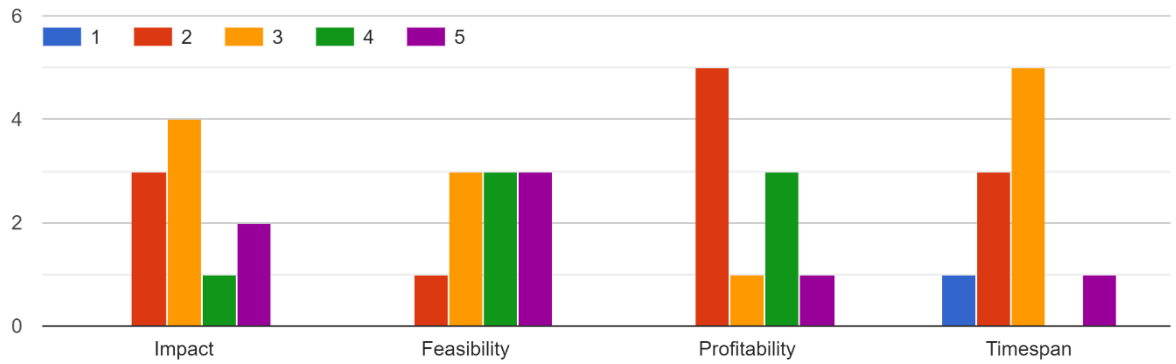

Figure 17. Reduce the amount of rejected products.

The focus of the design used for the packaging at Coloplast, which is shipped to the customer, is on appearances. However, is not at all circular, and a more circular neutral design would benefit the environment. This impact is also positively assessed by the experts (3.6 out of 5), whereas they believe that it is also feasible (3.4 out of 5). The main concern is the perceived willingness of Coloplast, which is only positively assessed by two experts. An investigation is required to find out if this assumption is valid, however, until this investigation is executed the idea remains one with potential for the future (Figure 18).

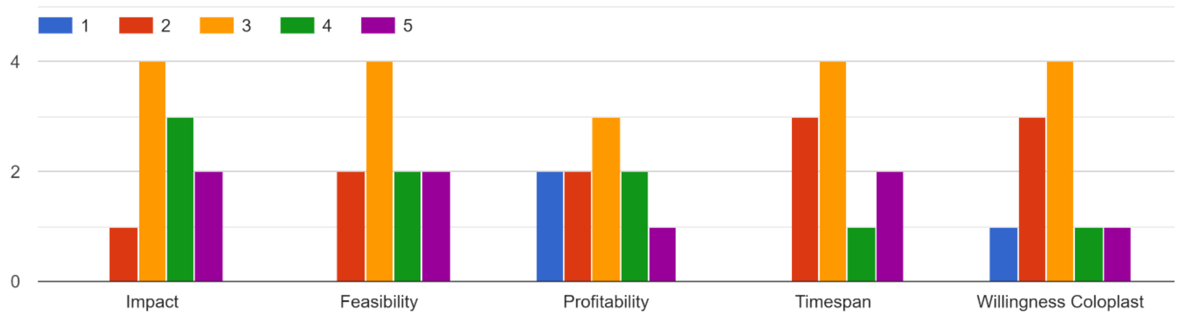

Figure 18. Designing a more circular packaging for Coloplast.

Extending

The battery is an element in the product itself. It is soldered on the PCB, resulting in the inability to quickly reuse or recycle the battery, or to improve or change it. Altering this design would massively impact the circular options, as is also recognised by the experts, as can be seen in Figure 19. The main problem with altering this design is the willingness of Coloplast, which also affects the feasibility of implementing this idea. Comments by the experts are:

> *"Coloplast themselves included this in their design anyway, will be cost-driven" (Expert 1). "The current design is very much fixed, even though there are several problems with it. I think there is little willingness (Expert 2)."*

The fact that the impact will be huge is the deciding factor why it is still preferable to pursue the investigation and negotiations with Coloplast to alter the design.

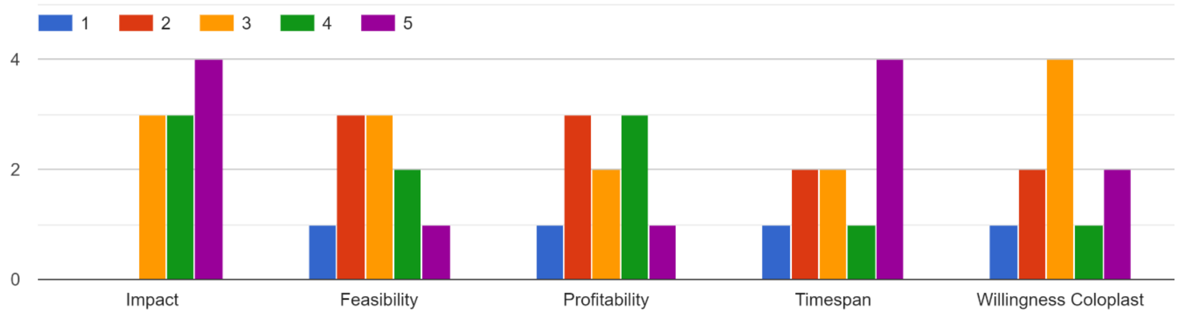

Figure 19. Possibly adapt the design around the battery.

Another idea in the area of extending the product is the possibility to make the product water tight. Therefore the probability that the product has to be repaired or even discarded is reduced. Unfortunately, the idea was not clear to a large amount of the experts, resulting in an assessment which is of no value at present.

Dematerialisation

The standardisation of, for example, screws is an idea to dematerialise the production process. This applies to the screws used for all clients of Benchmark, where various screws are used instead of a standard. All factors are assessed as neutral as is displayed in Figure 20, where the feasibility is limited as one expert says:

> *"Top idea, makes huge savings. Will take a long time though given the huge variety of assembly equipment."*

Therefore the idea itself is one with potential, however, as other customers of Benchmark are involved to successfully implement this idea, an investigation is required. However, the potential is large, which is also stated by another expert:

> *"Good idea, many products are designed by the customer. Redesign has big impact for customer. Want this one to come along. For new projects, we could create a template for the customer to choose from."*

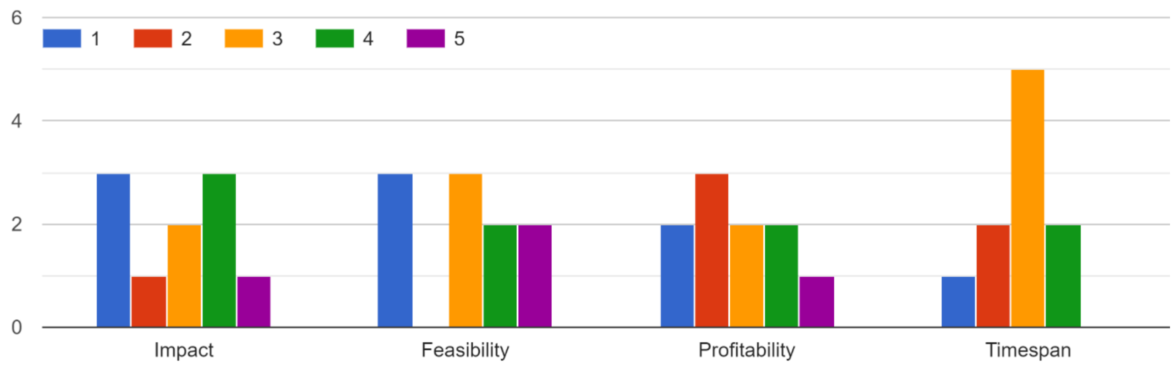

Figure 20. Standardise screws.

The technique of dematerialisation can also be used by leaving out the USB-C cable of the package to the customer. Due to the new regulations in Europe, USB-C is the standard for electronic devices, leading to customers already owning one or several USB cables. However, the experts value the factors as neutral (Figure 21), what could most likely be explained by the following experts:

"Target group not suitable (Expert 1). Maybe keep it optional. Not everyone is so aware of technology (Expert 2)."

Therefore altering the idea from leaving the USB cable completely out of the package, to offering the possibility to order a cable could positively affect this idea.

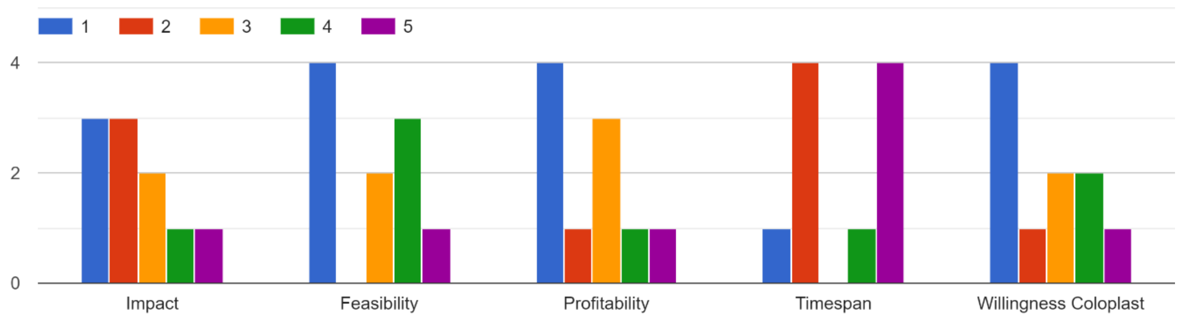

Figure 21. Leaving the USB-C cable out of the product.

Lastly, in the technique of dematerialisation, the plastic packaging that is used is purchased in large quantities and sometimes not even used. Furthermore, there are many types of plastic being purchased. The experts are critical towards the profitability of this idea, where one experts mentions:

"The parts are so cheap that the financial gain seems limited to me here."

However, taking into consideration the potential impact and feasibility of this idea, as assessed by the experts (Figure 22), the idea can be categorised as one with potential. No direct profit will probably be made, although indirect profit can be made by improving Benchmark's image as a sustainable R&D service provider. This may strengthen the bond with a customer or attract new customers.

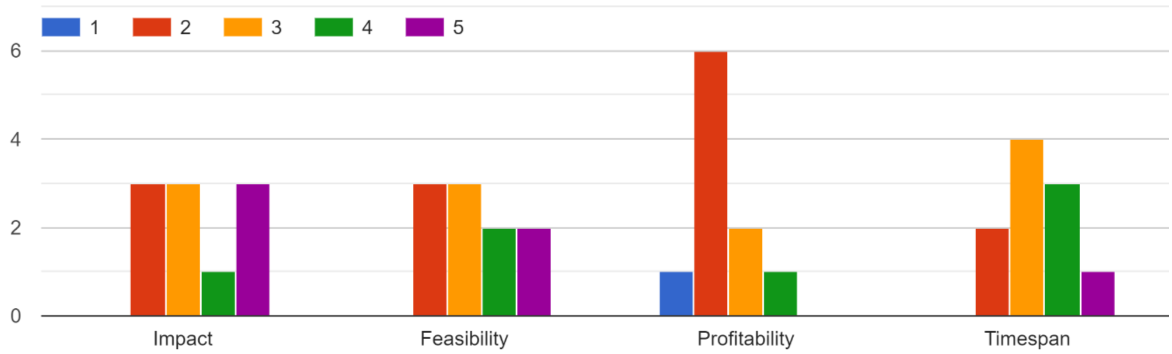

Figure 22. Reduce amount of plastics used.

At the production plant of Benchmark further improvement could be made in the transport to Benchmark. At this moment parts are being shipped from all around the world, for example from China, whereas options closer to Benchmark will benefit the CO_2 emissions related to the transport. Additionally, the countries closer to Benchmark apply similar safety measures and test rules, improving the feasibility of this idea.

However, the experts do not assess the feasibility positively as can be seen in Figure 23. Two experts explain this as follows:

> *"Feasibility; choices made are, due to our project organisation, often quite specific. I wonder how far this standardisation can go. At the meta-level, maybe possibilities (Expert 1). Tricky to implement and manage. If you look at human energy, I expect it will be a day job to manage a tool (Expert 2)."*

Taking into account the impact and profitability being assessed neutral, a follow up is required to investigate the process of altering the transport routes.

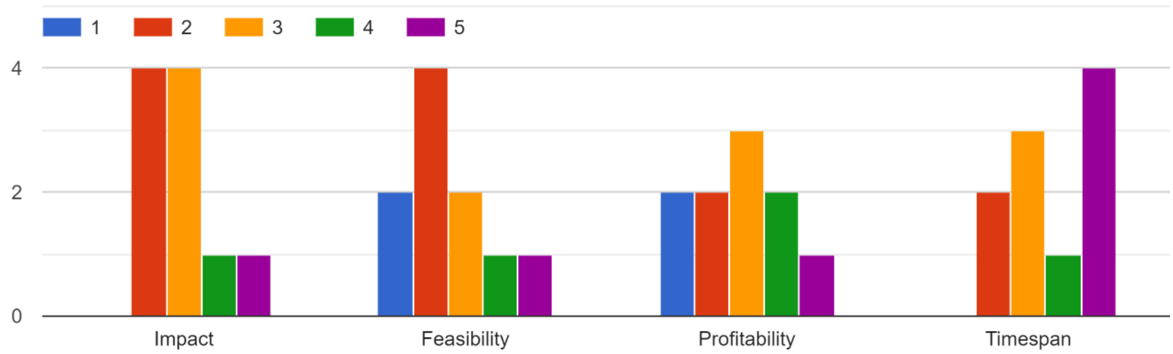

Figure 23. Reduce transport distance.

The technique of dematerialisation is also the focus point in the idea of the 110% to 120% materials purchased per product, resulting in a lot of scrap. However, due to the idea not being clear/incomplete, at least half of the experts could not properly assess the idea, making the assessment to be of no value in this report.

End-Of-Pipe

To further improve the level of circularity within the organisation of Benchmark, three end-of-pipe ideas could be investigated further to validate the impact, feasibility, profitability and the willingness of Coloplast. The first idea that could be investigated are certain electronic devices, which are switched on unnecessarily. The impact of automating the process of switching on and off is valued precisely as average by the experts, which is slightly better assessed than the profitability of this idea (Figure 24). This assessment is best explained by one expert, who says:

> *"The more often you save a little bit somewhere, the more that eventually adds up, so yes, this seems like a good philosophy to keep in mind on an ongoing basis. In terms of time: it's not something you implement once. You keep looking, even in the future, for places/devices/situations where you can make better efficiency choices."*

In addition, the feasibility of automating the process of switching the lights on and off is rather highly assessed, making it an interesting idea to be pursued.

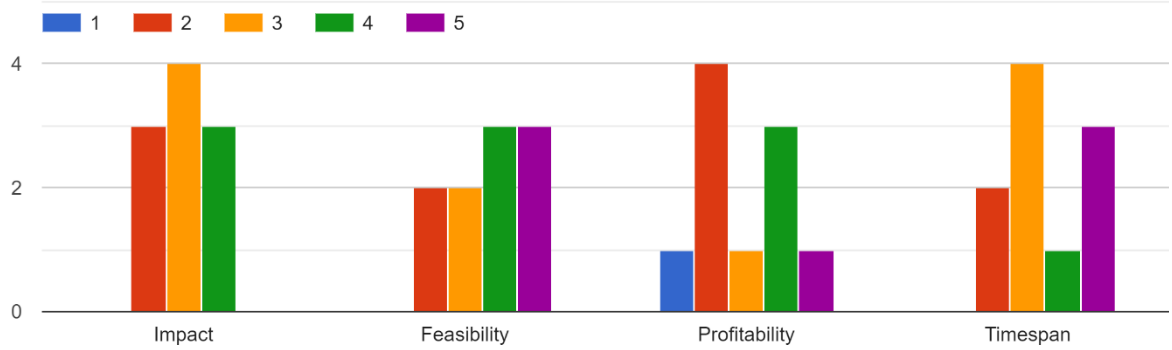

Figure 24. Reduce the use of electricity through automation.

What could further be improved in the end-of-pipe technique is to insulate and collect residual heat to heat offices. The experts mention that the plant is just renovated, wherein the subject of insulation is integrated. As for the collection of residual heat, the volume of the heat in the heat boxes is too low according to one of the experts. These heat boxes are required for the production process. Another one speaks from experience and mentions that it is really hard to insulate and collect the heat from these heat boxes. These concerns contribute to an assessment by the experts where all three factors are neither actually positive nor negative on average, as can be seen in Figure 25. This concludes that this idea should be low on the list to pursue, but should not be neglected.

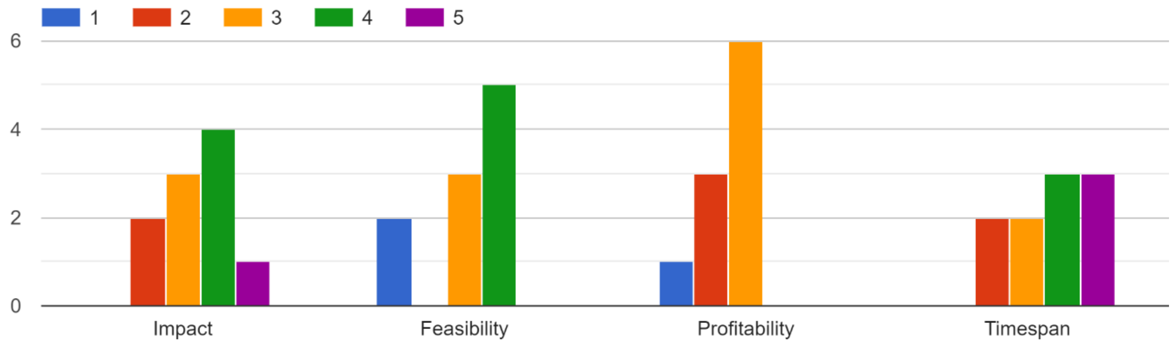

Figure 25. Insulate and collect residual heat to heat offices.

One of the ideas with the lowest amount of investment is the aim for a paperless office. Benchmark is already trying to digitalise as much as possible, but there is room for improvement. However, due to the fact that only a minimal amount of paper is used in the office, the experts assess the impact and feasibility of this idea as average, whereas the profitability is slightly negatively assessed (Figure 26). However, due to the low effort, this idea is worthy to pursue, because as one expert mentions:

> *"Ongoing awareness is required. Presumably, you cannot eliminate paper completely."*

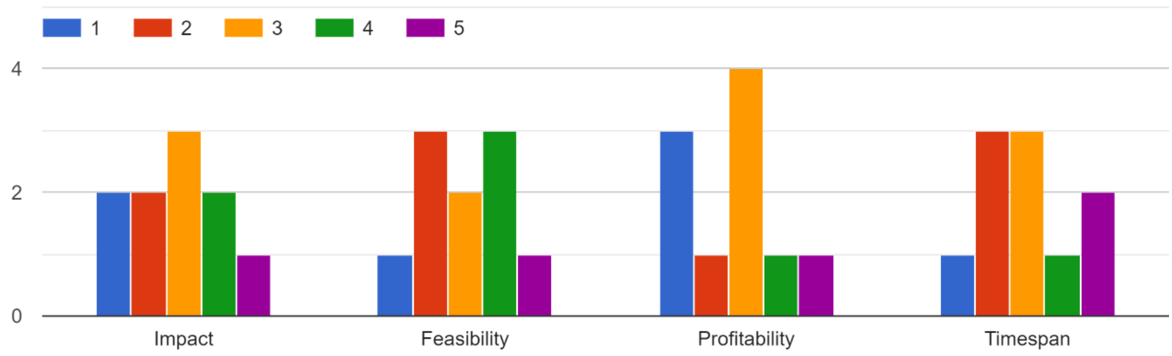

Figure 26. Aim for a paperless office.

Enablers

The experts are divided on the idea to create a global '*Be green*' competition. The idea is to involve Benchmark employees from all over the world to contribute to circular solutions. Some experts welcome it and believe that increasing the population who thinks about the subject will increase the quantity and quality of the ideas. On the other hand there are experts who believe that the Benchmark plants have their own problems, and that one uniform solution is not going to work in every plant. The diversion is also perceivable in Figure 27, where the assessment of the experts is displayed. A follow up question at other sites of Benchmark, or an alteration to the current idea could provide a solution.

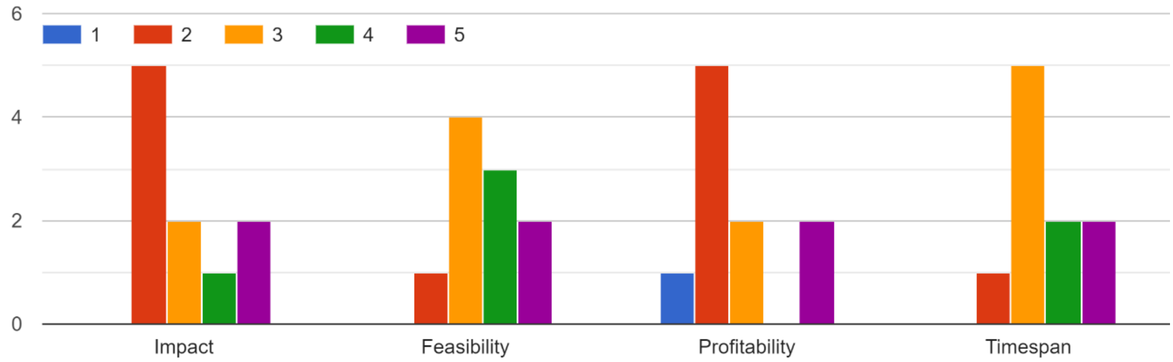

Figure 27. Create a global 'Be green' competition.

The last idea which is specified as a potential impactful enabler is offering a training for employees to provide an insight in the different methods to include circularity, and what they can contribute themselves. Or, as one expert puts it:

> *"Although sustainability is a hot-topic, still a lot of people have no idea what (simple) steps they can take. So education is important!"*

The impact of which the expert is talking is not recognised by every expert, as can be seen in Figure 28. The feasibility of this idea is considered neither high nor low, without the experts expressing their thoughts on this factor. The profitability is slightly negatively assessed, but the fact that the overall score of this idea is good nor bad, concludes that this idea is a potential idea to develop further in the future.

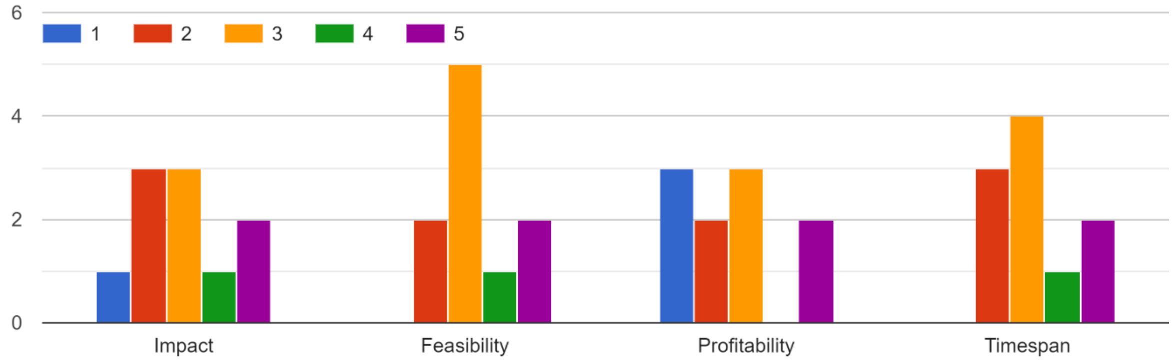

Figure 28. Providing trainings to employees.

Summary

In this chapter, general information about the 12 interviewees of this research is provided. Furthermore, the ideas and solutions from the interviews are presented and grouped as opportunities, shortcomings, enablers, barriers or employee capacities. The ideas and solutions are evaluated through a questionnaire, and the outcomes of this questionnaire are grouped as (1) ideas or solutions with potential, (2) ideas or solutions with potential for the future or (3) ideas without potential. The ideas or solutions that have potential in the future could need further research, or a better understanding with Coloplast on the opinion of the experts, or a thorough interview with the experts etc.

5. Roadmap to implement a circular business model

The third phase in the transition is the design of the CBM, with a focus on imitating successful circular business models in the medical field, which are described in section 2.5.1. In section 5.1, the ideas with potential from section 4.5 will be analysed and compared to the CBMs from the medical field. Furthermore, in the third phase the internal and external alignment are integrated. The internal alignment is discussed in section 4.1, while the external alignment depends on the external party which may be involved. This external alignment, as well as the design of the CBM, will be discussed in the second subsection where a link will be made to the current BM, and which parts of the BM should be adapted when implementing circular solutions. To complete the transition to a CBM, phase four should be executed. In this phase, a pilot is rolled out and a plan is drawn up for a continuous improvement cycle based on a maturity model. The roll-out of a pilot falls outside the scope of this research, a plan for a continuous improvement cycle is described in subsection three.

5.1. Using already existing CBMs

As mentioned above, the eight ideas with potential from section 4.5 will be analysed in order to investigate whether the CBMs from the medical field could be appropriate to implement an idea. Following the eight ideas that were positively assessed, only four ideas relate directly to the product or the packaging. The first idea which will be considered is the research to find the weakest link, the second idea is to reduce or remove glue from the production process, the third idea is to offer a green alternative and lastly the idea to use bio material instead of plastic is analysed.

The first CBM from the innovation BMs, as described in chapter 2.5.1., is not suitable for one of the four ideas mentioned above. Within this CBM, products are accessed by leasing, renting or through a contract, which is related to neither of the potential impactful ideas. The second CBM is a contract-based maintenance service, which is not viable for this product at the moment as the volume is not high enough to be profitable. Furthermore, considering the four ideas this CBM is not useful. The fourth CBM explained by Guzzo et al. (2020) is another type of PSS, where high-value equipment is rented out. Due to the high complexity and uniqueness of the product, the first and third idea mentioned as potential impactful ideas are not suited for this type of CBM. The second idea is unsuitable for this type of CBM as a new design is required which will be unique to this product, ruling out the sharing element of the CBM.

The sixth CBM which is mentioned by Guzzo et al. (2020) focusses on refurbishment, which is not compatible with the high safety and quality rules related to the product. Parts are not useful for refurbishment as they are destroyed or made inappropriate for reuse when the shell is milled open. This is also the reason why the last CBM for medium and high value products is not applicable to the four potential impactful ideas. This CBM focusses on the take back of end-of-life equipment with the intent to refurbish and recycling. This CBM could be used when the glue is removed from the product, but not within the current design.

The idea to use bio material instead of plastic corresponds directly with the ninth CBM as is described by Guzzo et al. (2020). The EMF (2017) especially provides a clear path on how to alter the package to a bio material, with the sixth chapter providing additional information to this topic to aid the transition. This chapter should be the starting point for the investigation to start using bio material as packaging.

The remaining four ideas that are assessed as positive potential ideas are the investigation for the instalment of solar panels, the offering of circular workshops at Coloplast, incorporating circularity in the Hoshi Kanri and in the newsletter and lastly the introduction of a circularity research group. The first idea relates to the plant itself, whereas the remaining three ideas relate to a shift in the culture, resulting in the CBMs described by Guzzo et al. (2020) being not useful for these ideas.

5.2. Business Model alteration

As seven of the eight ideas cannot be related to an innovating CBM found in the literature about medical products, the business model canvas of Osterwalder & Pigneur (2010) should be altered to identify the focus areas. Figure 29 represents the current BM of Benchmark.

A research to find the weakest link will affect the resources, as the knowledge and expertise will be improved. Furthermore, the value proposition is the focus area of this idea in terms of improving the business model. By finding the weakest link, this part will be improved or improved and the product will last longer, improving the value proposition to the customer. Adding a circular component can also strengthen the customer relationship. To conclude, the research and possible improvement/replacement will cost more, however, offering a stronger and longer lasting product could be sold for a higher price.

Reducing or removing glue from the product will impact the customer relationship, as this design change will result in a considerable investment in the product line. With such an investment, both companies benefit from extending the relationship to recoup the initial investment. Altering the BM for this idea will also result in the improved knowledge and expertise, where the enhancement of the design could benefit improving other products for other clients.

Offering a green alternative mostly affects the value proposition. Offering a green alternative not only improves the value proposition and customer relationship with Coloplast, but will also inform potential new clients that circularity is an important factor for Benchmark. The knowledge of circularity and the potential to apply the information to other products is another advantage of this idea. The idea will require a large initial investment for the research, an extra production line, more man hours etc. The revenue will increase as the green alternative will be sold for a higher price, and indirect revenue could occur when new clients are contracted.

Using bio material for the packaging will require a change in the resources, and possibly by changing the supplier of the packaging. The value proposition will also be improved with the circular aspect, which also results in the improved customer relationship. The packaging will probably not be earned back, but can have indirect revenues with the increased image.

Installing solar panels will result in lower costs for the plant, but requires the initial investment. The circular image is also somewhat improved but less than the other ideas. There are no direct customer relationships which are directly affected and the value proposition is also not changed. Activities and partners also remain the same. The resources will change as the production plant will be upgraded.

The sixth idea that should be considered is the offering of workshops at Coloplast to exchange knowledge. Obviously the resources in the BM will be altered, as the knowledge will be conveyed to workshops, which is an addition to the activities in the BM. Furthermore the customer relationship will be strengthened and improved. The costs will relate to man hours, as employees first need to acquire the relevant knowledge to provide the workshops. The revenue of this idea will be acquired by increasing the costs of consultancy.

Incorporating circularity in the Hoshi Kanri and the newsletter, will not influence the partners, customer segments, customer relationship, the value proposition, activities and the channels. The costs are man hours which are required to provide the information for the Hoshi Kanri and the newsletter, whereas there is no direct revenues. The only factor that is addressed by this ideas is the area of resources. By incorporating the circularity in the culture employees will start thinking about how they can contribute themselves, improving the knowledge and expertise.

Lastly, the introduction of a circularity research group will result in a similar affect as the incorporation of circularity in the Hoshi Kanri and the newsletter. The only difference is the change in the customer relationship, as the specifications will be specifications will be adjusted if Coloplast agrees to go for a more circular option. The revenues can thus be earned back quicker by increasing the price for the greener alternative, but it also requires a higher costs to alter the product.

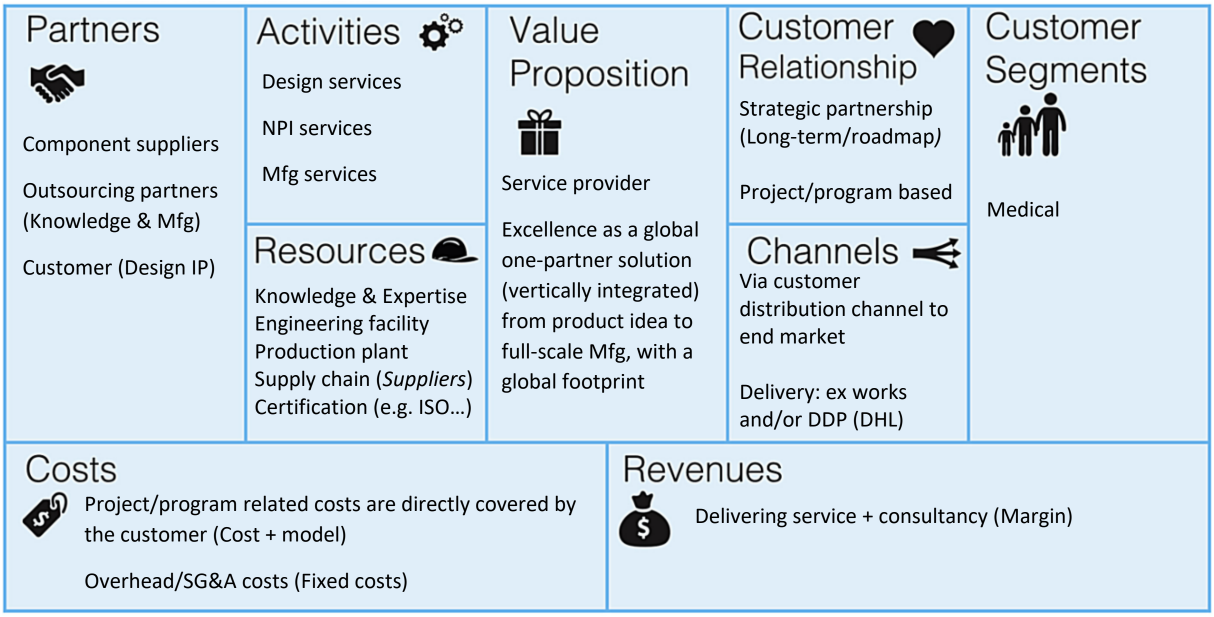

Figure 29. Business Model of Benchmark concerning Coloplast. (Filled in by author, template derived from Osterwalder & Pigneur, 2010)

Mfg stands for Manufacturing, NPI means New Product Introduction, DDP means Delivered Duty Paid and SG&A stands for Selling, General & Administrative Expenses.

5.3. Continuous improvement

In the case of Benchmark implementing one or more ideas as proposed in this study, the company reached the first level of the maturity model as proposed by Sehnem et al. (2019). The level is described as an executed level, where activities are carried out to reduce emissions and waste. In order to reach the second level of the maturity level matrix, Benchmark should install indicators to measure the exact reductions (Sehnem et al., 2019). Subject to which idea is implemented, the indicators could be the durability of the product in the case of the research for the weakest link. In the case of reducing or removing the glue, the amount of glue which is not used is an indicator, as well as the man hours that are saved by this time intensive work. Furthermore, the amount of recycled products or parts could be an indicator.

The offering of a green alternative could be measured by the times Coloplast chooses to go for the green alternative, as well as the amount of environmentally unfriendly parts that are taken out of the product. When implementing the idea of using a bio material for the packaging, the amount of plastics that is not being used anymore is a good indicator for the impact of this idea. The next idea is the instalment of solar panels, which could be indicated by measuring the decrease in electricity supply. The CO_2 emissions related to generating electricity are a clear indicator of the environmental impact.

The impact of offering the workshops at Coloplast could be measured by the actual improvements that are made by Coloplast after applying the knowledge. The actual indicator should be determined when the actual improvements are implemented. The next idea is the incorporation of circularity in the Hoshi Kanri and the newsletter. The impact could be measured by the amount of ideas concerning circularity before the introduction of the topic and afterwards. The individual indicators should be determined afterwards, but all contributions from the new ideas are directly related back to the implementation of this idea. The last idea is the introduction of a circularity research group, where the indicators are the specifications that are altered. The direct impact of these altered specifications could only be determined after the nature of the specifications are clear. Examples of indicators could be CO_2 emissions saved by standardisation, using environmentally neutral parts etc.

6. Discussion

In this chapter, a discussion on the findings is provided in Section 6.1., the theoretical contribution is elaborated on in Section 6.2. and the practical relevance in Section 6.3. Furthermore, in Section 6.4. the limitations of this research are discussed and in Section 6.5. the recommendations for future research are proposed.

6.1. Findings

The increasing amount of CO_2 emissions, scarcity of fossil fuels, scarcity of raw materials, and waste increasement are the biggest drivers to make the transition from a linear to a circular economy. However, this transition is often difficult for established companies to realise, as the product or production process must be adapted. This adaptation is often unclear in terms of establishing a plan and its execution, resulting in the concept of a circular economy which will not be performed. To address this issue, a request for a roadmap was inquired, to investigate how circularity can be obtained within the organisation. Therefore the research question belonging to this research objective is:

'How to implement a roadmap for the transition from a linear business model to a circular business model in businesses that provide R&D services?'

After conducting a literature study, a roadmap consisting of four phases was established. These four phases are the external alignment for the transformation to a CBM, identifying the internal opportunities and shortcomings in the current CBM, designing and implementing the CBM and to conclude validation and continuous improvement. In the first phase trends and guidelines are scanned and analysed. To complete the investigation of the external CBM transformation opportunities, the enablers and barriers are identified. In the second phase, internal opportunities and shortcomings are investigated, as well as the connection with the current BM. In the third phase, the CBM is designed. By analysing existing innovating business models, existing and tested methods could be applied in this CBM. Furthermore, in this phase the internal and external alignment are obtained, as well as a coherency between the internal and external alignment. The fourth and last phase is the implementation of the CBM and a small pilot roll out. The pilot roll out is outside of the scope of this research, but a continuous improvement cycle is suggested.

The interviews and questionnaire provided eight ideas which are assessed as the ideas with the most potential at this moment to successfully contribute to a more circular product or organisation. The associated change in the BM is explained, as well as the continuous improvement cycle for all eight ideas. Besides the eight ideas with potential, there were twelve ideas that were assessed as ideas with potential in the future. The difference is caused by disagreement between the experts, resulting in neither a good nor bad assessment. This is also caused by the difference in the departments of the experts, and can be explained by the following example: when changing or altering the packaging of the product, an employee from the test department is not directly involved, resulting in an opinion which should be less considered in comparison to the opinion of the employee from the purchasing department. The purchasing department employee is directly involved in the purchasing of the packaging material, and thus is better informed on this subject, resulting in a better informed opinion. A more in-depth interview or questionnaire, and an adjusted assessment criteria should determine the actual potential of the ideas. This should be only conducted for the ideas with potential for the future, as the process could be time consuming and costly.

Besides the ideas with potential for now or in the future, there are also ideas that can be labelled to have no potential. Table 6 shows which combined factors cause ideas to be labelled as ideas without potential. The ideas are not profitable, however, this is also the case for other ideas that are labelled as having potential for the future. Without any additional positively addressed factors, the costs will not be compensated and thus the idea is labelled as an idea without potential. In table 6 below, a minus means that an idea is rated negatively, meaning that the average coming out the questionnaire is 2.5 out of 5 or below. A '+/-' means that an idea is rated neither good nor bad (2.5<X<3.5). A plus means that a factor is positively assessed (X>3.5). N/A means not applicable, as the decision does not immediately concern the interference of Coloplast. A detailed explanation of the ideas can be found in Table 2, Table 3 or Table 4. The corresponding diagrams of the ideas can be found in Appendix D.

Idea/Factor	Impact	Feasibility	Profitable	Willingness Coloplast
Introducing a take-back system	+/-	+/-	-	+/-
A traceable transmitter	+/-	+/-	-	+/-
Multi-use same charger	-	+/-	-	+/-
Wireless charging	+/-	+/-	-	-
Reduce plastic packaging incoming	+/-	+/-	-	N/A
Smaller component size line	+/-	+/-	-	-
Smaller charger	-	+/-	-	-
Reusable gloves	+/-	-	-	N/A
Responsibility by management team	+/-	+/-	-	N/A
Utilise shipping trays more intensively	+/-	+/-	-	N/A

Table 6. Ideas that are negatively assessed by the experts.

The ideas that are stated in Table 6 would decrease the impact on the environment caused by Benchmark. Aside from the idea to increase the responsibility of the management team, the other nine ideas all cause less material to be used, or to use the product more intensively. This directly relates to two of the three most circular actions of the R-framework (Figure 4), which are reducing the amount of materials used (R2) and to use the product more intensively by rethinking (R1).

Analysing the eight ideas with the most potential, there are only four ideas that relate directly to the product itself. The first idea is to find the weakest link, so that the products lasts longer and can be better maintained, which is linked to R4 of the R-framework. The second idea which is directly related to the product, is the offering of a green alternative, with the hazard of using even more material, energy etc. to set up a possible extended or adjusted manufacturing line. This idea relates to R2, as the focus is to use fewer natural resources and materials. The third idea is also related to R2, which is to reduce of remove the glue from the production process. The fourth idea is to use bio material, in order to not having to recover (R9) or recycle (R8) the original plastic.

Concerning the other four ideas with the most potential, installing solar panels is not directly related to this product. The other three ideas mentioned, (1) offering circular workshops, (2) incorporating circularity in the Hoshi Kanri and in the newsletter and (3) introducing a circularity group are all specified to the principles and foundations of circularity. Achieving a better understanding about circularity and the possibilities on this subect, for all employees, is a highly valued opinion by the experts.

Therefore, an additional conclusion of this research is to focus on activities that are lower on the circularity ladder of the R-framework (Figure 4), in order for the feasibility, impact, profitability and willingness to be assessed positively, in combination with educating employees on the subject of circularity.

6.2. Theoretical contribution

This study has several contributions to the literature in this academic field. The first contribution is related to the sector of R&D service companies, where the issue of designing and implementing circular business models, and circular business model innovation in particular has not yet been examined. This sector has multiple similarities with companies that produce their own products and have an inhouse R&D department, upon which this study can draw information on. However, the main difference is the absence of creating a standalone product, resulting in small production lines for several clients (Lawson et al., 2015). This area differs from traditional companies as the design authority remains with the client, resulting in a culture where the R&D service company requires approval for the alteration of the product or the production process. These small production lines require their own approach in terms of the transition to a CBM, causing an additional challenge to overcome.

The approach also relates to the changing demand of the customer in the R&D service provided, changing the supply chain for the specific customer. This can cause other materials to be added to the production process, which need to be incorporated in the CBM (Lawson et al., 2015). When a company provides R&D services, it does not have the design authority, as this lies with the client (Lawson et al., 2015). Often a consultancy role is used to make the design and manufacturing of the transmitter as efficient as possible. Because the authority does not lie with the incumbent firm, the decisions about changes in design, other materials, finances etcetera are made by the customer, which is an additional obstacle in the transition to a circular economy (Schaltegger et al., 2012). This external alignment is further explained in the third phase of the theoretical framework for the roadmap, as the external alignment is harder to achieve for R&D service providers.

A roadmap from the earliest stage of the transition for R&D service companies is until now not optimally discovered, which is related to the second contribution of this thesis. This thesis is meant to help identify the best approach to adopt a CBM, but this was previously researched in companies that already established a certain level of circularity (Comin et al., 2019). Starting in the first stage provides an additional challenge, but also ensures a higher degree of novelty and freedom in the decision making (Comin et al., 2019). Researching and mapping the decisions related to the design and implementation of a CBM could serve as an example for other companies, not only in the sector of R&D companies. Companies that start without a degree of circularity usually struggle with the setup of a research, or how to start in general with the transition (Hansen et al., 2011). By providing an example of this process, this transition should become easier to start with.

As a third contribution, the use of maturity models in the transition within CBMs is well known, but was often used with companies that were already further along in the process (Sehnem et al., 2019). By integrating a maturity model in a company that has to start at the earliest stage of the transition to a CBM, the literature in this area is expanded. This contribution is also related to the second contribution, but the use of maturity models is something that is usually not used with companies without a certain level of circularity (Sehnem et al., 2019). This is due to the fact that these companies already have the knowledge that they are in the first stage in the maturity model. The contribution in this field is the clarity how companies can advance to the next level in the maturity model. By introducing all levels in the transition to a CBM, companies are provided with an overview what the steps are to the next level, increasing the willingness to implement a CBM (Wendler, 2012). By dividing the transition into smaller steps it is clearer for companies which step to take next, resulting in the roadmap that will be proposed in this thesis.

6.3 Practical relevance

The value of this study for the business relates to internal and external benefits. The internal benefits can be categorised under the topics within the triple bottom line, which are environment, social and economic factors (Du et al., 2016). Firstly, one can look at the environmental aspect. The traditional business models are organised as linear business models, following the principle of 'take, make and dispose' (Severo et al., 2017), whereas the principle used in circular business models is to reuse, remanufacture, recycle etc. (Claudy et al., 2016). Transitioning into a circular business model would result in a reduction of resource depletion and a reduction in pollution (Hansen et al., 2009). The second factor of the triple bottom line is the social aspect. In the transition to a CBM the employees can take pride in the fact that the company they are working for is reducing the resource depletion and the pollution. This pride can result in an improvement of the workers satisfaction, improving the efficiency amongst employees (Ahmad et al., 2019).

The third factor in the triple bottom line is the economic factor. Taking into account the reduction of resource depletion, there is no requirement to purchase new materials. Therefore the company is less affected by the volatility concerning the supply of the materials, and the prices associated with this volatility. The reduction in pollution can result in exceeding the governmental regulations and staying ahead of new regulations (Carro-Suárez et al., 2021). Furthermore, the increased sense of doing the right thing amongst employees will result in an increased incentive to stay loyal to the company. To conclude, new clients can be attracted as the shift to a circular economy is of greater strategic importance for companies nowadays.

As stated before, there are certain external benefits as well. These benefits are customer-related, as it is of greater importance from a strategic point to be circular, in order to be preferred by the client. Circularity can therefore also become part of the unique selling point (Hansen et al., 2011) of the company, which can also influence the status of becoming the preferred supplier of R&D services according to Jenkins & Holcomb (2021). Achieving this status can lead to the collaboration with new clients and strengthen the bonds with the current clients. By setting a standard on circularity within the organization, but also along the complete supply chain of suppliers and clients, the loyalty between these companies will grow (Lee & Kim, 2012). The relationship between R&D service providers and their clients will be strengthened too by ensuring the price stability due to a reduced demand in new materials. In the current industry, volatility in material supply is high (Gänser-Stickler et al., 2022), resulting in a high volatility in price for these materials, where the clients will be expected to pay for these increases in price.

Furthermore regarding the practical relevance of this research, the proposed roadmap helps practitioners to analyse the current situation regarding circularity, and aids in identifying the actions to undertake when designing and implementing a CBM. The main challenge practitioners face is the unclarity on the choice of a CBM that fits their organisation as optimal as possible, and how the CBM can be successfully implemented. With the inclusion of the maturity models, the current status of circularity within the company can be identified, as well as the proposed actions to reach a higher level of circularity. The maturity model also supports decision making in the transition to a circular economy by clarifying the levels of circularity, and the requisites to reach the higher level of circularity.

6.4. Limitations

This research contains a couple of limitations which prevents an optimal execution. The first limitation is a lack of data on the environmental factors resulted in a qualitative research. If data was stored for example on the CO_2 emissions, or the amount of waste generated in the production process, this research could provide quantitative arguments for the implementation of circular options. A reduction could be substantiated, resulting in an improved internal alignment, as is elaborated on in Section 2.5.2. Furthermore, data on the subject will clarify the impact of the circular solutions.

Besides the missing data for the practical part of this research, a financial foundation to support decision making is missing. An estimation on the proposed CBMs is derived from the knowledge of the interviewees, however, an exact calculation was impossible to conduct in this research due to limited data and resources. Calculating the exact costs and profits of the CBMs would enhance the value of the profitability in the decision-making process as the clients make the final decision, and profitability will be the most decisive factor. The formula to estimate the expenses can be found in Appendix A, however, the costs related to the process-integrated measures are a rough estimate due to the complexness of the costs determination. Criteria that permit an approximately objective estimate are vital, elsewise the expenses should not be communicated (VDI 3800, 2001). Additional research is required for the exact estimation of the costs.

Due to the stipulated period of this study, it has not been possible to actually implement any ideas, which makes it impossible to determine with any certainty whether the changes would have yielded the perceived benefits. By analysing implemented changes, future possibilities can be better estimated on their benefits, and the steps proposed in this research can be reviewed and altered if required. This does not mean that the roadmap cannot be successfully implemented, however, the roadmap should be evaluated and optimised with the outcomes of the implemented ideas.

The interviews were only conducted with twelve employees, whereas conducting interviews with more employees could have resulted in additional CBMs. Furthermore, an extended expert panel would have enhanced the certainty on whether the impact, feasibility, profitability and the willingness of both the employees as well as the client were estimated accurately.

6.5. Further research

As indicated in the introduction, the outcome of this research does not serve as a comprehensive roadmap which can be used in all occasions, due to the complexness and variety of product and organisation constructions. The generic roadmap of Frishammar & Parida (2019) that has been used as a starting point for this research provides a framework, where additional activities are required to complement the roadmap. This research provides an insight in which activities could be added, and how these activities should be implemented in the roadmap. The roadmap which is proposed for designing and implementing a CBM can be used by other practitioners and scholars as a starting point or as a guidance. The recommendations below are further extensions that should be implemented in the roadmap.

The first recommendation in addition to this research is the inclusion of the companies within the supply chain. The focus of this research is on Benchmark and Coloplast, however, the suppliers of Benchmark and the transport additionally contribute to the emissions and waste generated in the product life cycle. The inclusion of the complete supply chain is supported by the outcomes of the interviews, as multiple solutions towards the supply chain are mentioned. Examples are the shorter transport routes, the decrease in plastic packaging and the option of a take-back system.

The second recommendation relates to the production processes. The strategies mentioned by Geissdoerfer et al. (2020) focus on closing, slowing and narrowing the loop, indicating that the focus is on the product itself (Bocken & Ritala, 2021). The processes are addressed in the guidelines of the VDI 3800 (2001), but this is outside the focus of this research due to limited resources. The end-of-pipe measures are addressed in this research, and in particular the waste produced in these processes. However, these measures are not yet fully researched in this study and solutions are not provided for these measures.

This is a quantitative research, whereas an investigation for a qualitative research would provide a more comprehensive overview and a more thoroughly advisory report for Benchmark. Qualitative research to improve this study could be a risk analysis and a cost analysis. At this moment, the expert opinion is used to estimate the risks and costs. Furthermore, a research on the decrease in emissions and waste could be beneficial to the process of decision making.

Lastly, the social aspect is deliberately excluded from this research, but would improve the CBM to a Sustainability Business Model. In addition, the triple bottom line would be included, so the complete environmental impact can be estimated.

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Appendix A – Expenses formula

Formula to estimate the expenses (VDI 3800, 2001):

$$G = \sum_j a_j(I + \Delta I_j) + \sum_i m_i p_i \ + \mathrm{A} * \rho + \ \mathrm{S} + \ \mathrm{F} - \ \mathrm{E}$$

Variable	**Meaning**	**Measurement unit**
G	Total annual expenditure	(€ per year)
a_j	Capital-investment-related expenses	(% per year or 1/year)
I	Capital investment	(€)
ΔI_j	Additions to or cuts in the investment I when determining expenditure item j	(€)
$\sum_j a_j(I + \Delta I_j)$	Sum of expenses relating to capital investment	(€ per year)
m_i	Consumption level for item i	(Units per year)
p_i	Unit price of material i consumed	(€ per unit)
$\sum_i m_i p_i$	Sum of working expenses	(€ per year)
A	Manpower requirements	(Number of employees)
ρ	Labour costs	(€ per year per employee)
S	Miscellaneous expenses	(€ per year)
F	Consequential expenditure	(€ per year)
E	Possible revenues from the sale of joint products, proceeds from secondary raw materials etc.	(€ per year)

Table 7. Measurement variables. (VDI 3800, 2001)

Appendix B – Maturity matrix

Matrix of correlation between circular economy and maturity levels (Sehnem et al., 2019):

Levels	**Technical cycle**	**Biological cycle**
0: Non-existent	No practices were identified.	No practices were identified.
1: Executed	Collect, maintain/cascading, share, reuse/ redistribute and remanufacture/renew from technical materials.	Collection, cascading, extraction of biochemical raw materials, anaerobic digestion, biogas, biosphere regeneration, biochemical raw materials and agriculture/collection of biological materials.
2: Managed	Displays indicators related to the dimensions: collect, hold/prolong, share, reuse/redistribute and remanufacture/renew.	It presents indicators related to the dimensions collection, cascading, extraction of biochemical raw materials, anaerobic digestion, biogas, biosphere regeneration, biochemical raw materials and agriculture/collection of biological materials.
3: Established	Presents history of indicators (2 years or more) related to the dimensions: collect, hold/ prolong, share, reuse/redistribute and remanufacture/renew.	It presents a history of indicators (2 years or more) related to the collection, cascade, extraction of biochemical raw materials, anaerobic digestion, biogas, biosphere regeneration, biochemical raw materials and agriculture/collection of biological materials.
4: Predictable	Besides presenting a history of indicators, it presents continuous improvement goals for each indicator.	Besides presenting a history of indicators, it presents continuous improvement goals for each indicator.
5: Optimized	Besides presenting a history of indicators, it presents continuous improvement goals for each indicator and reports whether or not the goal was achieved. When not achieved, it reports the justification of not achieving the goal and establishes a new goal for the coming year.	Besides presenting a history of indicators, it presents continuous improvement goals for each indicator and reports whether or not the goal was achieved. When not achieved, it reports the justification of not achieving the goal and establishes a new goal for the coming year.

Table 8. Maturity model matrix. (Sehnem et al., 2019)

Appendix C – Interview Questions

General information

1. **Please provide your work experience at Benchmark: Year(s), client(s), job description.**

2. **What is your knowledge about circularity and CBMs in general on a ranking from 1 to 5:**

   1 meaning no knowledge at all, 5 meaning full understanding of circularity and/or CBMs and experience working with these concepts.

3. **How willing are you towards the adaptation of a revision of the BM, resulting in a change in work for you personally on a ranking from 1 to 5:**

   1 meaning not willing at all to change the working process, 5 meaning open and willing to discuss all sorts of change in the working process.

CBM design

CBMs focus on slowing, closing and narrowing product life cycle loops to maintain the embedded economic value for as long as possible, reduce environmental impacts and deliver superior customer value. Four categories are identified to carry out this goal, which are cycling, extending, intensifying and dematerialising.

4. Cycling measures comprise the recycling of materials or energy streams. This can be achieved by reusing, remanufacturing, refurbishing or recycling and simply closing the life cycle loop.

   What are the ideas, solutions or problems in this field for the product?

5. Extending a product is mainly focussed on improving the design for a longer lasting product, which can be easily repaired and is timeless designed for maintenance.

   What are the ideas, solutions or problems in this field for the product?

6. Intensifying means increasing the efficiency of the product use phase. This could be achieved by implementing a use-oriented product-service-system. This means that a company shifts from the traditional product selling approach to the provision of a service, which could be product leasing, renting, pooling etc.

   What are the ideas, solutions or problems in this field for the product?

7. Dematerialisation aims to provide a service as the product, by installing a result-oriented product-service-system, where the ownership of the product shifts from the manufacturer to the customer. This can be achieved with a pay-per-service unit business model, outsourcing or a functional result.

   What are the ideas, solutions or problems in this field for the product?

8. End-Of-Pipe measures apply to the waste generated in the production process, preventing the waste to end up in the environment. These measures can be incineration plants, waste water control plants and exhaust gas cleaning equipment.

   What are the ideas, solutions or problems in this field for the product?

9. **Besides the subjects mentioned before, do you have ideas, solutions or problems you want to address furthermore?**

<u>CBMI – Implementation of a CBM</u>

There are both enablers and barriers within an organisation that need to be identified before a CBM can be implemented, as essential missing enablers or insurmountable barriers are detected, the implementation will probably fail.

10. **What could be possible barriers for each design strategy when implementing a CBM?** The barrier categories that could be thought off are:

Technical	(E.g. lack of know-how)
Informational	(E.g. lack of knowledge)
Technological	(E.g. lack of required technology)
Supply chain	(E.g. lack of commitment in SC)
Customer management	(E.g. lack of customer commitment)
Organisational	(E.g. limits/insufficient support)

11. **What could be possible enablers for each design strategy when implementing a CBM?** The enabler categories that could be thought off are:

Technical	(E.g. required technical skills acquired)
Informational	(E.g. new knowledge acquired)
Technological	(E.g. new technology acquired)
Financial	(E.g. appropriate amount of resources)
Environmental awareness	(E.g. involvement)
Dedication of management	(E.g. commitment)

12. **Which capabilities do employees need to possess to successfully implement a CBM?** The capability categories that could be thought off are:

Basic capabilities	(Acquiring and facilitating knowledge)
Social skills	(Work with people)
Resource management skills	(Efficiently allocating of resources)
Systems skills	(Analyse and work in sociotechnical systems)
Complex problem solving skills	(Identify and solve complex problems)
Technical skills	(Design, operate, set-up, solve malfunctions)

Appendix D – Questionnaire results

Below, the ideas without potential are listed. The ideas are explained to the interviewees with the same phrase as provided in this Appendix.

A-take back system can be used, where products are returned at the end of their lifecycle so that they can be reused/recycled etc.

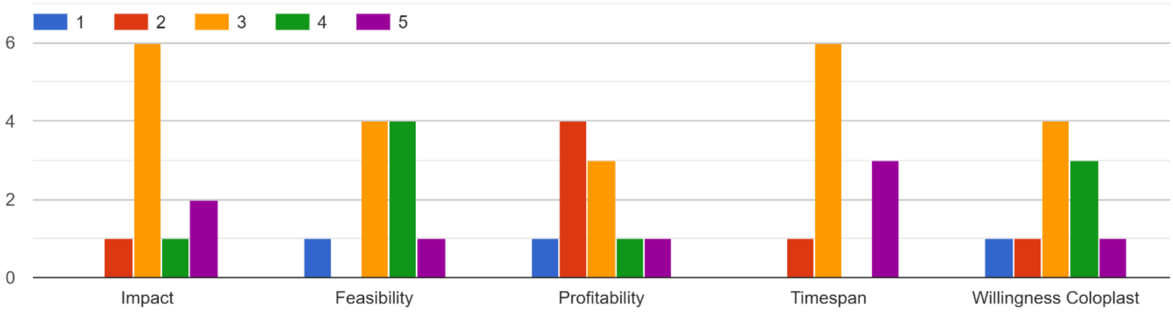

Figure 30. Introducing a take back system.

The transmitter is not traceable, so if it is lost, it is difficult to find such a small device. A notification of this in the app on the smartphone of where the transmitter is located could resolve this problem.

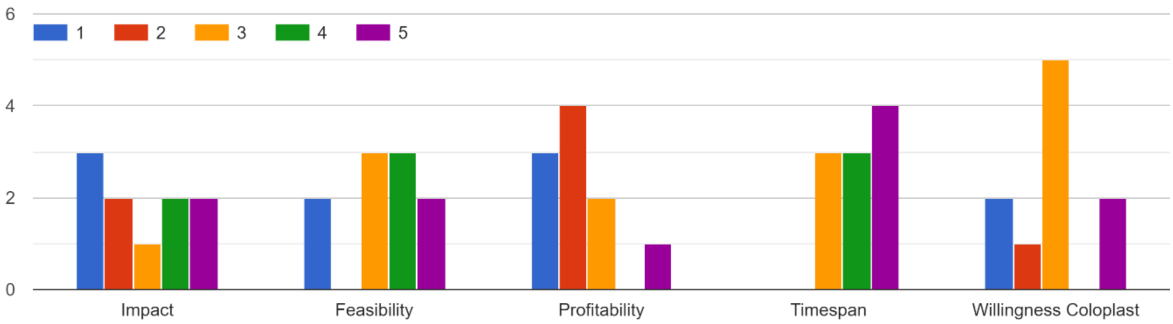

Figure 31. A traceable transmitter.

If possible, multiple customers can use the same charger.

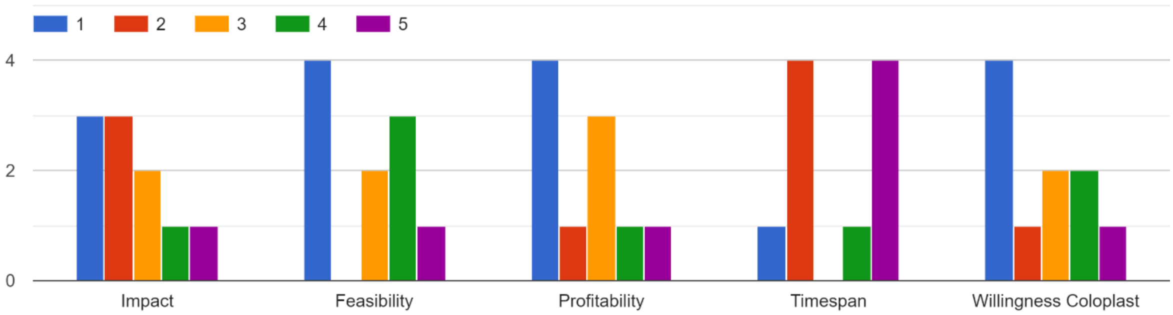

Figure 32. Multi-use same charger.

Investigate the option of wireless charging.

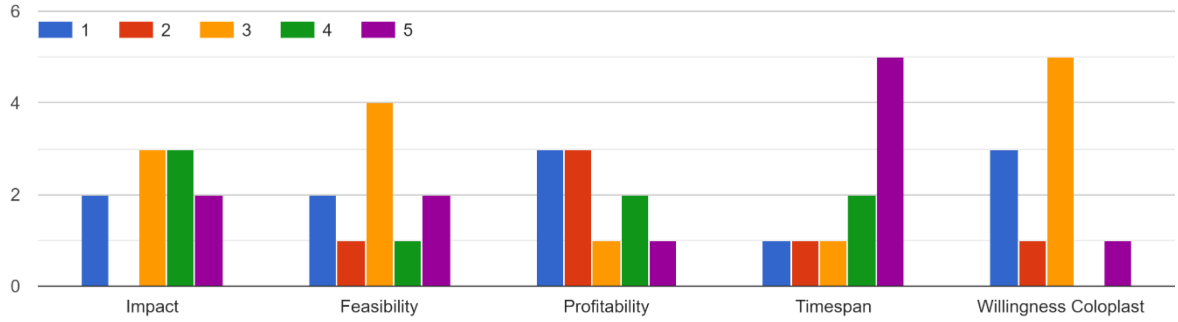

Figure 33. Wireless charging.

The plastic packaging in which materials arrive at Benchmark can be reduced as the current quantity is excessive.

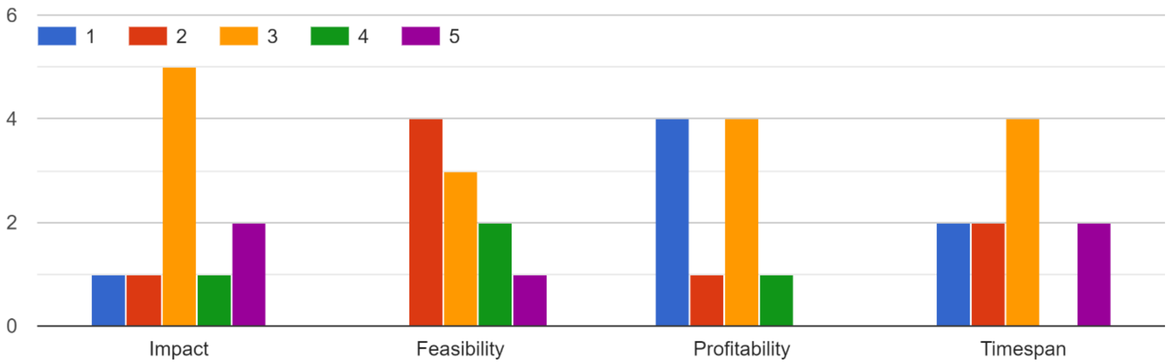

Figure 34. Reduce plastic packaging incoming.

When the current line is replaced by a smaller component size line, the product can be reduced in size, so less material is needed.

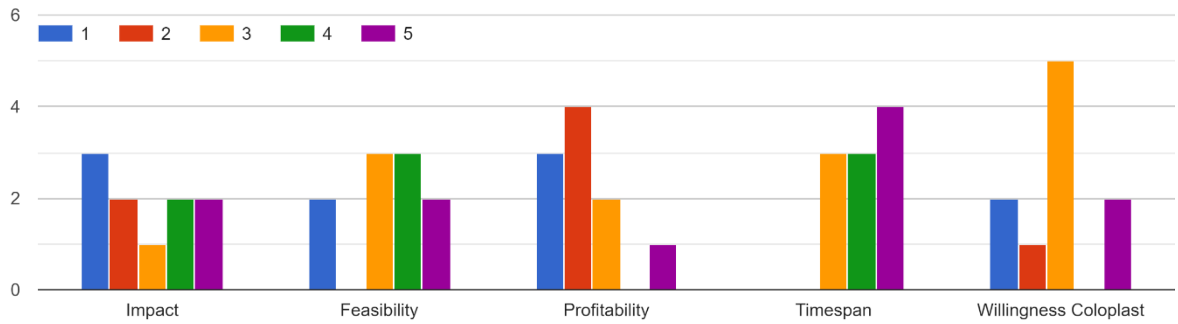

Figure 35. Smaller component size line.

The charger can be made smaller.

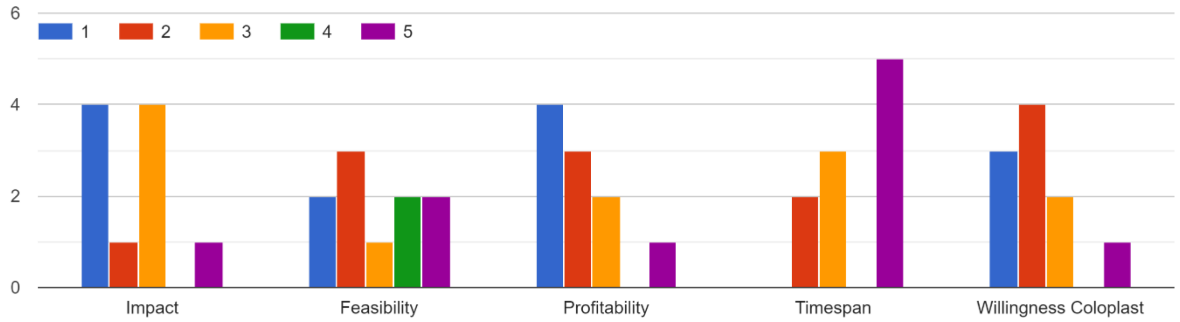

Figure 36. Smaller charger.

Use disposable gloves more often or use standard gloves.

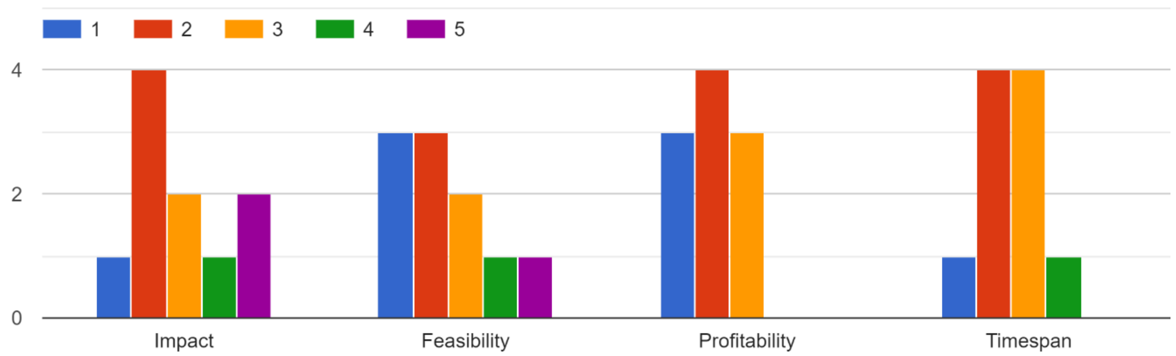

Figure 37. Reusable gloves.

To put emphasise on circularity, the management team should appoint a member to be responsible for this subject.

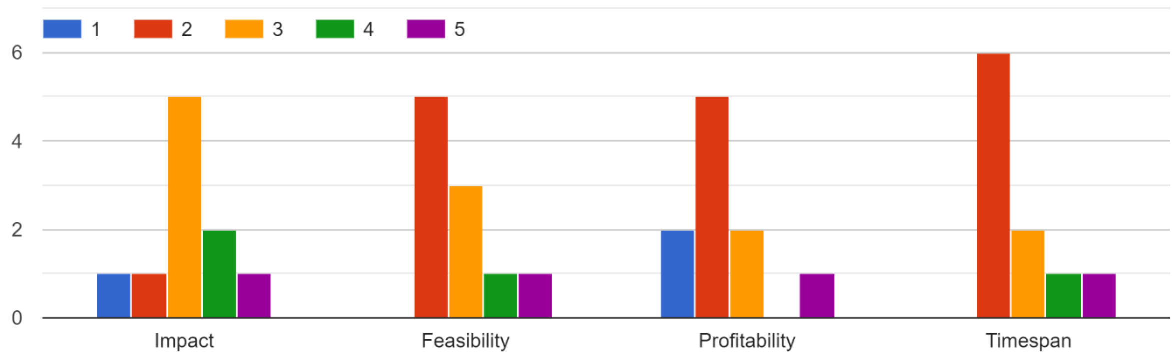

Figure 38. Responsibility by management team.

The box in which the trays are shipped can be designed smaller, as well as the packaging. In addition, the plastic trays can be made smaller or more PCBs can be put in the current tray.

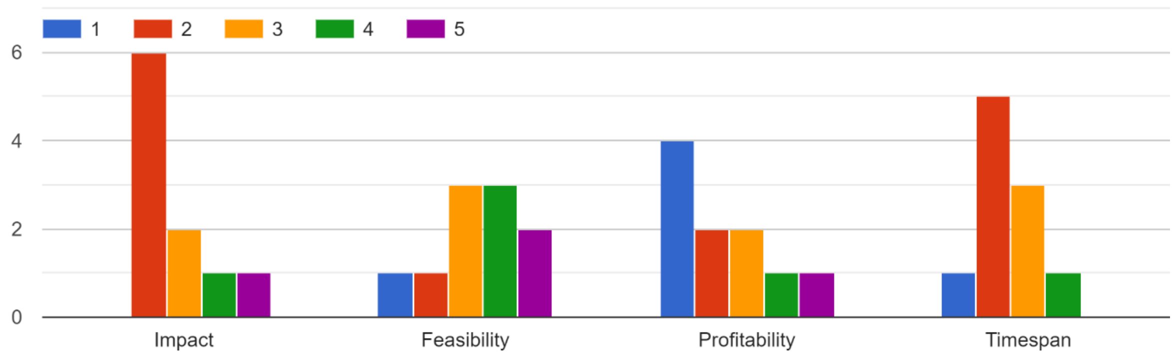

Figure 39. Utilise shipping trays more intensive.